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Addressing Near-Term Challenges of **UAS Integration**

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The Spring 2018 issue of *The Journal* featured multiple articles addressing the state of UAS integration into the NAS and its many challenges. "NAS Architecture in the Age of Autonomy" by Frederick Wieland outlines the complexity of enabling autonomy in the NAS for both manned and unmanned systems and poses the question: "Should this new age be 'force-fitted' into the current architecture" or "should an entirely new architecture be developed?"[1] Tom Farrier in his article, "Unmanned Aircraft Systems: The NAS at a Crossroads," captured the current state of integration efforts and the economic value of an integrated UAS operating environment. The article draws attention to the larger picture and just how much is at stake in that "every year integration is delayed, the United States loses more than $10 billion in potential economic impact."[2] Both articles do an excellent job detailing the difficult road ahead and the importance of adapting to move the industry forward.

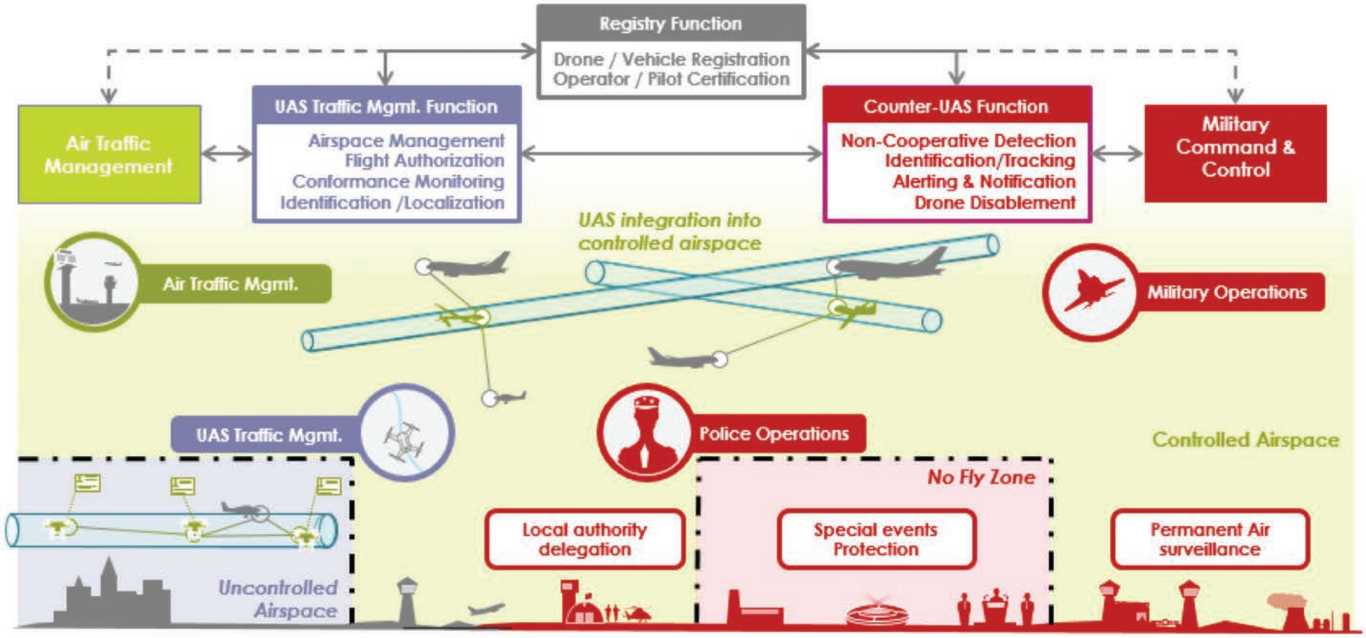

Figure 1. UAS operating environment.

In this piece, we propose a new, intermediate solution for UAS traffic management (UTM) that provides an efficient, near-term approach for low altitude integration. The model draws clear distinction from the operator-driven model widely promoted in the United States today. This approach draws parallels to traditional airspace management and applies it to low altitudes while continuing to promote the innovation of new entrants that are inspiring change amongst the aviation community. We believe this transitional approach will best mitigate the near-term risks of integration and allow for the potential economic impact to be realized more quickly while industry and regulators better understand the implications of a large-scale, autonomous UAS operating environment.

UAS Integration Demands

Advancements in UAS technology are invigorating the aviation industry – so much so that its widespread adoption and subsequent integration into the NAS have been hailed as aviation's third revolution. The market potential for using UAS is creating demands on traditional airspace systems, causing us to think differently about how to use these platforms commercially. However, integrating these platforms into low altitude airspace globally is challenging the conventional, "safety-first" aviation community culture. Ideas ranging from segregated airspace to integrating unmanned systems alongside manned aviation within airspace systems have all emerged. This uncommon pace of change in aviation requires close examination of the many challenges and approaches of integrating unmanned platforms safely and efficiently. Our challenge is to ensure the world's airspace systems can maintain exceptional levels of safety while accommodating and balancing the wave of aviation advancements poised to disrupt low altitude operations across controlled and uncontrolled airspace.

Globally, ANSPs and civil aviation authorities (CAAs) generally agree that new, commercially viable approaches must be developed to promote the use of unmanned systems while ensuring the safety of the existing airspace structure. Safety has always driven advancements in aviation and must continue to do so in the new era of unmanned platforms if there is to be any hope of large-scale integration. UTM for low altitude airspace provides a path forward for safe integration of all vehicles and reinforces the safety-first culture unmanned platforms must embrace.

The dynamic nature of UAS operations can lead to inconsistent definitions of major concepts. The term UTM, for example, is oftentimes misused or confused with other technologies and approaches. Ultimately, solutions can be categorized into one of three main concepts (depicted in Figure 1): UTM, integration of UAS into controlled airspace, and counter UAS (C-UAS).

- **UTM** – a system that facilitates the operation of cooperative UAS in uncontrolled or segregated airspace under the relevant local regulations. UTM often applies to low altitude airspace but can also apply to very high altitudes.
- **Integration of UAS into Controlled Airspace** – involves operating UAS in civil or military controlled airspace with the support of ATC. It typically requires onboard equipage and procedures as if it were a manned aircraft or explicit involvement of the tactical ATC authority to grant authorization via segregation or active separation management.
- **Counter UAS (C-UAS)** – a system that's designed to detect, identify, and track non-cooperative UAS which may represent a high risk or threat to critical facilities or locations (e.g. power plant and airbase).

Each component has its own set of unique characteristics that provide a portion of the solution necessary to achieve large scale UAS integration. In some cases, UTM poses the most unique challenge. It is intended to provide structure in low altitude airspace that incorporates new, higher levels of automation and autonomy in areas that traditionally have lower traffic densities and/or specialized operations (helicopter or military traffic).

UTM must address this operational density challenge – one that far exceeds any the industry has experienced with traditional manned aviation. Today's world of segregated test sites will soon pave the way for more routine operations into the NAS. As the operator and regulators alike satisfy current small UAS waiver conditions, the more operations and users industry can accomodate in the NAS.

In the fall of 2017, there were approximately 100,000 commercial operators and 800,000 hobbyists registered with the FAA.[3] The latest

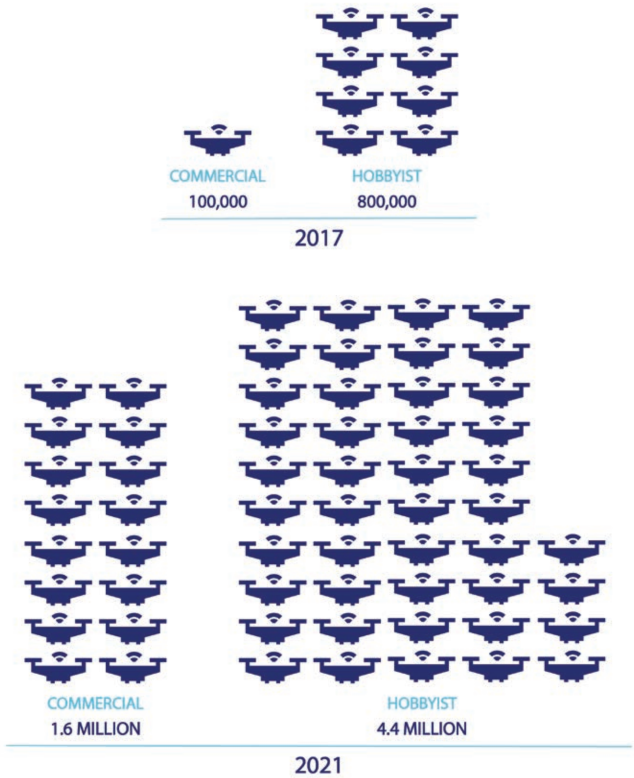

Figure 2. Projected number of registered drones in the US by 2021.

FAA Aerospace Forecast, illustrated in Figure 2, projects that these numbers will climb to 1.6 million and 4.4 million operators, respectively, by 2021.[3] It is important to note that this is not in reference to an anticipated number of operations which would be influenced by the readiness level of a UTM system. Rather, it is in respect to the 550 percent potential increase in new operators seeking access to the airspace regardless of progress made in UTM's development and implementation. This signifies an urgent dilemma for the aviation community. If no significant progress in UTM is made in the near future, it is unlikely the existing airspace structure will be capable of handling this influx of new operators, which will greatly impede the growth of this emerging industry.

The positive economic impact of drones is undeniable and a strong business case to support this operating density is desirable for many industries, including aviation. For economic impacts to be achievable, access to airspace for UAS operators will require a highly sophisticated, safe, and secure traffic management system that leverages increased automation technology that can someday support autonomous operations. A UTM solution capable of providing a sustainable, flexible path for airspace integration must incorporate advanced technology solutions (common design standards, cybersecurity, big data platforms cloud-hosted solutions, and artificial intelligence). It is critical for aviation to change and it must embrace the need for enhanced automation deep machine learning and robust cybersecurity. Until we do this, we cannot begin to adequately address the increase in traffic density and reduce the risks associated with integration alongside manned aviation.

One model being examined in the United States today is being driven from an operator perspective, or UAS Service Suppliers (USSs). The USS function delivers both mission planning for UAS operators as well as serving as distributed airspace managers through some as-yet-defined peer-to-peer coordination process.[4] This is referred to as the "operator driven model." With no one single USS being an authoritative system, the current concept relies on USS to USS communication and collaboration to share position information and mission planning elements to reduce the risks of conflicts in the airspace. The unique nature of the operator driven model puts UTM in the position of balancing the safety-critical responsibilities associated with low altitude airspace management with the commercial obligations connected to interfacing with UAS operators. This approach, if widely accepted beyond the concept development phase, could usher in a major shift in airspace integration and management philosophy. Longer-term, this could be a shift from ANSPs being the responsible authority for low altitude airspace and allocating it to third-party commercial providers.

The concept of an operator centric airspace management model is a major technological and philosophical shift from today's aviation industry approach and deserves close examination and consideration. However, before completely abandoning the existing structure of today's NAS, perhaps an intermediate solution can emerge as a viable option that will more quickly transition from the concept development, technical readiness world to an operational implementation.

An alternative approach introduced in this paper advocates for centralized functionality found in a UTM Core platform. Centralized services are necessary to alleviate challenges by allocating the safety-critical, airspace management functions from the collection of USSs to a common, centralized function. The UTM Core will reduce the need for excessive coordination and provide a centralized source for information exchange among all relevant stakeholders. It will address the challenges brought on by inter-USS communication and the collaborative structure the USS centric approach is built upon. As a result, safety is enhanced and functions are no longer separated and unverified, allowing for the USS providers to concentrate solely on the mission of the operator and not be burdened with additional functionality that will reduce their unique value propositions.

A vision for UTM that incorporates high levels of autonomous data sharing, prioritization, and deconfliction through USS collaboration might represent a utopian end-state where vehicles and airspace management systems leverage the enormous amount of data that will be prevalent from the airborne and ground systems. Artificial intelligence (AI) will be used for enabling the high density of operations anticipated within the next decade. However, in order to reach the ideal end-state, the needs of aviation community must be fully satisfied. The operator driven model may introduce unique challenges that, when more broadly applied, could impede industry's progress towards large-scale integration.

Aviation has traditionally taken a conservative approach to implementing new technologies into operation. UAS operations will become more prevalent and we ignore the usefulness of these systems at our own peril.

More Research and Development Needed to Validate an Operator Driven Model

The operator driven model to manage low altitude airspace depends on accurate, validated, timely, and consistent information. Its viability also depends on standardized development, universally applied prioritization, and de-confliction processes to execute the safe integration of unmanned platforms. The key is not to dispute the operator-driven model but rather it is not desirable in the short to mid-term due to either a) lengthy implementation delays that will result from the standardization effort associated with this approach or b) the accidents and incidents that will occur as a result of a "trial and error" methodology that would be needed for it to be implemented more quickly.

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Though the USS to USS, an operator-driven model might be capable of satisfying requirements for the limited operators in a research environment today, it is not necessarily well positioned to manage expanded operations in a more complex UAS operating environment. In a future where high traffic density is coupled with increasingly complex operations, the need for complete situational awareness and continuity across all stakeholders will be critical. This will require unparalleled levels of automation never before implemented in ATM. Automation will be required to enable efficient inter-USS communications and collaborative low altitude airspace management, concepts that are currently not well defined and could lead to significant challenges when it comes to airspace operation and coordination.

Risk mitigation strategies need to be employed to address the many questions that exist in this model. For example, today's USSs are designed and implemented on "industry best practices." Currently, no published standards exist for mission planning or traffic management systems. Each player in this space maintains its own notions of what acceptable design criteria means and what is an acceptable baseline to start from. If the operator driven model will become the de facto standard for low altitude operations, it is incumbent on us, as industry, to push for the development of design and interface standards to ensure mission critical data is treated the same way within each system and implemented uniformly.

If a de facto standard is developed, who bears the responsibility to "certify" these platforms? In the United States, the FAA, under charter, is responsible for airspace management and mission services. Will the FAA safety organization, Aviation Safety (AVS), now face the growing burden of reviewing each USS platform to ensure it meets the appropriate levels of design standards? This approach does not seem feasible in today's austere budget environment. If the FAA is facing the increasing burden on simply reviewing and authorizing waivers for the Part 107 Small Unmanned Aircraft regulations, how can industry help alleviate that hardship?

Similarly, access to validated, high update rate surveillance over the near-term will be a necessary input into USS systems. Surveillance data, whether it comes from radar, cameras, cellular or satellite communications networks, or a combination of sensors to support operations will reinforce the safety risk management process and help prove some operations can be done routinely. Collecting the information for complete situational awareness approaches a near impossibility if USSs are not built to a common design standard capable of validating the accuracy and consistency of surveillance data in a decentralized UAS operating environment.

A decentralized UAS operating environment introduces its own set of unique challenges. Since it will be up to USSs to manage low altitude airspace, it will also fall to them to prioritize and deconflict the many operations taking place. Prioritizing and deconflicting the airspace has always fallen to a single authoritative source. An abrupt changeover to a decentralized model that disperses this safety-critical responsibility among USSs could jeopardize industry efforts and investment towards UAS integration if and when an accident occurs. Adopting a gradual transition, however, to a decentralized model will face a long and rigorous road but one that may prove feasible.

The operator centric model to advance the UTM concept has provided energy and a starting point for aviation and the public to garner acceptance for the use of unmanned platforms. As emerging needs and requirements continue to emerge within the UAS industry, it is incumbent on us to maintain aviation's safety-first culture while enabling safe integration of UAS into the airspace. Ultimately, though this model captures the importance and benefits of commercially-driven aspirations within UTM, it proves too high a risk for short- to mid-term implementation.

The UTM Core Model

With all of the innovation and change occurring in UAS integration into airspace systems globally, perhaps there is room for consideration of an intermediate step that bridges the divide of the world's known, orchestrated aviation system to the world where autonomous operations will prevail in decades to come. Building consensus from the public and the aviation community at large for the use of unmanned platforms to conduct operations in place of manned operators must be the focus. Inspiring innovators to continue to push the boundaries of unmanned technology can be preserved while segmenting safety-critical functions to a centralized system or UTM Core.

The UTM Core model can aid in addressing issues the industry is facing to build community acceptance of unmanned operations. Airspace management, mission prioritization, and deconfliction of operations (especially while missions are in progress) will be a subset of the challenges seen in the immediate future. Why not try to maintain some connection to traditional architectures to reduce angst of the public and regulators while investigating what else must be done to truly enable autonomous operations?

The UTM Core model is more closely tied to airspace management and is best suited to address the major hurdles faced today by isolating the low altitude airspace management functions from the commercial services for UAS operators. The UTM Core can serve as the low altitude airspace manager to connect stakeholders, facilitate data exchange models between the commercial USSs, enable community-based regulation implementation and help plan the efficient use of airspace while maintaining the highest level of safety.

A UTM solution leveraging an airspace management model segmented between USSs and UTM Core, depicted in Figure 3, captures the essence of the operator-driven model and simplifies its mission. The functions and responsibilities of the other stakeholders remain largely unchanged and streamlines their interface with UTM. UTM will continue to provide data to NAS systems through a platform comparable to the FAA's Flight Information Management System (FIMS), which will serve as the interface between the ANSP and UTM.

A further examination of how operators will interface with and exchange mission details with ANSPs is taking place under the FAA's UAS Integration Pilot Program (IPP). As the requirements and goals for the project continue to evolve, it is possible that the UTM Core can integrate other notification systems or databases to monitor local

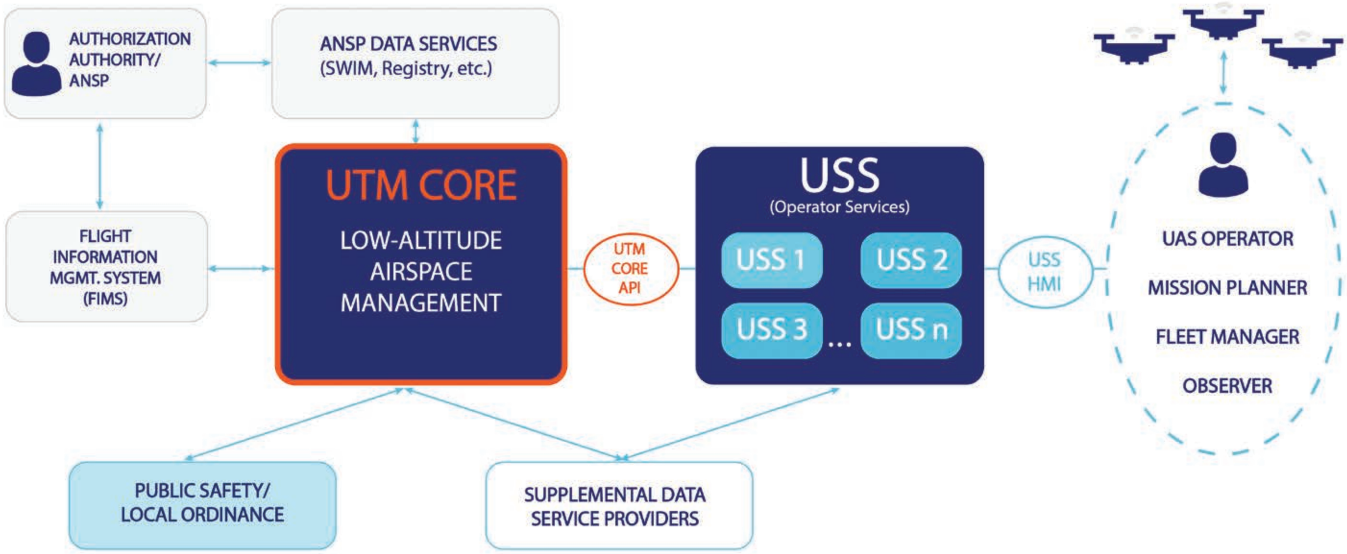

Figure 3. High-level architecture of airspace management model.

community ordinances or airspace restrictions. In the United States, the future for pre-emption of the airspace is undecided. If municipalities "own" low altitude airspace, it will be the responsibility of a UTM Core to interface with the respective local authorities to obtain their own subset of priority and operation constraints along with notifications and important information.

Along with understanding the airspace structure, the UTM Core will attain additional information for mission planning and execution through supplemental data service providers including terrain models, low-level weather, obstacles, UAS performance, and surveillance information. Through multiple connections and exchanges of information, a single UTM Core for a region will possess the means to validate, reject, or suggest further coordination of operations.

Under the UTM Core model, USSs will plan and execute the missions of their respective UAS operators. Each USS will be able to transmit that information to the UTM Core through an established API to satisfy the requirement for collaboration with other USSs. In exchange, the UTM Core will provide the USS with the necessary information required to conduct operations. In addition, the UTM Core will interface directly with the other stakeholders acting as a centralized source in the defined region for the exchange of mission critical information. By piecing together the information obtained from the combined USSs and the other engaged stakeholders, the UTM Core constructs a complete situational awareness picture of the airspace for executing the safety-critical functions of a low altitude airspace manager.

Many of the near-term challenges presented by the operator driven model stemmed from requiring the individual systems to balance mission planning and execution with airspace management. The risks brought on by lack of data interface requirements, ability to construct and maintain complete situational awareness, and the complexity of integration are intermediately mitigated through the UTM Core to provide industry a more streamlined and lower risk approach.

Complex Mission Management

At any given time, operators will seek authorizations to enter the airspace. Whether there are multiple USSs managing overlapping or adjacent operations, the complexity of airspace management will increase, requiring more communication and coordination to plan operations.

Based on the operating region for a USS's respective UAS operator, the UTM Core can authenticate and validate where that flight information must be communicated. This will simplify the process for managing that individual flight and will no longer have to ensure that data is communicated to other USSs. This responsibility can easily be allocated to a UTM Core, which will provide consistency and structure to the exchange of safety-critical information.

Streamlined Information Exchange

The UTM Core will streamline information exchange for all participating USSs by establishing a centralized platform to exchange mission-critical information. Without a central location for submitting and retrieving information from one USS to another, APIs will be created to facilitate information sharing with each existing USS.

Communications interfaces grow exponentially more complex with each USSs collaboratively managing missions in the same region. In addition to requiring each USS to communicate with the others, all USSs must also interface with the ANSP FIMS, ANSP data services, local ordinances, and required supplemental data service providers for the safety-critical information pertaining to the operation. Parallel with this is the potential for lack of awareness to what USS is operating in what area. Today there is no central database for this and as more and more USS come online, the lists will continue to grow and exacerbate the problem.

In the UTM Core model, exchange of information is streamlined through a centralized function. Figure 4 illustrates just how rapidly the number of communication streams transferring safety-critical information grows in the USS to USS model compared to the UTM Core.

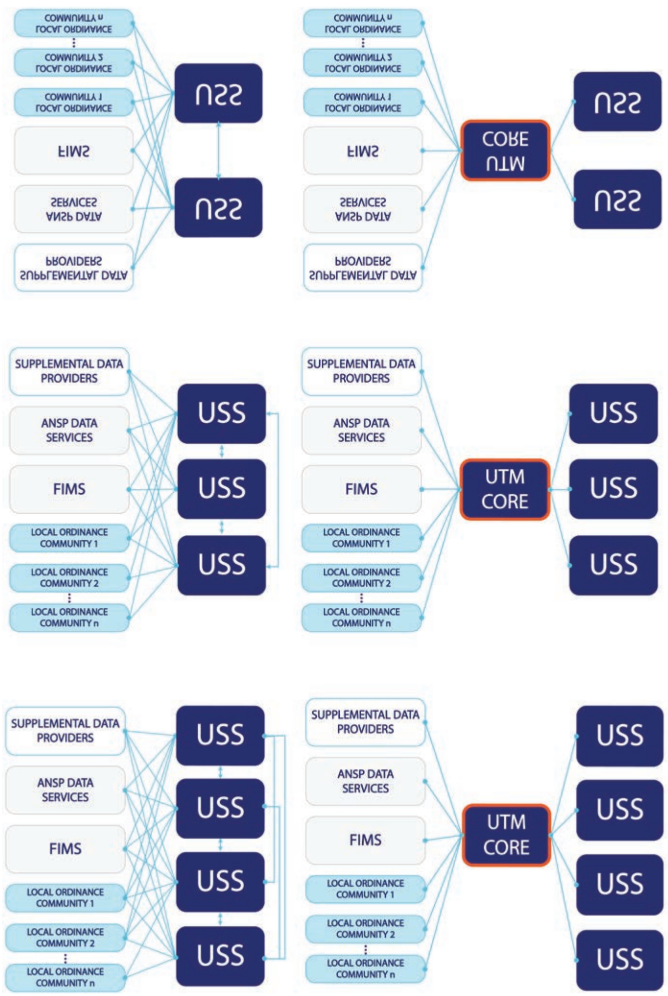

Figure 4. UTM Core streamlines communications.

Not only is the number of USSs operating in a region dynamic and uncertain but so will be the number of communities with their own local airspace ordinances and regulations (possible under the IPP and beyond). Each USS, if they're providing services in this area, will have to connect to different sources to get the information. A connection to a UTM Core service may simplify this approach.

From a test and integration standpoint, this approach greatly reduces the risks of improper interface implementation and allows for the introduction of authoritative data sources or common data sources (such as geofencing, geo-referencing, and barometric pressure correction/QNH) for all stakeholders. By streamlining the information exchange, the greater UTM system relies on only one additional communication stream to ensure safe airspace integration with each additional USS in the region. Figure 4 highlights the benefits of a UTM Core in the exchange of the safety-critical information to increase efficiency of UAS integration in addition to providing structure through a defined constant.

Cybersecurity

Similarly, reducing the number of access points to the airspace management systems will limit the vulnerabilities that a potential bad actor could exploit in the system. As each USS will have some level of external system connection, each of these offers a gateway for emerging cyber threats.

The threat of cyber attacks on infrastructure providers is rising. Whether it's a known bad actor or a seemingly innocent action done by an operator or developer inside one's system, resiliency of the overall platform must be taken into consideration during development. General data protection rules must be in place and authentication and multilayer security protocols should be included at the time of the system development and not an afterthought.

UTM Core solutions that are designed specifically for aviation data protection and security will help prevent the threat of cyber attacks on UTM systems. Aviation companies routinely secure key airspace management elements and personal data to lessen the effect on the greater aviation system. New entrants may not have the cyber expertise or the ATM background to design systems to this level, which leaves a major vulnerability in the system that can easily be exploited.

The provision of authentication managers, encryption keys, signing certificates, and trust shields must be put in place to ensure that data exchanges are secure and proper. Open systems will have vulnerabilities so it's incumbent on the industry to ensure that the NAS' overall stability and security isn't affected.

Simplified Prioritization of Operations

Prioritization challenges may be one of the largest topics to contend with for low altitude operations. USS providers will charge for commercial services, increasing the need for a model that will balance public safety and commercial airspace usage. When multiple USSs are added to the same airspace, it further illustrates the need for a third party system to centrally maintain organization over the airspace that will preserve equity for all. The local airspace provider using UTM Core services can implement rules that will ensure impartiality and remove the need for unnecessary negotiation and levy a series of rules to make the system safe and fair.

The provision of a centralized airspace management function or UTM Core can help to alleviate unnecessary USS-USS coordination and establish equitable access for all operators. In manned aviation today, air traffic controllers carefully orchestrate the planning and efficient usage of runways and airspace. They prioritize operations through the careful consideration of wake categories, routes, and schedules to efficiently use the system. As the operating environment transitions to more dense and complex operations between manned and unmanned aviation, coordination is even more important.

Airspace Deconfliction

Finally, one of the remaining functions of a centralized, low altitude airspace manager will be deconflicting UAS and aircraft in low altitude airspace. It is important to emphasize that unmanned aircraft will not just be flying in proximity to other UASs but also other manned aircraft including helicopters, general aviation, and personal air vehicles. There must be a structured and standardized process to deconflict overlapping operations of manned and unmanned alike in planning and in a tactical and pre-tactical environment.

Real-time deconfliction will also become more important as UAS density increases in subsequent years. The industry is working hard today to create detect and avoid algorithms for ground systems as well as airborne platforms that can work autonomously. Large-scale UAS integration will be at risk if this requirement cannot be satisfied safely and with confidence.

Deconflicting airborne vehicles is made more difficult through the operator driven model. It will require significant research to ensure that conflict detection and alerting is implemented in a manner that does not jeopardize the drone, the public, or manned aviation. The UTM Core centralizes these functions, removing the significant and unfamiliar challenges faced with a collaborative deconfliction approach.

Challenges That Remain

The UTM Core offers an intermediate approach for large-scale integration and embraces the operator-driven model's efficiencies. While highlighting potential issues that it may face in a more complex and dynamic future of low altitude operations. However, the UTM Core model is simply a start and does not solve all industry's challenges.

Initially, the deployment of a UTM Core function will avoid geographical overlap of platforms. To move towards more autonomous operations, there must be a mechanism in place that maintains only one UTM Core with centralized services be responsible for the management and coordination of airspace within a particular region. This is similar to what En Route Automation Modernization (ERAM) does today with terminal radar approach control facilities (TRACONs) and airports sending data designated en route centers for larger NAS coordination. The challenge that arises now requires a dedicated UTM Core be selected for a specific region, whether that be by local ordinance, state, country, and so forth. Regardless of how it's approached, it will be an important factor in successfully implementing the UTM Core.

This model also preserves the need for a country-wide FIMS platform that the ANSP will use to monitor and control the airspace system, particularly in relation to existing manned aviation and ATM systems used to manage these operations. FIMS will become the authorization engine for the entire NAS. In the interim, turning on application volumes for low-level UTM integration with an airspace manager and data collator, like the UTM Core, provide an interim step in moving towards autonomous, low altitude airspace integration.

Conclusion

UAS technology is revolutionizing aviation at a very intense pace. There are a host of industries seeking to leverage UAS technology, their applications and advance their operations to new levels of efficiency and enhanced productivity. Consolidating the varying needs of all those seeking to implement their UAS vision portrays a future of complex and dynamic operations in an array of wide ranging environments. It is a challenge to fly any of these operations in a segregated environment. Yet this challenge will not derail the success of large-scale integration. Success in achieving the collective vision of the future hinges on the ability for all operations to fly harmoniously. This can only be made possible under a comprehensive UTM that recognizes the challenges that lay ahead.

As the needs for UTM evolve so must its approach and structure. Intermediate steps must be taken now to ensure safety and security with its operations, and the public. UTM must be implemented safely, practically, and also satisfy the requirements of the regulators and operators alike to move the industry forward in a manner that works for everyone. The UTM Core vision is intended to serve as a practical, intermediate step to gather data to move us towards a more autonomous airspace system in the future - one where big data analytics and reliable, robust secure solutions that leverage the latest computing technology and artificial intelligence organize the NAS.

It's essential to encourage USS providers to innovate while still maintaining some organization and integration into the airspace.

UTM development efforts by NASA and the global community are forcing us to change, embrace the next wave of innovations in technology, and truly modernize our airspace infrastructures. As we look to make aviation more inclusive, we must not overlook the more than a century's worth of work that has been put into making our system safe. We must embrace new ways to manage airspace and the various platforms that operate within it, but we must recognize this cannot be done instantly. We must find a way to transition gradually and in a way that maintains our safety-first culture.

Large-scale UAS integration into the world's airspace is one of the greatest challenges faced by the aviation industry. Its ultimate success will be the result of continuously challenging the approaches put forth and questioning whether or not there is a more efficient, effective way to achieve the desired results. The UTM Core model proposed in this paper introduces a new solution that alleviates the many challenges of the current approach. Challenges remain and difficult questions still need to be addressed, but by adopting the UTM Core approach, large-scale UAS integration is that much closer to becoming a reality..

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