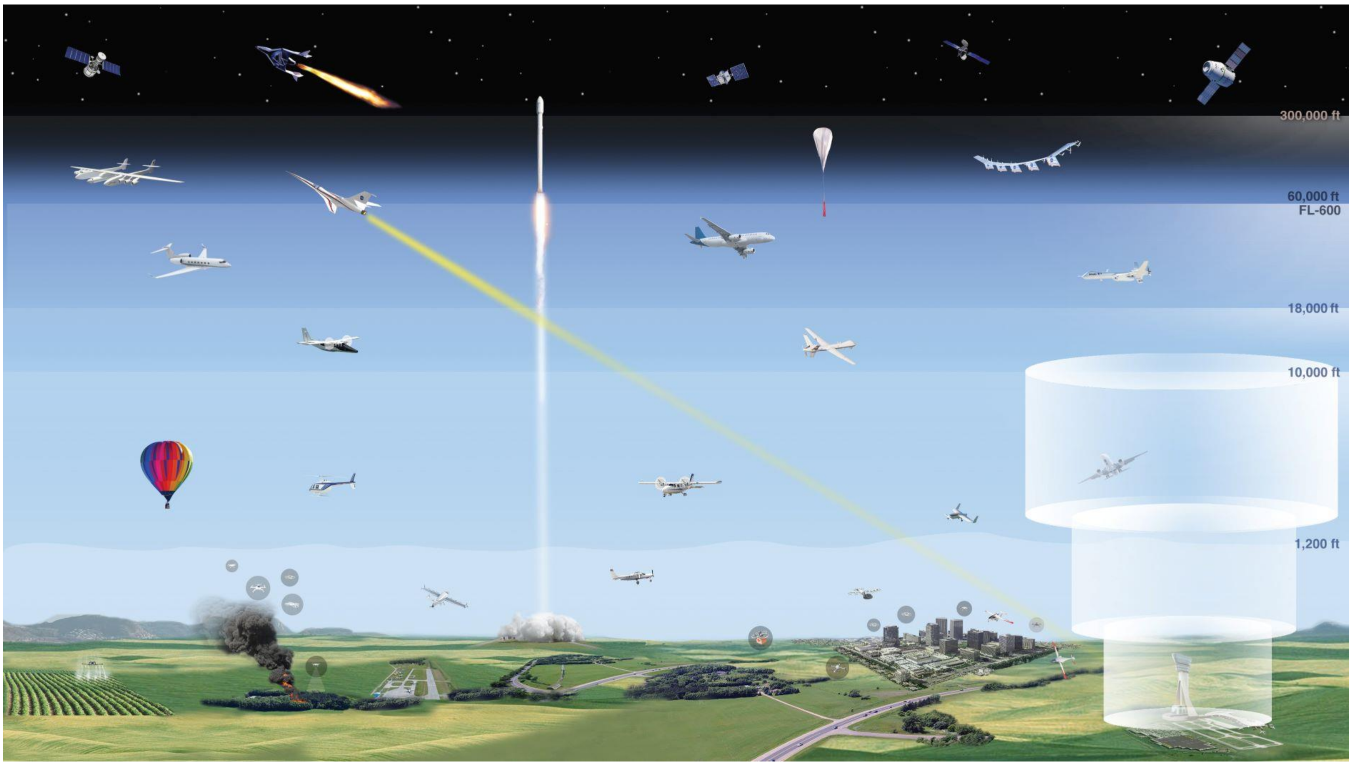
High-Level Concept Paper on a Changing Environment for Flight Rules



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I. Foreword

The global spread of COVID-19 has affected the best laid plans for investment in technology and future infrastructure. However, the pandemic may have fast-tracked certain future concepts. Primarily driven by the use of technology, digitization, and the expanding movement of people from mega cities to urban areas, demand for Urban Air Mobility (UAM) is expected to grow. The UAM global market is forecast to be worth USD 15.54 Billion by 2030, according to the latest analysis by Emergen Research. At the same time, there is a growing demand for remote inspection and surveillance of critical infrastructure. Changing consumer and purchasing behaviours are prompting the need for faster parcels deliveries. Such potential transformations combined with the anticipated developments in automation on the ground and on-board aircraft, are prompting the aviation community to reimagine the future of airspace and traffic management.

With the future technological advancements, the role of the pilot, operator and ATC is expected to evolve and become more focused on critical and decision-making tasks and also on monitoring for non-normal events, as opposed to actively flying/controlling. On the path towards such future environment, several technical requirements need to be fulfilled and a number of challenges will need to be overcome before this end state is reached. Additionally, with the aviation existing cycle for developing any new standard or proposal, it is important to initiate discussions now about future operational scenarios and assess compatibility with some of the existing requirements for manned aviation.

At the same time, commercial space operations and supersonic flights are advancing. Because their performance envelope is different from manned aviation, there is a need to ensure that space operations and supersonic flights can be efficiently integrated into airspace.

This concept paper introduces high-level considerations for future operation of new entrants and outlines how the operational environment may look in 10 to 20 years from now. It also identifies some requirements that will be needed to integrate new entrants into airspace. The main goal of the concept paper is to provide context when discussing the current flight rules and the extent that they do or do not support integration of the new entrants. An additional or adapted set of flight rules for new entrants will have implications on the existing rules and airspace classification. Therefore, work beyond this concept paper should consider such complexities and impacts on existing standards.

II. Explanation of Terms

Throughout this concept paper, several terms are used to explain the future operating environment. The following definitions are meant to help the reader of this concept paper better understand the high-level considerations that are discussed.

Advanced Air Mobility: a new concept of air transportation using vertical take-off and landing (VTOL) aircraft to move people and cargo between local, regional, intraregional and urban places not currently or easily served by surface transportation.

Airspace Manager: in the context of increased automation, future function of an ATCO moving from controlling traffic to managing the airspace.

Air Traffic Management: The dynamic, integrated management of air traffic and airspace including air traffic

services, airspace management and air traffic flow management — safely, economically and efficiently — through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions.

Collaborative Airspace Management: coordinated flight and flow decision-making by flight planners, operators, remote pilots and where applicable UTM/ATM to ensure safety, provide greater flexibility to flight planners, and make the best use of available airspace capacity.

Collision Avoidance: is the action performed to avoid a conflict. It is achieved when a pilot (remote or not) maneuver(s) the aircraft after becoming aware of conflicting traffic by one of the following means:

- Visual observation:
    - The pilot or observer takes visual avoiding action; or,
- Airborne system alert:
    - The pilot takes the avoiding action based on an equipment alert; or,
- Traffic information provided by ground systems or personnel:
    - The pilot follows avoiding action based on ground system alerts or as instructed by Air Traffic Control or Unmanned Traffic Management systems

Collision Avoidance is the last safety barrier should strategic and tactical deconfliction fail.

Cooperative Separation: Pilots to separate their aircraft from other traffic and obstacles using ground and on-board automation with ATC coordination.

Digital situational awareness: is the capability for a UA pilot or operator to have real-time knowledge of the operational environment while not being on board the aircraft, through digitally sourced information.

New Entrants: refers to all types of operators mentioned under Section III of this concept paper. Some types of operators are not considered new, but for ease of reference under this concept paper, they are grouped together.

Operator: a person, organization or enterprise engaged in or offering to engage in an aircraft operation.

Note.— In the context of this concept paper, an aircraft operation includes the unmanned aircraft.

Pilot: a person charged by the operator with duties essential to the operation of an aircraft and who manipulates the flight controls, as appropriate, during flight time.

Note.— In the context of this concept paper, an aircraft operation includes the unmanned aircraft.

Remote pilot: a person charged by the operator with duties essential to the operation of a remotely piloted aircraft and who manipulates the flight controls, as appropriate, during flight time.

Remotely Piloted Aircraft (RPA): an unmanned aircraft which is piloted from a remote pilot station.

Remotely Piloted Aircraft Systems (RPAS): a remotely piloted aircraft, its associated remote pilot station(s), the required C2 Link and any other components as specified in the type design.

Strategic Deconfliction: conflict management primarily in the pre-flight and pre-tactical phase through arrangement, negotiation and prioritization of intended operational volumes, routes or trajectories of aircraft operations in order to minimize the likelihood of airborne conflicts between operations.

Tactical Deconfliction: assurance of a safe distance or safe time between aircraft in flight based on real-time information throughout the flight.

Unmanned aircraft system traffic management (UTM): a specific aspect of air traffic management which manages UAS operations safely, economically and efficiently through the provision of facilities and a seamless set of services in collaboration with all parties and involving airborne and ground-based functions.

Additional details can also be found in the ICAO document: Unmanned Aircraft Systems Traffic Management (UTM) – A Common Framework with Core Principles for Global Harmonization.
https://www.icao.int/safety/UA/Pages/UTM-Guidance.aspx

Unmanned aircraft (UA): an aircraft intended to be operated with no pilot on board.

Unmanned aircraft system (UAS): an unmanned aircraft and its associated components (e.g. remote pilot station, C2 Links, launch and recovery equipment, etc.).

Urban Air Mobility (UAM): a sub-set of Advanced Air Mobility which air transportation using vertical take-off and landing (VTOL) aircraft to move people and cargo between urban places not currently or easily served by surface transportation.

III. Scope of the Concept Paper

3.1 Scope

3.1.1The types of new entrants' operations considered in this concept paper are:

a) Small unmanned aircraft (below 25 kg) operating in lower airspace, up to 1000 ft.

b) Unmanned AAM electric vertical take-off and landing aircraft (eVTOL) and medium to large UA carrying cargo.

c) Upper airspace operations (while the lower limit of Upper Airspace is functionally defined, in general terms current operations and airspace management have a lower limit of between FL600 and FL660) which include:

- Medium to larger UA that will transition through ATC controlled airspace into upper airspace. Such UA are expected to be remotely piloted during the transition and then remotely managed once at target altitude.

- Supersonic and hypersonic which will transition through ATC controlled airspace into upper airspace as well as top of Class A airspace.

- Unmanned high-altitude platform systems that transition through ATC controlled airspace into upper airspace which may be remotely managed and organised into loitering clusters.

3.1.2 The following types of operation are not included in the scope of this concept paper:

a) Recreational free balloons;
b) Hand flying gliders (no power, no engines, no human on-board);
c) Recreational UAS;
d) Ballistic vehicles, that will cross different airspace levels during launch and re-entry e.g. space rocket; and
e) UA of less than 200 grams.

IV. Evolution of Flight Rules

There continues to be an evolution of air traffic control (ATC) since its introduction in 1920 at Croydon Airport. In the early days of commercial aviation, there were very few aircraft flying and technology was rudimentary. Therefore, reliance on VFR was sufficient to allow for safe air operations. At that time, separation from other aircraft, obstacles and meteorology were the responsibility of the pilot. As air traffic increased and technology evolved, instrument flight rules enabled pilots to fly in all-weather conditions when needed and the responsibility for preventing collisions moved to ATC due to increased ground surveillance capabilities and communication advancements. For example, Annex 11, sections 2.2 and 2.3. explain how separation is a mechanism used to achieve these aims, as is traffic information depending on the flight rules and Class of airspace. Communication between the pilot and ATC became critical for safe operations. VFR and IFR provisions enable safe flight operations in today's environment with a range of capabilities, including: aircraft navigation, collision avoidance, protection from meteorological hazards and predictability of the traffic.

Currently, in existing airspace, roles and responsibilities are shared to a greater or lesser extent between the pilot and ATC to ensure safe flight operation, while automation supports the operation and is monitored by pilots and/or ATC. The main role of automation is to provide information that can help humans carry out all cognitive functions, from routine tasks such as continuous monitoring in normal conditions to decision-making and maneuvering traffic in abnormal conditions. Collision avoidance, colloquially referred to as 'see and avoid' applies is expected to apply to all aviation. In VFR operation, the pilot should "see and avoid" other aircraft, and where required, ATC will provide supporting services. In an IFR environment, ATC is responsible for continuously monitoring traffic and making decisions to prevent air collision, while the pilot has the ultimate collision avoidance responsibility, supported by airborne collision avoidance systems (ACAS).

Current ATM systems are based on technology that is at least 20 years old. Technologies such as big data, machine learning systems, internet of things, work-flow automation systems, service-oriented architectures, application protocol interface based extensible systems and increasing automation capabilities are slowly making their way in aviation to improve the efficacy and system optimization. Additionally, segregation of different types of airspace users may be feasible in the short term but as traffic numbers increase integration will be needed if efficiency is to be maintained/achieved.

In the next 20 years, an increased use of automation, robotics, unmanned aircraft systems (UAS), and artificial intelligence (AI) in aviation is expected. New entrants including all sizes of UA, high altitude balloons, supersonic and hypersonic aircraft, and advanced air mobility (AAM) are being pursued by companies with significant investments. At the same time, future manned aircraft designs are expected to include higher levels of automation. Automation is expected to play a larger role in managing/controlling a flight from planning through execution to landing, i.e. throughout the whole mission. Automation is also likely to expand beyond a single flight into systems enabling optimization of large fleets and fleet management with multitudes of interdependencies and constraints.

In the future, aircraft are envisioned to be digitally connected, and their operating environment will be continuously monitored by automated systems (from ground, on-board and/or in space). In such an environment, traffic movements will be managed on a strategic and tactical level. Strategic management will include flight planning and collection of data for a pre-defined time period. There is also a need to optimize the planned traffic to utilize the available airspace efficiently. Therefore, the airspace constraints and traffic density will need to be considered during this planning or strategic management phase. The outcome of strategic traffic management will be shared between the pilot/operator and air traffic management (ATM) and enabled by automation. Tactical management of traffic will include monitoring and tracking which is expected to be carried out by automation and enabled by digital situational awareness. Tactical Traffic conflict resolution will be implemented by the automation and monitored by the pilot/operator. Voice instructions will be kept to a minimum and aimed at solving airspace management problems. Within this context, the aircraft separation function may be re-distributed between the UA pilot/operator and ATC. Communication channels will also have to be rethought in the context of increased automation, as an example voice communication may not be fit for purpose to manage traffic with the anticipated traffic levels and higher levels of automation.

In addition, not all new entrants will be operating at low levels. For example, UAM operations are expected to occur above 400 feet. Upper airspace operations will involve aircraft which have varying performance levels, from balloons with few manoeuvring capabilities to supersonic and commercial space aircraft that will cross the airspace much faster. The duration of the operations in upper airspace will also differ from a couple of hours to months. Accordingly, flight planning and knowledge of other aircraft performances becomes more important and will need to be shared not only with the ground but also potentially between airspace users.

With the anticipated increase in the number and diversity of airspace users, ATC may not be able to reliably manage and support such a large scale of diverse traffic without resorting to prohibitive restrictions. Therefore, automation and re-distribution of some functions between operator, pilot and ATC will be key to managing the expected traffic volumes and types of aircraft operating in any given airspace. There is a need to re-visit systems and assumptions to ensure that airspace remains safe, efficient and provides equitable access. One area that requires attention is the compatibility of such a future operating environment with VFR and IFR. There is a need however to differentiate between operation type and flight rules. Visual line-of-sight (VLOS) and beyond visual line-of-sight (BVLOS) are types of operation, not flight rules.

V.The New Operational Environment

5.1 Scenarios for Future Operational Environments

To evaluate the need for new requirements, including new or adapted flight rules, use cases for the diverse airspace users expected to operate should be considered. In addition, the performance of the different types of aircraft, fleet management systems, and the varying levels of automation will impact what requirements will be needed. The scenarios listed in this section dive into the different elements of three operational environments in a time horizon of 10 to 20 years from now:

1. Very low airspace operation with a high density of UA traffic operating in a specific airspace typically around 500ft, and potentially up to 1000ft;

2. mixed mode operation with manned and unmanned aircraft operating between low altitude and FL300 ; and

3. upper airspace operation with different types of aircraft.

The current RPAS operations between FL290 to FL500 are in accordance with IFR (as facilitated by the recent amendments to ICAO Annexes and PANS) and no change in the type of operation is foreseen in the immediate future, and therefore not addressed in this paper

5.1.2 Low Altitude Operation of Small to Medium Size UA

For the purposes of this document it is assumed that, in this operating environment, the UA traffic density will vary depending on the region and location. For this scenario it is expected that the majority of the traffic operating will be unmanned with a lower percentage of manned traffic. Types of UA operation will include: inspection, surveillance, precision agriculture, highway traffic monitoring, critical infrastructure inspection, deliveries, etc. There will be low levels of AAM traffic using hybrid/ EVTOL aircraft. Manned aircraft operating at these altitudes will be mainly helicopters, for police or medivac. State aircraft, agriculture spraying aircraft and general aviation aircraft may also be operating at low altitude. It should be noted that the current VFR requirement do not allow to operate over the congested areas of cities, towns or settlements or over an open-air assembly of persons at a height less than 1000 ft above the highest obstacle. Likewise, the IFR levels requirement expressed in Annex 2 are even more constraining. Neither of these are compatible with foreseen Scenario 1 operations.

Below 500ft AGL, there will be limited interactions between UA and manned aviation due to the different types of aircraft and varying levels of automation. This will result in additional requirements for flight planning for all operators (UA and manned aviation) to ensure safe execution of the flight. Information about other operators in the airspace, weather, airspace restrictions will be required for operators to plan their flights. Future concepts for UA at low altitudes aim to have a remote pilot supervising a fleet of UA. Therefore, there will be reliance on information and systems to ensure alerts to the remote pilot for intervention where and when needed to resolve any traffic conflict throughout the flight. It is expected that situations requiring fast reaction (such as an imminent risk of collision) will be fully managed by automation, while humans will deal with more complex strategic problems on longer timeframes. In this scenario, multiple UA will be flying at the same time in a mix of VLOS and BVLOS type operation, with the types of UA ranging from singularly remotely piloted aircraft to automatically supervised UA fleets. An ecosystem of airborne and ground automation will be working together to enable dispatch, navigation, and operation of multiple aircraft.

Future systems should enable manned aviation to have access to the operational intent of new entrants and their electronic location through approved and connected digital exchanges. The UA operator& the remote pilot, will be able to make decisions related to pre-flight planning and strategic deconfliction based on automated indications from data gathered with regards to projected airspace occupancy, weather and other factors that may impact the flight. At the same time, manned traffic will need to be known to either the UA operator and remote pilot, or the traffic management service provider (in some cases this will be UTM). Therefore, the UA operator should provide details about the operations to help other users of the airspace assess the safety of their intended operations. In controlled airspace, specific alerts to manned airspace users and ATC may be required for off-nominal / contingency situations.

Tactical deconfliction may be carried out by the UA operator and remote pilot. The UA operator and remote pilot are expected to assume responsibility for safe deconfliction of traffic throughout the flight. In portions of airspace where Air Traffic Services (ATS) are provided, ATC should focus on intervention in off-nominal situations and managing traffic by exception or managing the system's constraints. This will differ from managing traffic by clearance, as carried out today in controlled airspace.

For VLOS operations the remote pilot is responsible to keep the UA clear from all other aircraft, unmanned or manned. Due to the reliance on automation for situational awareness and the expectation that one remote pilot may in the future manage multiple UA, VLOS operation may not be identical to VFR operation. Having a ground observer is not equivalent to an on-board pilot scanning the horizon for any aircraft that may be on a collision course with their aircraft. On the other hand, BVLOS operations will rely more on technology for shared awareness, strategic deconfliction and collision avoidance. The higher dependency on automation to provide digital situational awareness will result in the pilot and operator taking on additional tasks for traffic de-confliction. In that sense, BVLOS operation at low altitudes will not be identical to IFR operation. IFR comes with a precise set of rules including distance from obstructions, other aircraft and height above ground which are, almost entirely, inconsistent with current BVLOS operations. In addition, the expected reliance on information to ensure safe distance from obstructions, other aircraft would require an augmentation or variation to existing flight rules.

Further information can be found in Appendix I regarding the European U-Space concept and at the following links:-
https://www.faa.gov/uas/research_development/traffic_management/
https://www.sesarju.eu/U-space

5.1.3 Mixed Mode Operational Environment

For the purposes of this document it is assumed that, in this operating environment, the airspace is shared between different airspace users with varying levels of on-board automation. Specifically, for AAM, while the current use cases will have on board pilots, future plans are to have these aircraft without a pilot on board. However, even with pilot on board AAM aircraft, areas of operation and flight trajectories may still not comply with either VFR or IFR. In addition, it is forecast that the total traffic density, of all types of airspace users, will be higher than traffic operating in today's airspace. However, the traffic density will vary from one region to another, because some airspace volumes are more congested than others.

In this scenario, the airspace is proposed to be considered as 2 parts. At lower altitude bands (airspace below FL120), where in today's environment there is a mixture of VFR and IFR traffic, urban/ advanced air mobility aircraft as well as unmanned medium size cargo aircraft will operate. At higher altitude bands of (between FL120 and FL300), mainly corresponding to controlled airspace where traffic is expected to be predominantly IFR, certificated remotely piloted aircraft (RPA) and some unmanned large size cargo aircraft are expected to operate.

Types of unmanned aircraft operating in the airspace will include:

1. AAM/UAM aircraft (manned and unmanned).

2. Unmanned large cargo aircraft with varying levels of on-board automation.

3. RPA operations in higher altitudes of controlled airspace, specifically between FL120 and 300.

4. Unmanned medium size cargo aircraft.

In this operating scenario, traffic volumes will be high, and types of manned aircraft will vary in terms of on-board automation and capabilities. Operation will be enabled by sharing of data and information, specifically with regards to location and intent, so that UA operators can self-manage their operations and their interactions with other airspace users. Digital situational awareness and automation will enable a more coordinated approach towards traffic deconfliction among the UA of an operator and ensure avoidance of other UA, manned aircraft and obstacles. Digital situational awareness will enable automated decisions to be taken throughout all flight phases of the UA while also helping manned aviation.

Presently, in controlled airspace, ATC is the primary source of information and airspace situational awareness, and hence gives instructions to each aircraft or user in the airspace for every change; change in altitude, speed, heading, etc. In a digitally connected environment where ATM/UTM[1] is expected to manage information sharing and airspace access, every aircraft will be able to get the same information about surrounding traffic and constraints so that their operation can be planned safely and without conflicts. Such digital interconnectivity between operating aircraft will trigger a shift in the role of ATC to managing by exception. At lower altitudes in this scenario, a UTM service provider (USP) should have the capability to provide real-time information regarding airspace constraints and other aircraft intentions to UA operators. A USP can support operation planning, intent sharing, aircraft de-confliction, conformance monitoring, and other traffic management functions. In upper altitude bands of airspace for this scenario, existing and evolution of ATM systems and capabilities such as TBO or SWIM should support such functionalities.

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[1] **How ATM and UTM may be integrated or interfaced will be further defined pursuant to this concept paper.**

In this scenario, the UA pilot or operator will be responsible for managing its operations safely within known constraints, without receiving voice instructions. Elements of separation management will be with the UA pilot or operator. Information such as traffic location, MET conditions, and obstruction locations may be provided by the USP. Some UAM operations may be over longer flight distances, e.g. between cities.

At higher altitude bands, RPA operation will follow IFR procedures. Therefore, depending on their location and operation type, RPA may be required to provide identification, intent, and telemetry information over an information exchange link. At the same time, the awareness of manned aviation to RPA operators will be needed to assure safety of operations. Digital and cloud-based applications and implementation of standardized communication protocols will enable sharing of safety and flight critical information amongst all airspace users.

Under this scenario, strategic de-confliction and dynamic airspace allocation will allow operations to take place without the need for regular UA operator and ATC intervention as is the case today. Strategic de-confliction may be more complex below FL120 because some operations may not be predictable, e.g. use of UA for firefighting, military, emergency rescue and general aviation. As a last layer of defense and for traffic collision avoidance with unplanned/unpredictable traffic, the UA will need to have automated obstacle and collision avoidance. When flight re-planning occurs after departure, tactical deconfliction is expected to address uncertainty and changing operational conditions.

Dedicated volumes of airspace (also known as dynamic airspace allocation) designated for flight using an established set of procedures and rules can enable separation from conventional aircraft operating under IFR flight rules. Such set of rules and procedures will help coordinate traffic flows within that corridor. The status of such an airspace volume or corridor will vary over time, enabling it to be opened and closed depending upon environmental conditions (e.g., wind, weather), traffic density/demand, and airport configurations. The underlying principle for the allocation of such airspace volumes is that the aircraft which utilize them will be equipped with flight automation technologies that may enable different procedural mechanisms than are typically available for conventional aircraft. The boundaries of dynamic airspace allocated for such purposes will be digitally available. Some conventional aircraft may choose to equip with technology to enable smooth integration into the allocated dynamic airspace, when operationally necessary. Access to and from the allocated dynamic airspace may be automatically coordinated and will be subject to a digital authorization. Dynamic airspace may be allocated within the boundaries of Class B, C, and D airspace; however, such airspace volume should not be limited to the locations where VFR corridors are defined today. Future work and research should focus on how such dynamic airspace allocation could work in controlled airspace and what would be the impacts on traffic management.

5.1.4 Upper Airspace

For the purposes of this document it is assumed that at higher altitudes (FL500 and above), a high percentage of unmanned aircraft will be sharing the airspace with a low percentage of manned aircraft, given that many of the manned aircraft will not stay at such altitudes for a long period of time. One differentiating characteristic of operations of some of these aircraft types is their long duration: duration of anticipated operations ranges from hours to months to years.

The main types of new entrant aircraft operating in this environment include:

1. Remotely Piloted Aircraft systems (RPAS) operating around FL500.

2. High Altitude Long Endurance (HALE) UAS: which include fixed wing operators operating above FL600 during the day and descending to Class A at night. Descent altitude varies by season and location, but the lowest altitude aircraft can tolerate will be FL500.

3. Airships: planning to operate between FL500 and FL650. They may descend of ascend at night.

4. Unmanned high-speed fixed wing aircraft: typically operating between FL500 and FL550. Such aircraft have a temporary need to operate above FL600.

5. Supersonic aircraft flying at speed equal to or above Mach 1 (subsonic and transonic) and hypersonic aircraft flying at speeds above Mach 5 which typically operate at FL500-FL600.

6. Balloons providing communication and internet connectivity: dynamically adjusting their altitude between FL500 up to FL650 to catch wind currents. Other types combine limited, punctual assistive true air speed capability, with frequent altitude changes (between FL500 and FL650) to navigate.

In this scenario, the airspace will be shared by aircraft with very different performance levels in terms of maneuverability and speed, from subsonic business jets, supersonic and hypersonic flights, to slow moving (or stationary) unmanned balloons, and very slow (or stationary) long endurance fixed wing aircrafts. All such aircraft must safely interact without impacting current operations expected to continue. While some operational profiles will support point-to-point operations, many operations will loiter in a pattern (regular or irregular), move very slowly, or even remain stationary for extended periods of time. In addition, many aircraft operating at such altitudes will be vulnerable to wake turbulence and/or environmental conditions and will require considerable amount of airspace buffer in which to separate and/or operate. Airspace below FL600 is used regularly by HALE balloons and fixed wing operators, particularly between FL500 and FL600. Supersonic aircraft will primarily operate their cruise phase between FL500 and FL600.

In upper airspace, traffic management will be cooperative and will primarily rely on the operators themselves. The main principle for managing traffic will be a 'shared situational awareness' among operators. Specifically, above FL500, a federated, self-managing environment in which operators are able to share 'intent' can be ideal for managing and de-conflicting traffic. To achieve this environment, elements of the traffic management system foreseen for low-altitude operations can be used, in addition to using dynamic airspace allocation. ATM-managed operations will only be available where necessary and when traffic density so requires. Airspace allocation will be managed in accordance with safety requirements and airspace policy principles. When relevant, operators will be expected to continuously share and update their flight intent with each other to ensure traffic de-confliction and safe separation of trajectories. The known level of confidence regarding adherence of the aircraft to the operator's shared flight intent may vary significantly between different types of aircraft (e.g., supersonic transport vs. HALE balloon), due to characteristics unique to each aircraft type. Future ground systems will have the capability to capture and analyze data received from operating aircraft and provide probabilistic intents or predictions that contain the actual/flown path. When considering upper airspace operation, regard should be given to the interface between operations above FL500 and transition from/to Class A airspace. For the transition to and from operating altitude, coordination with ATC will be required.

Due to the performance characteristics of the aircrafts operating at or above FL500, flight planning and strategic deconfliction are key. Access to meteorological (MET) information will also be critical since the behavior of some of the aircraft operating at or above FL500 is largely impacted by the wind patterns. Collision avoidance procedures, which may vary depending on the type of aircraft being operated, will be enabled by aircraft and ground automated support.

Supersonic remotely piloted aircraft should be able to avoid other aircraft using ACAS-like technology for some traffic and will require a combination of strategic deconfliction (updated continuously via interaction with the ground) backed up with a more advanced detect and avoid capability. Balloons will rely on intents' awareness of the surrounding traffic for collision avoidance. Due to their speed and maneuverability capability, their ability to avoid other traffic may be limited. Therefore, the strategic deconfliction timeframes for conflict identification (based on shared intents) will dynamically adapt to provide sufficient time for operators with low maneuverability to negotiate and maneuver if necessary. This is expected to maximise airspace access fairness over static right of way rules. In addition, new collision avoidance technologies will be required to cater for this diverse environment and acknowledge the different maneuverability of the aircraft.

One or multiple USPs can provide operators with information about planned and on-going operations in and around a volume of airspace so that the operator can ascertain the ability to conduct its flight safely and efficiently. A USP can support operations planning, intent sharing, aircraft de-confliction, conformance monitoring, and other airspace management functions in accordance with safety requirements and applicable airspace policy principles. An ANSP providing ATS can also be a USP if it has the system capability to provide the required services.

Operator supervisors are expected to play an active role in the high-level operation, airspace and system planning, automation and system maintenance, overall system supervision and contingencies/exception management. Those human supervisors are also expected to act on hours or days timeframe to solve and diagnose complex problems, leaving situations that require rapid response and alertness to automation.
Further information can be found at the following links:

- ECHO: https://www.eurocontrol.int/project/european-concept-higher-airspace-operation#:~:text=The%20European%20concept%20for%20higher,where%20conventional%20air%20traffic%20operates.&text=Commercial%20and%20State%20space%20operations,for%20launches%20and%20re%2Dentries.
- FAA UPPER E: https://www.faa.gov/uas/advanced_operations/upper_class_etm/

5.2 Requirements for the New Operating Environment

Considering the scenarios included in this concept paper and with the anticipated growth in the number of manned and unmanned aircraft, it would be very demanding to monitor and control air traffic in a traditional way. At the same time, technological advancements are expected to motivate a re-distribution and automation of some routine tasks of the control loop, shown in Figure 1 below, leading to a change in human responsibilities. There are already examples of such re-distribution like the use of RNP AR on parallel approaches that get both aircraft on the procedure (well before final) and remove the need for ATC to monitor the vertical separation because the combination of FMS and the procedure provided sufficient guarantee of tracking. In the future, combination of automation and procedure (e.g. a pre-programmed path through urban canyons) will not only provide guarantee of obstacle and terrain clearance, but also traffic “clearance” too. This will affect ATC’s role in managing traffic, as well as how manned and unmanned aircraft operators manage their operations. Automation is expected to increasingly perform more holistic optimization at the fleet level (such as mission assignment, dispatching, navigation optimization, etc.). The role of the remote pilot will evolve to focus on configuring the system, managing trade-offs, setting priorities, managing risk and handling system constraints, as well as exceptions. The role of ATC is also expected to continue to grow into managing and enabling traffic and intervening in off-nominal situations, rather than what is predominantly used today in controlled airspace where the controller performs most of the tasks and manages traffic by clearance.

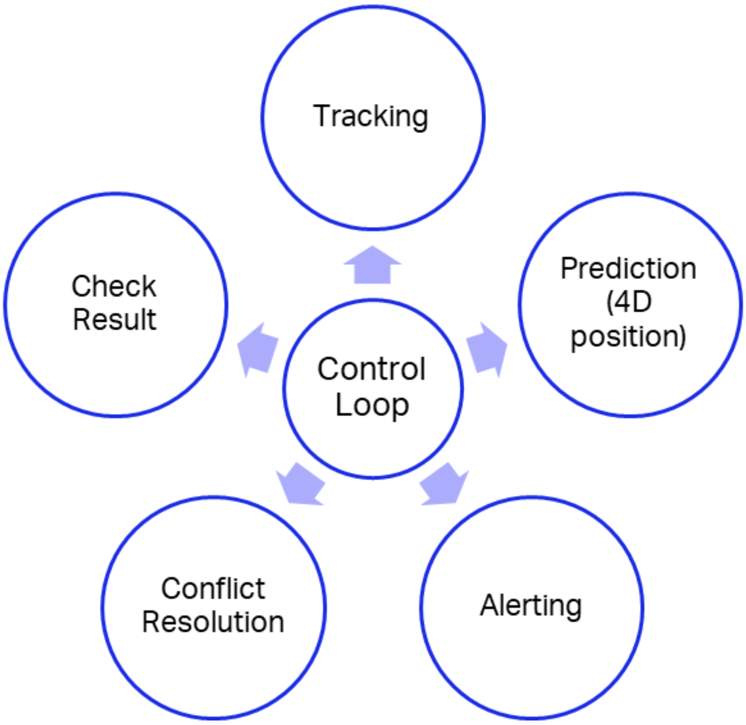


Figure 1: Control Loop

Data from on-board sensors will create a 4-Dimensional (4D) representation of the aircraft and its environment. With the large computing and simulation capabilities of Machine Learning (ML) algorithms, it will be possible to analyze data from multiple sources and provide prescriptive and predictive diagnostics of aircraft 4D position and the likelihood of a collision. With such future capabilities, the pilot or operator will be responsible for managing its operations safely without receiving voice instructions and routine ATC intervention. Traffic location, MET conditions, and obstruction locations may be provided for UA by the USP. Future ground and on-board capabilities will enable the sharing of digital representation of the situational awareness among operators. This will allow aircraft to be collaboratively separated with some functions related to traffic de-confliction shifting from ATC to the pilot and operator.

Automation will handle large quantity of data and only provide the UA operator with what is needed for their situational awareness. Automation will also give alerts about exceptions that cannot be handled automatically and present the UA operator with the necessary information to investigate off-nominals and take necessary actions. Likewise, the role of ATC is expected to shift to critical tasks, supervising the airspace and intervening in off nominal situations in order to continue to fulfil the objectives documented in Annex 11.

A high percentage of new entrants' operations are expected to be strategically managed through interactive planning and orchestration of intent information. Access to airspace constraints and weather reporting and forecast should enable strategic de-confliction for multiple new entrants' aircraft. Such increase in automation and availability of data, reduces the need for tactical separation management as well as the frequency of in-flight intent changes due to weather or airspace restrictions.

Strategic and tactical deconfliction performed by operators, or the service providers they rely on, will assure safe spacing between aircraft throughout the flight. Tactical de-confliction methods – the next layer of collision avoidance - will be necessary when strategic de-confliction alone is not sufficient to support the safety of operations. With regards to 'see and avoid, human vision will in order to continue to fulfil the objectives documented in Annex 11 ultimately be replaced in some situations by digital situational awareness in varying levels. For high altitude types of operations, there will be a requirement for constant planning and re-planning throughout all flight phases. For flights that last several months, the planning is done continuously, with regular adaptation to evolving conditions.

The different levels of automation, different aircraft performances and equipage of new entrants offer potential advantages in future aviation that are, as yet, un-capitalized upon by existing flight rules limitations. These aspects should be scalable to enable the operation of existing and future evolution of airspace users. Where applicable, requirements should apply to the operation of small UA for cargo deliveries, advanced air mobility, reduced crew operations, or a mix of operation of different types of new entrants and use cases. In future operating environments, airspace organization should consider the conditions for integrated operations of unmanned and manned aircraft as well as their specificities when defining the services available and the requirements to be applied. Supporting user preferred trajectories should be guiding principle of the airspace organization.

The current organization of the airspace in classes was tailored at supporting a static description of the airspace, where each airspace class corresponded to a level of service. What is envisioned is a more dynamic and flexible use of the airspace building upon the flexible use of airspace (FUA mode of operations already being implemented to facilitate integration more seamlessly In this construct inside an existing airspace class a sub-part or a designated part of the airspace might be temporarily allocated to a given operation or set of operations pending certain performance and cooperation rules being met.

In the near to midterm, the progression towards the future environment described under this concept paper will be faced with several challenges and gaps. For example:

- The need for separation standards between the various categories of UA, or between UA and manned IFR and/or manned VFR. Or between UA and AAM have not been clarified yet
- manned aircraft may not be able to efficiently separate themselves from UA; and

- until communication channels and protocols are available, the UA operator and/or the UTM system may not have full awareness of all surrounding traffic.

5.3 High Level Considerations

Airspace users in the future will be able to fly pre-negotiated trajectories while ensuring safe separation from traffic, obstacles and weather. Historically separation capabilities evolved from visual only to procedural/visual to radar/visual. Throughout this evolution, pilots relied on systems for navigation and separation when needed initially on the ground only and later also on-board the aircraft (e.g. RNP). With the evolution of automation over the next ten to fifteen years, the roles will shift between ATC, the operator, the pilot, and automated systems while the airspace will be used by a more diverse plethora of users. The key paradigm shift will lie in the degree of authority over the trajectory and responsibility for safe separation a remote pilot or operator or service provider will have, given the wide differences in the type of operations and performance capabilities of the aircraft. A new or revised set of flight rules may be needed to translate this new environment, whereby digital situational awareness is provided in the air or on the ground, into a set of requirements ensuring safety of the new operations. Management by exception like in the Trajectory Based Operations (TBO) concept for manned aviation, will be the norm and intervention the exception. Traffic density and complexity will dictate how separation are provided.

To support the needs of new entrants and the new operational environment, there is a need to conduct a comprehensive assessment of the assumptions supporting VFR and IFR and identify if an adaptation or an additional set of flight rules are needed. The underlying principle of such an assessment is that the traffic collision avoidance (such as separation tasks), trajectory management, and assurance of efficient, equitable airspace use, can be carried out by the operator. The assessment goes beyond the concept paper, and is considered necessary future work to be undertaken, however based on the scenarios discussed in this concept paper new flight rules may be required for low level and upper airspace operations, which would accompany the current VFR and IFR. Additional research and work will identify whether additional sets of flight rules are required or if an adaptation of existing flight rules will suffice. The following figure shows an illustration of what the envisioned future operating environment could look like.

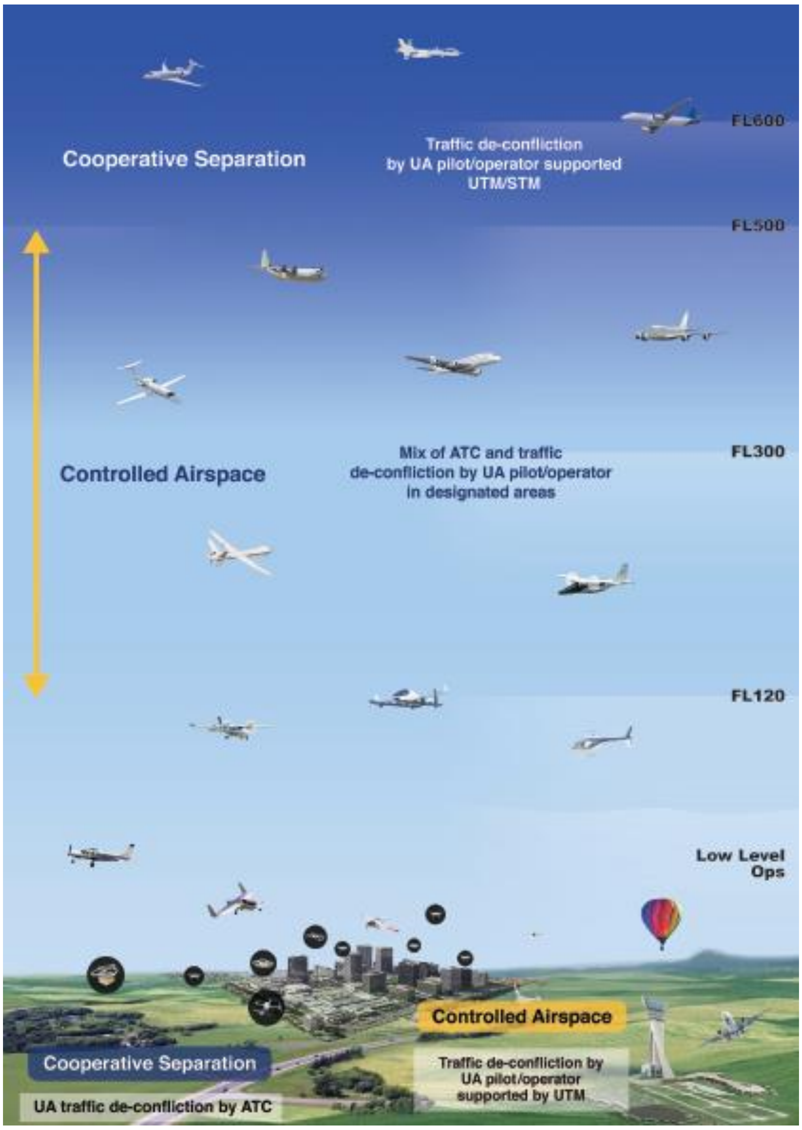


Figure 2: Future operating environment

Based on the three main operating environments outlined in this concept paper, the following table proposes how a digitally shared situational awareness and performance per operating environment will impact the distribution of roles and tasks. The proposed assumptions in the table can be used to identify new or adapted flight rules.

<table>
<tr><th rowspan="2">Altitude band</th><th rowspan="2">Aircraft Performance</th><th rowspan="2">Current Service & Rules</th><th colspan="2">Future Roles & Task Distribution</th></tr>
<tr><th>System / Automation</th><th>Human role</th></tr>
<tr><td rowspan="2">At and above 15 250 m (50 000 ft) AMSL</td><td>High speed and high manoeuvrability</td><td>ATC provider / FIS

Subject to Flight Authorization and managed by instructions in airspace classes that provide the service</td><td>• Digital situation awareness
• Automated collision avoidance (as needed)
• Probabilistic and real-time sharing of information (4D-positions, ID, weather)
• Airspace bubble moving with aircraft for launch and re-entry</td><td>• Operator:
○ Mission/flight planning including continuous de-confliction (shared role with system automation)
○ Off-nominal intervention
• ATC:
○ Off-nominal intervention
○ ATS for transitioning traffic</td></tr>
<tr><td>Low speed and limited manoeuvrability

Autonomy up to several months</td><td>ATC provider / FIS

Subject to Flight Authorization and managed by instructions in airspace classes that provide the service</td><td>• Automated operations
• Digital situation awareness
• Automated collision avoidance
• Automated dispatching, mission assignment
• Probabilistic and real-time sharing of information (4D-positions, ID, weather)
• Automated and continuous flight planning/re-planning (pre-flight and in-flight)
• Airspace bubble moving with aircraft for launch and re-entry</td><td>• Operator:
○ Mission/flight planning including continuous strategic de-confliction (shared role with system automation)
○ Limited pilot intervention capabilities
○ Off-nominal intervention

• ATC:
○ Off-nominal intervention
○ ATS for transitioning traffic</td></tr>
<tr><td>1L Below 10 150 m (30 000 ft) AMSL and above 300 m (1 000 ft) AMSL, or above 300 m (1 000 ft) above terrain, whichever is the higher</td><td>Unmanned Aircraft

40< speed< 400 Kts

100 < Weight< 30 000 Kg

Manned Aviation</td><td>ATC/Separation in controlled airspace (except Class E) all IFR and VFR

Subject to Flight Authorization and managed by instructions in airspace classes that provide the service</td><td>• Digital situation awareness
• Automated collision avoidance
• Probabilistic and real-time sharing of information (4D-positions, ID, weather)
•</td><td>• Operator:
○ Mission/flight planning including strategic and tactical de-confliction
○ Off-nominal intervention

• ATC:
○ Off-nominal intervention
○ Overall airspace and traffic management</td></tr>
<tr><td>At and below 300 m (1 000 ft) AMSL</td><td>Unmanned Aircraft

Speed <100 ktsrea

High manoeuvrability

Autonomy < 1h

Weight < 25 Kg

Manned Aircraft</td><td>Most VFR / FIS provider

Subject to Flight Authorization sometime managed by instructions in controlled airspace (except Class E)</td><td>• Digital situation awareness
• Automated collision avoidance
• Probabilistic and real-time sharing of information (4D-positions, ID, weather)</td><td>• Operator:
○ Mission/flight planning including strategic de-confliction
• Remote pilot and UA operator responsible for collision avoidance throughout the flight

• ATC:
○ Off-nominal intervention
○ ATS when required & available</td></tr>
</table>

The choice of which flight rules to use should continue to be up to the operator for each flight, according to where they fly, their technical capabilities, the services available, the level of services desired/required, and their business model. In such a future operating environment, the act of choosing the set of flight rules under which one will operate a flight is a formal declaration and acceptance of roles that the operator will assume throughout the flight. One flight may move from one flight rule to the other, which increases the importance of pre-flight planning in order to declare intent and capabilities and assumed functions by the pilot and operator.

Given the diversity of potential users, any systemic bias that unintentionally delivers benefits to one type of airspace user over another should be avoided. Any airspace user that meets the performance requirements should be able to access the airspace and be provided with the appropriate level of service. The revision of the current flight rules, or development of a new set of flight rules, and a review of Class(es) of airspace and associated service level provision, will facilitate a structured approach to the assurance of equitable access.

While at the beginning a gradual application of additional set of flight rules can be achieved through localized segregation of homogeneous operations, this essentially provides no benefit over current mechanisms such as SUA or restricted airspace. Therefore, the desired end state is to have integration and equitable access to airspace. Gradual introduction in dedicated airspace of an additional or amended set of flight rules with careful monitoring will ensure safety and learning from operations to accommodate adjustments and improvements as needed without disruption to IFR and VFR operations. This will, in turn, facilitate the integration of such operations into other airspace classes, and equitable accommodation alongside current operations. Due to the duration of flights and other characteristics, operation of UA can move across multiple Flight Information Regions (FIRs), and even States. Therefore, it is important to develop solutions that enable operations at a global level.

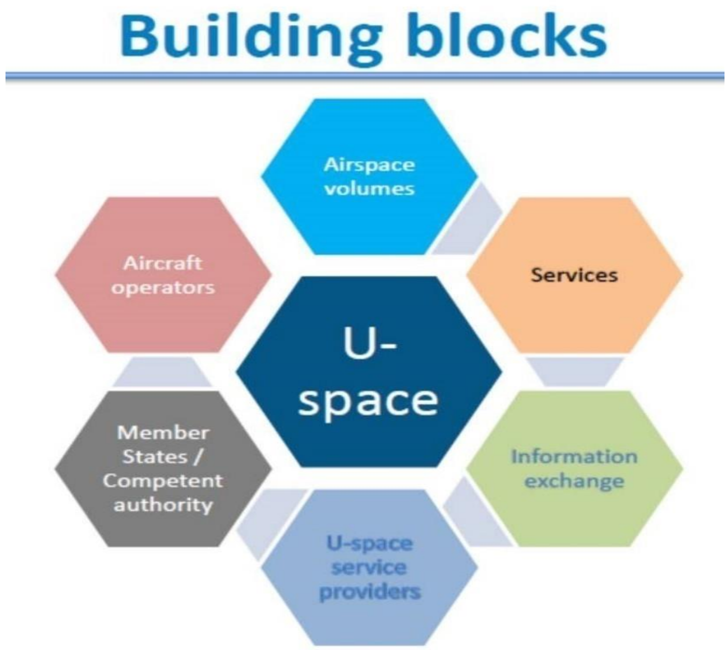
Appendix I – U-Space Concept

The European Union has developed a vision called U-Space, which includes a phased introduction of procedures and a set of services to support the safe, efficient, and secure access to airspace for high traffic volume of UA. U-space was developed to encourage the growth of the unmanned industry. The services and procedures reflected in the U-space concept rely on a high level of digitisation and automation of functions, whether they are on board the drone itself, or are part of the ground-based environment.

In support of this initiative, in 2017 the SESAR Joint Undertaking drafted the U-space blueprint, which is a vision of how to make U-space possible. The blueprint proposes the implementation of 4 sets of services to support the EU aviation strategy and regulatory framework on UA:

- U1: U-space foundation services covering e-registration, e-identification and geofencing.
- U2: U-space initial services for drone operations management, including flight planning, flight approval, tracking, and interfacing with conventional air traffic control.
- U3: U-space advanced services supporting more complex operations in dense areas such as assistance for conflict detection and automated detect and avoid functionalities.
- U4: U-space full services, offering very high levels of automation, connectivity, and digitalization for both the drone and the U-space system.

The main building blocks for the U-space concept are reflected in the following figure.



The following figure illustrates the proposed services available under U-space.

The Concept of Operations for European Unmanned Traffic Management (UTM) Systems (CORUS) project encompasses recommendations to achieve a harmonised approach to integrating drones into very low level (VLL) airspace. The ConOps suggests the need for two new sets of rules: at low level – low-level flight rules (LFR), - and high level (HFR). These sets of flight rules would accompany the current VFR and IFR.

Appendix II – Other Concepts and Research

In 2020, the National Aeronautical Space Agency (NASA) Aeronautics Research Institute (NARI) released an initial concept of operations (https://www.nari.arc.nasa.gov/etm) and associated operational requirements for cooperative air traffic management in High Altitude Airspace (Upper E) Traffic Management (ETM). In this ConOps, it is proposed that Class E Traffic Management (ETM) consist of the following methods of separation management:

1. Cooperative Separation: which is a community-based separation, where the operators are responsible for the coordination, execution, and management of operations, with rules of the road established by the FAA
2. ATC Separation provided by ATC

The ConOps further discussed how operations above FL600 are organized, coordinated, and managed by a federated set of participants. Operators will use a complementary set of services to air traffic-provided services that support the safe execution of flight. These services can be provided by the operator or by a network of third-party service suppliers. ATC may manage operations above FL600 upon request.

In such an environment, operators conducting cooperative operations are ultimately responsible for maintaining separation from other vehicles, and avoiding unsafe conditions (e.g., atmospheric conditions, solar flares) throughout a mission. Information exchange protocols provide the means for Operators to share information and access FAA information - for common situational awareness among all stakeholders. The ConOps also proposes that the FAA and other airspace users have on-demand access to ETM operational information.

The ConOps further defines how cooperative separation can be achieved via shared intent, shared awareness, de-confliction of operations, conformance monitoring, technologies supporting de-confliction, and the establishment of procedural rules of the road (e.g., right-of-way rules). Operators share their flight intent with each other and coordinate to de-conflict and safely separate trajectories. Vehicle de-confliction (e.g., Operator to Operator, vehicle-to-vehicle [V2V]) can ensure safe separation while procedures and clear rules-of-the-road ensure harmonized user interactions.

At the same time, NASA has already started working on concepts related to digital flight rules to enable the era of aerial mobility in the national airspace system. This work focuses on how VFR and IFR be augmented by new flight rules, Digital Flight Rules (DFR), that leverage modern and emerging technologies and are not bound by today's restrictions and limitations. Under DFR, the UA operator can assume full responsibility for traffic separation and therefore full trajectory management authority in all visibility conditions and airspace regions. The changes in roles and responsibilities of the pilot, operator and ATC are expected to enable greater airspace access and operational flexibility than afforded by IFR and VFR, thus enabling the emergence of new operations and a new era of advanced aerial mobility.