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NEXTGEN AND SESAR: OPPORTUNITIES FOR UAS INTEGRATION

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Abstract

Globally, many nations are anticipating tremendous future growth of aviation and air traffic. In the U.S., the Federal Aviation Administration (FAA) is planning for the Next Generation Air Transportation System (NextGen), which involves coordinated concepts and programs to increase capacity and efficiency, improve user access and safety, and to reduce environmental impacts. In Europe, the European Commission is coordinating its Single European Sky Air Traffic Management (ATM) Research (SESAR) program to similarly improve safety and air traffic flows, to create additional capacity, and to increase efficiency. These two visions share many common elements and assumptions about the air traffic system twenty years from now. Selected elements of these initiatives may also make it easier to permit Unmanned Aircraft Systems (UAS) to fly seamlessly in the same airspace as manned aircraft. This paper analyses the opportunities for integrating UAS into the future airspace system through concepts such as 4D Trajectory Management, ADS-B surveillance, improved information sharing, and dynamic airspace structures. Synergies between concepts are highlighted, and potential methods for manned/unmanned aircraft operation are discussed.

1 Introduction

Globally, many nations are anticipating tremendous future growth of aviation and air traffic. In the U.S., the Federal Aviation Administration (FAA) is planning for the Next Generation Air Transportation System (NextGen) which involves coordinated concepts and programs to increase capacity and efficiency, improve user access and safety, and to reduce environmental impacts. In Europe, the European Commission is coordinating its Single European Sky Air Traffic Management (ATM) Research (SESAR) program with similar objectives. These two visions share many common elements and assumptions about the air traffic system twenty years from now. A number of the capabilities being sought may, in addition to benefiting manned aircraft operations, facilitate the integration of Unmanned Aircraft Systems (UAS) in non-segregated, civil-managed airspace.

Methods exist today in the U.S., Europe and elsewhere to authorize UAS operations outside military controlled areas. These authorizations, however, are temporary, restrictive and approved on a case-by-case basis. These constraints on UAS could also affect manned aircraft operating in the vicinity of UAS by restricting airspace normally open to them.

A variety of technical and regulatory impediments must be overcome before UAS will be allowed routine access to airspace. Two primary barriers concern the absence of a civil spectrum dedicated to UAS control and telemetry, and lack of a “sense and avoid” capability equivalent to manned “see and avoid”. [1] There are many government, industry, research and academic initiatives seeking to develop technologies, formulate standards, and refine regulations to address these and other issues.

This paper analyzes opportunities for integrating UAS into the future airspace system through NextGen/SESAR concepts such as improved information sharing, trajectory-based operations, self-separation capabilities, and dynamic airspace structures. These features are extracted from a review of NextGen and SESAR concept documentation. Next, the attributes of UAS are examined, and the similarities and differences to manned aircraft are discussed. Each NextGen/SESAR concept is studied for its proposed impact on manned operations, after which they are analyzed to discern if there are similar potential impacts on unmanned aircraft. Then, the concepts are examined in aggregate to formulate an overall UAS role in the system. Synergies and gaps between the future concepts are highlighted and potential methods for unmanned operation are discussed.

2 Future Concepts – Features

In this section, we summarize the features of the U.S. NextGen and European SESAR Concepts of Operations [2, 3], pointing out the similarities and differences between the two.

2.1 NextGen

In the U.S., the current National Airspace System (NAS) is limited in capacity and adaptability. Increasing demand and the introduction of new airspace users (including UAS) are placing a significant strain on the current air traffic system. The vision of how this system will operate in the 2025 timeframe is being coordinated by the cross-agency Joint Planning and Development Office (JPDO). Representatives from FAA and several cabinet-level departments, including Transportation, Defense, Homeland Security, Commerce, NASA, and the White House Office of Science and Technology Policy, as well as the private sector, all participate in the JPDO. NextGen is considered an unprecedented initiative in scope and participation, and is anticipated to address the long-term needs of the U.S. NAS over the next two decades. [4]

To that end, NextGen seeks to transform the NAS, not just to supplement it, and to do so requires new methods and new technologies in almost every aspect of its operation. The JPDO proposes a portfolio approach to managing the diverse, interconnected research and programs that will accomplish the broad goals of NextGen.

As stated in the Operational Concept (ConOps) for NextGen, version 2.0, the "…goal of NextGen is to significantly increase the safety, security, capacity, efficiency, and environmental compatibility of air transportation operations, and, by doing so, to improve the overall economic well-being of the country." [2, p. ES-1] There are eight features that are identified as key for achieving this goal in an integrated fashion. These features are listed and described here, based on descriptions in the NextGen ConOps, version 2.0 [2].

- **Network-Enabled Information Access**: Today, many separate paths exist for each type of flight planning and surveillance information in the NAS. Through advances in network technology, key information needed by every user in the NAS will be made more accessible and timely. This will permit more timely coordination and decision-making.
- **Performance-Based Operations and Services**: Today, most services are targeted to specifically equipped aircraft. By describing regulations and procedures in terms of performance requirements, services will be more broadly accessible, and airspace usage will be maximized during busy and congested times.
- **Weather Assimilated into Decision-Making**: Today, weather is the main factor for reduced capacity in the NAS. By incorporating probabilistic weather information into decision support tools, weather disruptions will be reduced.
- **Layered, Adaptive Security**: Security today tends to be single-thread and single-system based, to address specific threats. With a comprehensive system to address threats, layers of defense will be used to minimize the risks of any one threat, while adaptation will focus security resources on threats as needed.
- **Positioning, Navigation, and Timing (PNT) Services**: Today's navigation system is driven by ground-based NAVAIDS,

which provide a geographically fixed level of service. Through technology improvements in both ground and satellite systems (and in the cockpit), and the use of performance-based services, navigation will be provided with greater accuracy, reliability, and flexibility.

- **Aircraft Trajectory-Based Operations (TBO):** Today's flight plans are based on air traffic procedural and system constraints. With TBO, 4D trajectories will be defined to optimally match aircraft performance, which will be coordinated with the changing airspace characteristics along the flight path.
- **Equivalent Visual Operations (EVO):** Today, there are significant airspace capacity differences when visibility conditions change. Improved information on the ground and in the cockpit will permit sustained pace of operations in low visibility conditions.
- **Super-Density Arrival/Departure Operations**: Today, much of the flow constraints in the NAS are driven by the capacity of terminal operations. New technology and procedures will increase the peak throughput of the busiest airports and terminal airspace.

An integrated system involving these eight features is expected to meet the goals of NextGen, providing safe, scalable, user-focused operations.

The environment of the future NAS under which NextGen is expected to operate is worthy of note. According to the NextGen Conops, not only is the number of flights and destinations expected to increase in the next two decades, but the types of aircraft and operations are to become more varied. [2] Aircraft are expected to have a wider range of capabilities and performance, and the NextGen system needs to be able to accommodate them. The NextGen Conops states that the future system will be able to accept a wider variety of point-to-point flights (scheduled, irregularly scheduled, and unscheduled) and a variety of new types of operations, such as UAS and space vehicles, that are not on point-to-point routes, which will be handled in an integrated fashion.

2.2 SESAR

The Air Traffic Management (ATM) structure in Europe today is limited by fixed, rigid airspace and routes, inefficient information sharing, stove-piped decision-making, limited situational awareness in the cockpit, system capacity that is limited by today's tools and procedures, and constraints on and around airports [3]. The SESAR program proposes a plan of ATM modernization through the year 2020 to address this situation.

The plan has been defined by the SESAR Consortium, an organization composed of air traffic agencies, airlines, and manufacturers. It is funded by the European Commission and EUROCONTROL. Similar in scope to NextGen, SESAR takes a broad technological, economic and regulatory perspective to make needed improvements.

SESAR is defined in a series of guiding documents that have been completed recently. The ATM Target Concept document [3] states that the "…ATM vision for Europe is to have an affordable, seamless ATM Network enabling all categories of Airspace Users to conduct their operations with minimum restrictions and maximum flexibility, whilst meeting the agreed targets for safety, operational efficiency, cost effectiveness, environmental impact and meeting security and national defence requirements." [3, p. 14]

This vision is based on a "Performance Partnership" among aircraft operators, service providers, and airports to strive for several aggressive targets – enabling a threefold increase in capacity to reduce delays and costs per flight, gradually improving safety levels, and minimizing the effect on the environment.

The Target Concept document outlines some key features for achieving these performance targets [3]. These key features are listed and described briefly here:

- **Performance-based Partnership**: The airspace user (airlines, business aviation, general aviation, or military) needs are of primary consideration, and will be factored into ATM decisions. Each flight will be flown as close to the original intent as possible, to maximize value to both ATM and the user.

- **Trajectory Based Operations (TBO)**: Airspace users describe intentions "…with the required precision in all 4 dimensions..." [3, p. 17], in either a Military Mission Trajectory, or a Reference Business Trajectory (RBT). The former is the 4D trajectory for military users, which is more complex that the civil equivalent because of more variations in military missions. The latter (the RBT) is the 4D trajectory that the airspace user agrees to fly, and the service providers agree to facilitate.
- **System Wide Information Management (SWIM)**: Information at all levels will be shared with the affected parties through a net-centric architecture. Planning, decision-making, and tactical operations will have trajectory and ATM information of the required "quality and timeliness in a secure environment." [3, p. 17]
- **Collaborative Decision Making (CDM):** Collaboration among the affected parties will enable better system decisions, based on common situational awareness.
- **Layered Network Management:** Network management will be used to manage long- and short-term user objectives, to "reach agreement on demand and capacity balancing." [3, p. 17]
- **Airports as Integrated Partner:** Runway and airport movement throughput will be optimized to achieve capacity increases, through infrastructure and procedure changes, and greater use of secondary airports. Departure and arrival corridors will be developed to maximize throughput. "The impact of adverse weather conditions shall be minimised to allow for airport throughput to remain close to 'normal'." [3, p. 17]
- **Airspace Capacity:** Airspace will be designed to match capacity to provide the appropriate and timely level of services. Controller task loading will be managed by the use of data link for clearances, thus reducing the per-flight tasking for the controller. "New separation modes supported by controller tools, utilising shared high precision trajectory data, will increase the valid duration of each clearance. Tools will also support task identification, clearance compliance and monitoring." [3, p. 18]

SESAR is planning the systematic development of this set of capabilities over the next 15 years.

The airspace and aircraft changes expected in the SESAR future are also worthy of note. The airspace users are expected to possess a wide variety of capabilities, to be accommodated under several ATM capability levels with the appropriately structured airspace. The SESAR concepts largely focus on one airspace category, "managed" airspace, though it acknowledges the existence of "unmanaged" airspace. "Managed" airspace is defined as the airspace where "…information on all traffic is shared and the [service provider] is the pre-determined separator, but the role of separator may be delegated to the flight crew…." [3, p. 19] Within "unmanaged" airspace, users are responsible for separation assurance – ATM or Air Traffic Control (ATC) does not play a role. The SESAR concept briefly discusses new types of aircraft or operators such as Very Light Jets (VLJs) or unmanned aircraft, but does not account for new variations in mission beyond point-to-point flying.

2.3 Comparison

The U.S. and Europe air transportation systems share many of the same pressures, constraints, obligations and opportunities. Each region sees the need to accommodate growth, improve efficiency, limit restrictions, reduce environmental impacts, maintain safety, improve security, and contain costs for air navigation service providers and airspace users. Further, each region strives to harmonize their efforts and comply with ICAO obligations and to develop many of the same advanced technologies.

Apart from these similarities, there are significant differences between the U.S. and Europe, driving the approaches being taken by

NextGen and SESAR. These differences include geography, ATM systems and services, aviation markets, traffic volumes, weather, culture, and politics. There is a much larger general aviation segment in the U.S. than in Europe. This is of particular interest to the UAS community, as many prospective UAS operations will take place in environments flown by general aviation.

Common concepts and features of NextGen and SESAR, such as those listed in the previous two sections, are based on a foundation of improved aircraft performance characteristics and flexible airspace structures to balance demand and controller workload. These lead to several key attributes of future system development, which are primary opportunities for the UAS community:

- Network Enabled Operations
- 4D Trajectory Management
- Self Separation
- Dynamic Airspace and Flows

Of these attributes, the first two are directly taken from common concepts expressed by NextGen and SESAR, while the second two are foundational attributes on which both future concepts are based. However, before we can decide how these features and characteristics are applicable to UAS operations, we must examine the attributes of UAS, and what makes them different from manned aircraft.

3 UAS Attributes

In this section, we examine the attributes of UAS, and what makes them similar to and different from manned aircraft.

3.1 UAS Types and Missions

UAS represent a diverse set of aircraft, control stations, autonomous systems, and communication methods. Unmanned aircraft are typically smaller and have longer-endurances and different performance characteristics than manned aircraft (e.g., slower cruise speeds and climb rates). At the extremes, these aircraft have no equivalent to manned aircraft. Some weigh only ounces and can be operated from virtually any site, including indoors. Others operate at very high altitudes with proposed durations of months or perhaps even years. Unmanned aircraft also include manned aircraft converted for use as a dedicated or optionally-piloted unmanned aircraft.

The control stations used to fly and monitor these aircraft range from hand-held units resembling video game controllers to large, conventional cockpit environments. These control stations can be networked across multiple sites or can be placed aboard other aircraft. The management of basic flight functions can be achieved manually or allocated to automated systems. Communication links can be localized within line of sight or extended globally through a series of ground- or satellite-based relays.

These wide variations in UAS design, configuration, size, and performance pose challenges to airspace systems globally. Current ATM systems have evolved to meet expectations associated with manned aircraft and their operations. Whether UAS can integrate within the confines of the existing airspace remains an open question, but there are areas within future plans that may permit opportunities to facilitate integration. [5]

3.2 UAS Markets and Applications

Unmanned aircraft have been around since the early years of aviation but only in the last decade have their numbers, operational uses and popularity increased significantly—especially in the military. Experience and investments made by the military have increased their missions and capabilities, and consequently spawned potential markets for civil government, scientific research and commercial applications.

Despite the many advances made, predictions of where the industry is headed remain speculative. A number of influencing elements, such as technology, cost containment, operational constraints, regulatory controls, and public acceptance influence the direction and strength of the UAS market.

In its broadest context, the UAS market comprises four segments: military, civil government, research, and commercial. While market drivers and the dynamics among these segments differ significantly, their success depends on unique characteristics offered by unmanned aircraft (e.g., long endurance) relative to the cost of services provided by manned aircraft operations.

While prospects for UAS market expansion appear strong, restrictions to accessing and operating in civil-managed airspace may constrain growth. Today, allowances have been made to accommodate a limited set of operations. For example, public (state-owned/operated) UAS in the U.S. can obtain special FAA authorizations to permit limited operations. Manufacturers can test UAS under experimental certificates, but again only under strict limitations imposed by the FAA. The one market segment excluded from such government-authorized allowances is commercial operations. Commercial activities will have to wait for completion of standards and regulations, which could take a decade or more to achieve. Figure 1 offers a sample comparison of military, state, and commercial applications, and the timeframes that those applications are expected to be available. These are notional application timelines, based a synthesis of government and industry UAS market studies [6-13].

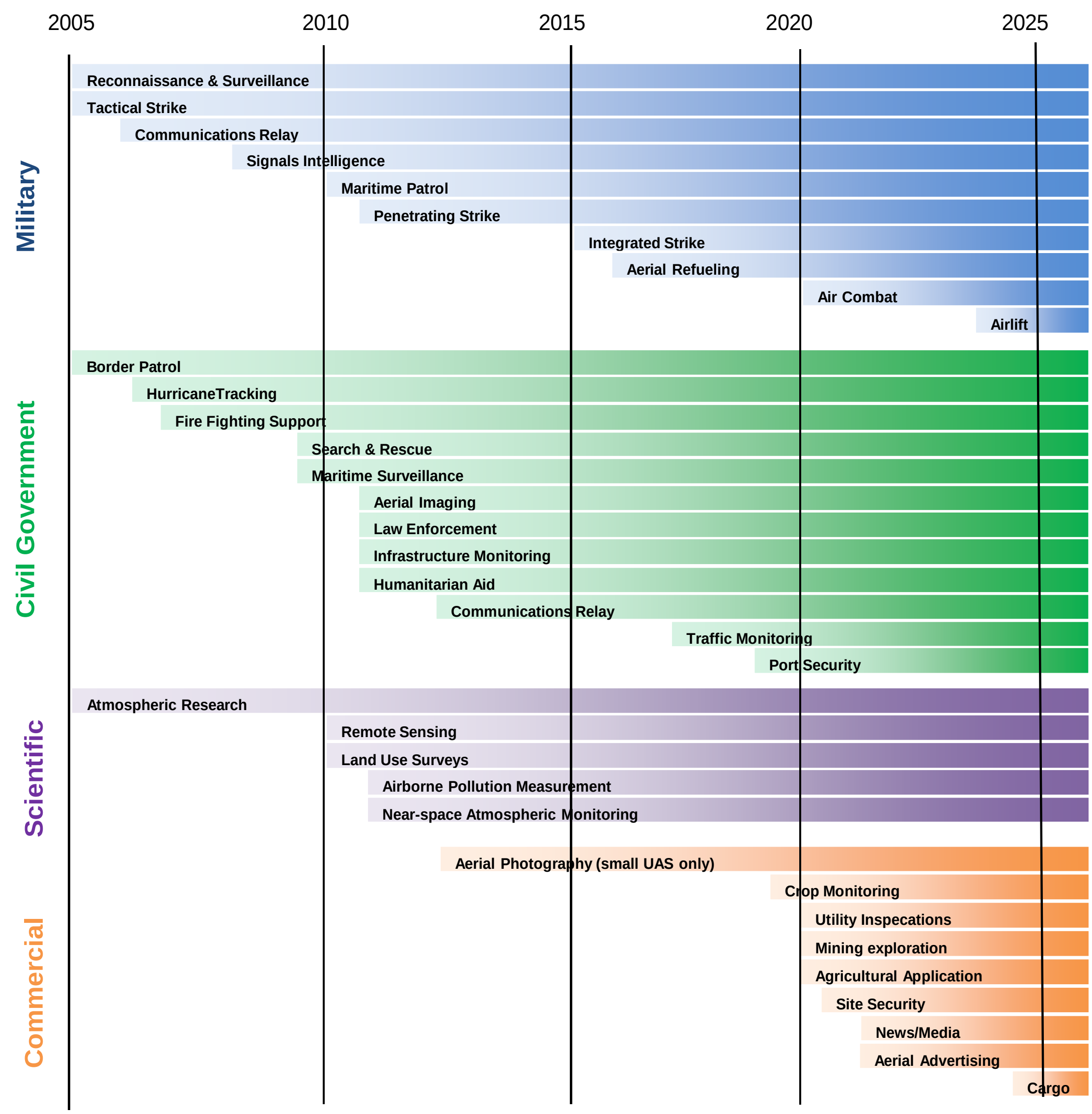


Figure 1: Applications by Market Segment (2005-2025)

The military will continue to hold the dominant share of unmanned aircraft in terms of quantity of airframes, but actual usage in non-segregated airspace will be proportionally less than other civil government, scientific, and commercial UAS operators. This is because the military will need access for few missions outside their restricted airspace and warning areas. Those missions taking place in civil-use airspace will be primarily for transition flights and training. In contrast, the civil government sector will require proportionally greater access to civil-use airspace; and for the commercial sector, missions generally will take place in unrestricted airspace.

3.3 UAS Operating Environments and Airspace Usage

While an understanding of the market helps in characterizing the numbers of UAS and their prospective applications, it does not necessarily give an indication of where within the civil airspace they will be flown and to what extent they intend to participate with the ATC system. This becomes an important consideration when trying to understand the implications of NextGen and SESAR capabilities against the intended uses of UAS.

Unmanned aircraft will operate in every airspace class. Most of the smaller, reciprocating propeller aircraft will operate primarily under Visual Flight Rules (VFR) outside controlled airspace, whereas larger turboprop and turbojet aircraft will operate under Instrument Flight Rules (IFR) within controlled airspace. Unmanned aircraft flying VFR will perform a relatively even mix of planned air work where the route is predetermined, such as photo mapping, and unplanned routes where the ground path is unknown, such as in a vehicle tracking operation. For UAS operating within the ATC system (IFR or VFR), most will tend to fly in more remote locations (e.g., maritime) or at higher altitudes relative to manned aircraft.

In reviewing prospective UAS applications it becomes apparent that the vast majority of these aircraft do not plan on conducting point-to-point operations but rather some form of patterned or orbiting aerial work. This use of airspace contrasts sharply with manned aircraft operations wherein point-to-point operations constitute the vast majority of their operations, especially in controlled airspace. This contrast is illustrated qualitatively in Figure 2.

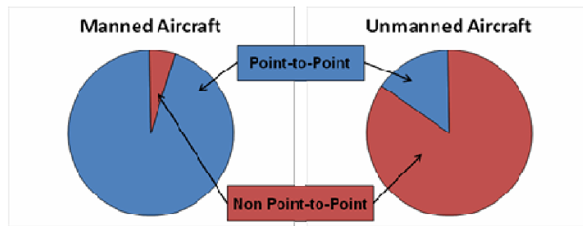


Figure 2: Manned vs Unmanned Operations: Notional Comparison

In terms of filed flight plans, again it appears that many UAS would operate under VFR, so that they would not be required to file a flight plan. VFR allows the needed flexibility for many of the missions and eliminates the limitation imposed by ATC. For the remainder of UAS choosing to file IFR or VFR flight plans, only a minority would likely fly traditional point-to-point operations (e.g., transition flights), and virtually none would fly on the busiest routes, such as between city pairs. Questions concerning acceptance of flight plans associated with UAS aerial work activities, such as those having designated tracks unrelated to established routes and published waypoints, remain unanswered.

3.4 UAS Challenges

UAS market potential depends on integration of UAS into civil airspace. In turn, achieving safe integration depends on a complex set of regulatory, technical, economic, and political factors. UAS must fit within a mature civil aviation system—one filled with aircraft, controlled and monitored by complex systems, dominated by large commercial markets, scrutinized by special interest groups, and governed by a voluminous regulatory structure. Following is a brief summary of the primary issues to overcome.

3.4.1 Standards and Regulation

The development of standards and regulations for the certification and operation of UAS will be a key enabler to their successful integration in civil airspace. Most in the aviation community believe these standards and regulations should conform to requirements for manned aircraft, be harmonized internationally, and result in a system that "does no harm" to existing air traffic service providers, to users of civil airspace and to the public. Premising such a regulatory structure on manned aircraft is a reasonable approach, but developing such regulations to cover the vast array of UAS will be a challenge. The U.S. and many other countries have begun moving toward the development of standards as a basis for regulation.

3.4.2 Technology

Though there are numerous technology challenges, two are paramount in realizing UAS integration: communications and collision avoidance. Effective and assured data link communications are essential to UAS operations. Currently, there is no dedicated civil, government-protected frequency available for UAS control and telemetry (most UAS today use military frequencies).

In addition to communications, UAS must have a "sense and avoid" system capable of avoiding collisions with aircraft and with other airborne and ground-based hazards such as parachutists, gliders, terrain, and structures. Requirements for such systems are being defined in standards and will be adopted in certification specifications or operational regulation.

3.4.3 Operational Constraints

Existing operational procedures are based on known performance values and expectations of manned aircraft, pilots, air traffic controllers and their supporting systems. Within NextGen/SESAR some operational concepts and procedures are set to change, but not all. This means that many of the operational constraints placed on UAS by today's environment will remain. For example, visual procedures used to identify and maintain safe separation from other aircraft on the ground and in the air will persist, as will procedures such as wake vortex spacing. These operations do not acknowledge the technical limitations and unique aspects of unmanned aircraft (e.g., high susceptibility to wake turbulence). Such operational constraints will ultimately limit the use of UAS unless their unique attributes and requirements are taken into account by future NextGen/SESAR evolutions. The ability to influence such changes will depend on the active involvement of the UAS community in communicating needs and working to find solutions.

3.4.4 Public Acceptance

For UAS to be accepted, the public must be convinced that the perceived benefits outweigh potential costs. The extent of public acceptance (or opposition) remains to be seen. If the public perceives UAS as being unsafe, an intrusion, or an annoyance, it could significantly limit the extent of operations, or even prohibit UAS access to civil airspace altogether. The relative newness of UAS to the public makes them uniquely vulnerable to criticism, skepticism, and rejection. However, to date UAS remain favorable or at least neutral in the public eye. Most are viewed as a needed and proven tool in the military arsenal. As UAS are flown with greater frequency in civil government roles (e.g., climate research, humanitarian assistance, and border security), public support likely will remain as long as tangible benefits exist.

3.5 Current Efforts and Activities

There are a variety of efforts ongoing worldwide to address challenges of UAS airspace integration. Governments are working to develop regulatory guidance, create temporary authorizations and to work on collaborative methods and technologies to broaden UAS applications. Also in the near-term, FAA has constituted an Aviation Rulemaking Committee (ARC) to develop a set of regulations for small UAS flown in visual line of sight. Beyond these near-term and temporary measures, standards bodies such as

RTCA, EUROCAE, Society of Automotive Engineers (SAE) and American Society for Testing and Materials (ASTM) are working on government and industry standards to define minimum requirements for UAS systems, components, and operations. While many of the standards may take a decade or more to be realized, the ongoing work is needed to solidify requirements acceptable to a broad set of stakeholders.

In the mean time, the UAS industry and research organizations continue to improve the reliability and capability of their systems. They are also investigating new approaches and technologies to ease restrictions and expand access. Some of these improvements may lead to advances that can become de facto standards, thereby shortening the timeline associated with the traditional standards development process. These improvements may also inform and perhaps even alter directions taken by NextGen and SESAR.

4 UAS Opportunities in Future Concepts

In this section, we highlight and analyze parts of NextGen and SESAR that facilitate UAS operation, as well as identify features of UAS that would complement future concepts.

4.1 UAS Missions Relevant to NextGen and SESAR

At the heart of NextGen and SESAR is a drive to improve the safety, security and efficiency of the airspace systems through technology and capability improvements. These improvements are rightly placed on areas exhibiting the greatest public need: scheduled air transport operations to and from major airports. Most UAS operations, however, fall outside the focus areas of NextGen and SESAR. Few unmanned aircraft intend to operate from air traffic controlled airfields or to fly point-to-point operations along common routes serviced by ATC. Rather, the majority of these aircraft will be employed in aerial work that typically takes place on the fringes of where manned aircraft operate, even when under control of ATC. This is not to say that unmanned aircraft will be absent from the influence of NextGen/SESAR changes, but it does imply that potential benefits will be limited to a minority of UAS operators.

There are a series of UAS mission and airspace/ATC handling combinations that are possible ways of operating in the future. The following are five summary descriptions of UAS mission types as they relate to IFR and VFR environments (also illustrated in Figure 3).

- **IFR Flight Plan, Point-to-Poin**t – UAS must operate like manned aircraft to be integrated, or be allocated a separate route or airspace if allowed by ATC. Special allocations are allowed today for unique operations, such as aerial refueling.
- **IFR Flight Plan, Different (non Point-to-Point) Profile** – The UAS mission is pre-planned, but it does not operate point-to-point. These different profiles (e.g., loitering patterns) are specified in the flight plan. These operations could be accommodated near established routes if the unique profile does not interfere with aircraft on point-to-point routes.
- **IFR Flight Plan, Unplanned Segments** – The unmanned aircraft is on a flight plan that is largely point-to-point, but may exit that flight plan to perform unplanned activities (e.g., loiters, scans). These unplanned segments must be accommodated away from aircraft on major traffic flows.
- **VFR Under ATC** – The unmanned aircraft (like general aviation aircraft) provides ATC with intent to obtain ATC service (i.e., flight following) or to access controlled airspace. Control remains in the cockpit, with the pilot flying VFR.
- **VFR Not Under ATC** – The unmanned aircraft flies on its own recognizance, separating itself from other aircraft and obstacles. It cannot fly in controlled airspace without ATC permission.

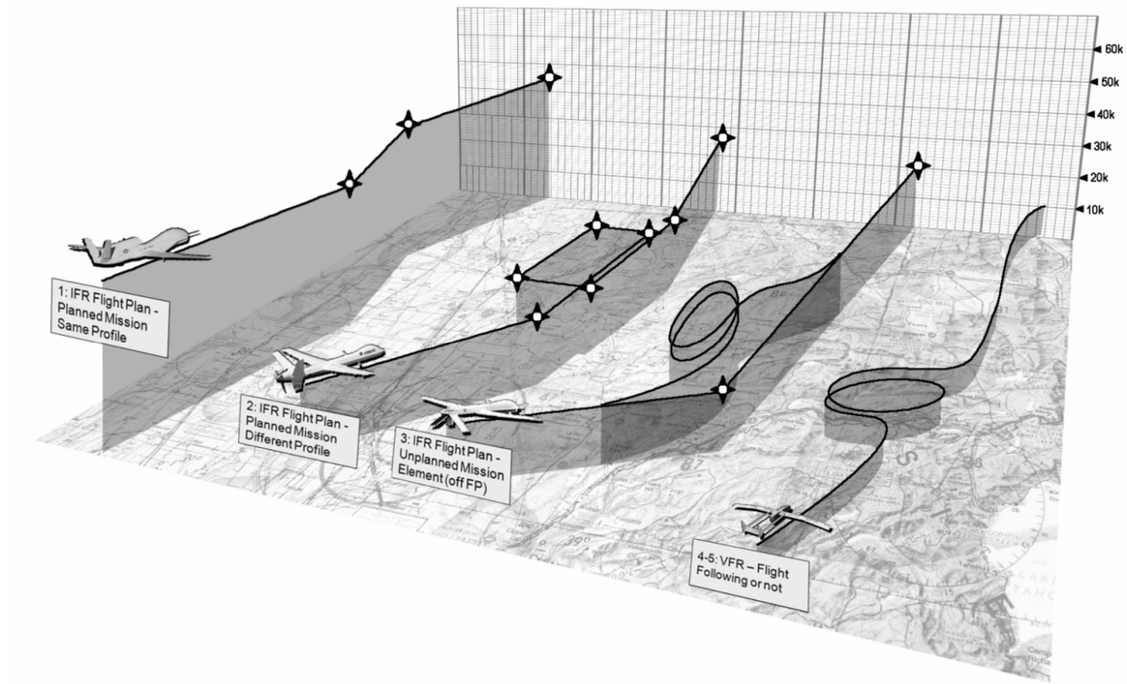


Figure 3: UAS Mission Types

4.2 NextGen/SESAR Capabilities Relevant to UAS

NextGen planning documents make specific mention of UAS (along with commercial space operations) as a new class of airspace user exhibiting different performance and usage patterns. [2, p. I-6] SESAR documents briefly address UAS as a new aircraft type that needs to be considered in the system, but state that "…specific technologies needed for UAV/UAS to ensure a transparent operation similar to a manned aircraft (e.g., dedicated high integrity UAV/operator command and control data links) fall outside SESAR…" [3, p. 48]. In both cases, no specifics are provided concerning potential impact or how these unique users will be accommodated; nonetheless, there are intersections with NextGen/SESAR that can be drawn. The key features of NextGen and SESAR that are useful to UAS integration are:

- Network Enabled Operations
- 4D Trajectory Management
- Self Separation
- Dynamic Airspace and Flows

These common points are extracted from the NextGen and SESAR capability discussions above. Although they may not be explicitly listed for one of the concept sources, they are key capabilities that NextGen and SESAR share, and that present opportunities to facilitate UAS integration.

4.2.1 Network Enabled Operations

Vital to UAS operations is the ability to exchange and process information. UAS rely on databases, sensory systems, and awareness of their environment to accomplish necessary applications and functions. Although much of this data is uniquely required for UAS operation, some of the data will be required for the UAS to operate in the system. Such data dependency is expected to grow not only for unmanned aircraft but also for manned aircraft participating in the ATM system.

The importance of managing real-time and projected aviation operational information becomes increasingly critical to performance, efficiency and safety. Both NextGen and SESAR recognize this need, and are pursuing similar net-centric information exchange systems. By linking data needs of airspace users with those of air traffic service providers, everyone benefits from a common picture and improved collaboration and decision-making. This network-based approach offers an opportunity for UAS to be accepted as routine, cooperative nodes and not as exception to the system, as is the case today.

To be a full participant in a NextGen/SESAR network sharing environment, UAS will need to conform to the rules, standards and expectations of the future system. The extent to which they conform will vary based on needs. For unmanned aircraft expecting routine IFR operation in complex air traffic environments, full compliance with data generation and distribution will be required, whereas unmanned aircraft seeking only flights at lower altitudes in VFR may limit their participation or opt out altogether.

When participating in a network-enabled environment, aircraft will be viewed as "flight objects" defined in terms of performance, capabilities and intent. Flight object information will be communicated as part of the flight planning process and dynamically updated as the flight progresses. Air traffic providers will use this information to evaluate potential impacts from a strategic traffic flow perspective and a tactical conflict management perspective. Pilots will use the information to collaboratively negotiate changing conditions (e.g., weather hazard, system outages, and congested areas) with other airspace users and the ATM system. This constant sharing, managing and analyzing of data will provided the foundation for other data- and communication-dependent NextGen/ SESAR capabilities, such as trajectory-based management and self separation.

4.2.2 4D Trajectory Management

All aircraft desire to fly their preferred four-dimensional trajectory (location, altitude, and time) free of impediments. Unfortunately, constraints in the current ATM system do not allow for this flexibility. Anticipated growth in airspace users and greater varieties of aircraft, including UAS, will only compound the inflexibility and lead to more disruptions. The intent of trajectory-based management is to alleviate these constraints through better analysis and management of declared routes and self-delivery times, along with greater demands on aircraft and crews to adhere to stringent navigational requirements that result in highly predictably and accurate trajectories. Once an aircraft's position in time can be assured, the information is processed using probabilistic logic to determine optimal use of the ATM system.

Within the context of trajectory-based management, UAS pose unique challenges. Their preferred trajectories vary (e.g., orbits or tracking along geographical features such as shorelines) and performance differs considerably from other airspace users (slow relative speeds and turn rates). Further, many UAS missions require intermittent changes to their intended route (much more so than manned aircraft), such as when tracking a suspect vehicle. These attributes are more likely accommodated by the SESAR Military Mission Trajectory than the civil Reference Business Trajectory, both of which the system must be able to handle. However, these attribute differences leave open questions concerning the ability of a trajectory-based system—one reliant on predictably—to manage UAS.

It is unknown how many UAS operators would use, need, or be willing to invest in trajectory-based capabilities, especially given the nature of their operations, intended environments, and the low-cost of their systems. Unmanned aircraft will typically operate to and from surfaces, within airspace, and during times having little in common with the heavily-travelled terminal areas and IFR routes of manned aircraft.

Despite potentially minimal use of trajectory-based operations, UAS will still benefit from its capabilities. Most UAS operators will manage their aircraft by some form of route or trajectory, at least as an emergency fallback procedure, so they are familiar with path type operations. UAS operators who do file flight plans will be accounted for in the system and, along with other participants, will be provided common situational awareness. Knowing the relative position and time-sequencing of other aircraft in proximity to unmanned aircraft operating areas will help in determining the best time, speed, altitude and route to be used. This is true whether in a VFR or IFR environment. Once the unmanned aircraft is airborne, trajectory information could be used to coordinate climb and transit procedures that intersect with high-density areas or flows, even for those UAS operations not filing a preferred trajectory. Having advanced and accurate knowledge of aircraft movements may also permit UAS to define temporary containment areas, to allow for limited access where full trajectory-based compliance is not possible. Such containment areas could be structured to avoid areas near high traffic densities (i.e., arrival and approach paths), areas of high population density, and other sites that may result in risks or nuisances to other aircraft or persons on the ground.

4.2.3 Self Separation

With increased equipage and capability, aircraft can be made more aware of the situation around them, and more capable of accepting the responsibility to maintain separation between other aircraft and themselves without ATC direction. This concept can range from the limited case (flight following) to the more general case (airspace designated as self-separation airspace, with all aircraft self separating from each other, without ground guidance). SESAR has introduced the Airborne Separation Assistance System (ASAS) levels of separation for incrementally introducing this notion; NextGen also considers additional separation responsibility for the cockpit as a key enabler of capacity increases.

Whether the pilot is in the cockpit or on the ground, the concept of self separation can be equally applied. If flown under flight plans, on point-to-point routes or other pre-planned missions, separation by the UAS autonomous system or pilot (if flown manually) depends on the quality of data exchanged through the communication links with ATC and other aircraft. The paradigm for operating UAS in this fashion is equivalent to a pilot operating a manned aircraft, with the exception of latencies in the UAS communication links.

If the unmanned aircraft is not on a flight plan, the concept of self separation becomes less clear. With improved situation awareness anticipated in the NextGen/SESAR timeframes, the UAS pilot can separate the unmanned aircraft from controlled aircraft and routes without ATC direction. This is especially useful if the pilot has departed the UAS flight plan, as is anticipated for some UAS missions. If the unmanned aircraft is flying VFR, then the UAS automation or the pilot must assume the responsibility to separate this aircraft from all traffic and obstacles.

4.2.4 Dynamic Airspace and Flows

Today's ATM system is constrained by static airspace boundaries (limited by the configurability of automation) and unique airspace and route characteristics (navaids and waypoints) that require specialized controller knowledge and training. These factors greatly reduce the flexibility of airspace configuration, usually to pre-arranged sectorizations. Routes as well are typically charted over named fixes to facilitate voice communication of flight plan and controller direction.

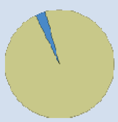
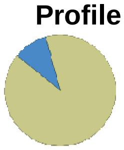
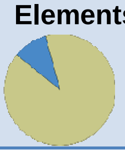
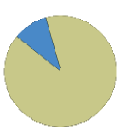
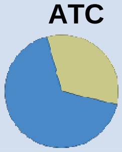
NextGen and SESAR propose more flexible airspace and route structures to help with demand and capacity balancing. By making use of data communication of route information, route waypoints are not constrained to named fixes, thereby permitting more direct routes and distributing routes away from single congested points. Since less specialized fix knowledge is required, sectors can also be reconfigured in more flexible ways, to allow workload to be rebalanced more dynamically.

Dynamic sector and route structures would be useful in accommodating UAS in civil airspace. Since most unmanned aircraft would not fly point-to-point missions, the ATM system must become more adaptable to unique flight profiles and patterns. Instead of fitting specialized UAS routes (e.g., pre-planned loiters) into a fixed route system, the airspace system should change to accommodate the unique route, if only for the time that the UAS requires it. For unplanned unique changes, the flexible airspace and routes would permit more options to accommodate it, though a minimal impact on planned and optimized routes should be considered. Improved situation awareness on the part of the UAS pilot and ATM would greatly enhance the ability to accommodate these unique aircraft and missions.

4.3 UAS Synergies in NextGen and SESAR

These four key NextGen and SESAR concepts are able to help UAS integrate into airspace with manned aircraft. In some cases, UAS are able to integrate because they act and are treated in much the same way as manned aircraft (see the first two rows of Table 1). In these cases, the four key concepts will be highly beneficial to UAS, though it is expected that only a small number of unmanned aircraft will be flying this type of mission by 2025.

Table 1: UAS Mission vs NextGen/SESAR Concepts

Mission; Relative Number of UAS	Benefit to UAS	Network Enabled Operations	4D Trajectory Management	Self Separation	Dynamic Airspace and Flows
IFR Flight Plan: Point to Point 	**High (for small # of UAS)**	Same reqt and benefit as manned – acts as routine, cooperative node.	Same reqt and benefit as manned – UAS flies 4D profile point to point.	Same as manned: on flight plan (FP) – under autopilot, UAS can keep sep from other a/c, same as manned.	Same as manned – airspace can be changed to meet demand.
IFR Flight Plan: Different (non Point-to-Point) Profile 	**High**	Same reqt and benefit as manned – node can exchange info about different profile more easily.	UAS flies planned route as 4D, though route is different. Very useful to system planning of different profile.	While UAS is on different profile, UAS pilot can use situational awareness to separate from regular manned routes.	Controller can flex airspace to meet the unique UAS route; can plan route to not conflict with manned.
IFR Flight Plan: Unplanned Elements 	**Medium**	UAS can go “off-FP” more easily; can still provide info to system as node.	UAS flies 4D for most, but goes “off FP” for unplanned elements which would not be 4D.	UAS can participate under FP; and has situational awareness when “off FP”.	Airspace may be tactically flexed to accommodate UAS when “off FP”.
VFR Under ATC 	**Medium**	UAS can still provide info, though it is less useful to point to point aircraft.	Though 4D not used, still get 4D info for others and can plan VFR around their activity.	Controller can offer flight following services, and point out aircraft to the UAS pilot, who has better situational awareness and can separate self.	Airspace may be tactically flexed to accommodate UAS when “off FP”.
VFR Not Under ATC 	**Low (most UAS)**	Very limited use as node, or opt out.	Minimal use except for situation awareness.	Not using self separation methods; fully responsible for own separation.	Not flying in dynamic airspace conditions; only flies in uncontrolled airspace.

* Dark blue wedge in pie chart indicates notional percentage of UAS population in 2025.

In other cases, UAS are able to make some use of advance capabilities for accommodating their unique missions and features mixed in with manned aircraft (see the third and fourth row of Table 1). For these mission types, the four concepts will provide a level of situation awareness of and to the UAS, so they will be somewhat beneficial to the UAS pilot and ATC. In contrast, a majority of unmanned aircraft are expected to not be flying under ATC in 2025; for these aircraft, most of the benefits of the four concepts will not be realized (see the last row of Table 1).

5 Conclusions

In summary, it is evident that the concepts that NextGen and SESAR propose are potentially of great benefit to all controlled aircraft, and to the system that monitors and controls them. These benefits extend to UAS, to the extent that they are like other aircraft and must interact with other aircraft in the system, manned or unmanned. However, based on anticipated applications and concepts for use of UAS, there are few UAS that would operate in this manner. The economic and people-moving drivers that make trajectory-based operations and time delivery a good idea for manned aircraft simply do not apply to most UAS applications. UAS missions do not deliver people and goods on a schedule – they provide surveillance services in areas that are often not known in advance, frequently change in the course of the mission, and often do not have a fixed delivery schedule. Currently, NextGen and SESAR are concepts for modernizing the ATM system, focused on a point-to-point schedule, getting aircraft into and out of dense airspace. UAS are the opposite – most are focused on loitering missions with no fixed schedule, typically away from dense airspace.

To be fair, there are some UAS missions and profiles that will benefit greatly from the NextGen/SESAR concepts, though, in the 2025 timeframe, these will be a small percentage. Adaptations to these future concepts will be necessary for UAS needs and missions to be fully considered. The UAS community has the opportunity to provide input to these future concepts to address the issues of fully integrating UAS into the NAS.

Disclaimer

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