# Towards the Integration of Higher Airspace Operations in the European ATM Network


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***Abstract*— While very limited HAO are supported today by existing ATM processes, owing to innovation the number of operations is expected to grow substantially in the coming years. This will involve different geographical distributions and types of vehicles, ranging from slow-moving HAPS to very high-speed vehicles. New entrants will provide new challenges in terms of flight-performance envelopes, operating at level bands not used today and where their operational behavior and performance may generate additional uncertainty in ATM. Therefore, the major challenge is to research new solutions needed for a safe, fair and effective integration of the new entrants in the new operational environment by providing validated flight trajectories, procedural packages for both nominal and contingency scenarios and real time monitoring capability. This paper presents principles, assumptions and concept elements for the integration of HAO in Europe, which have been developed during the SESAR project European Concept for Higher Airspace operations (ECHO).**



***Keywords-Higher Airspace Operations, New Entrants, ConOps***


## I. Introduction

Recent technological breakthroughs have enabled the development of new vehicles with new mission profiles, ranging from low-speed high-altitude platform systems (HAPS) to very high-speed operations, notably supersonic and hypersonic transport, plus commercial space activities transiting from and to European States. These new higher airspace operations (HAO) will need to be integrated with traditional aviation operations as they will temporarily transit the current ATM environment and will be generally conducted above FL550 on a global scale.

For the European region, with the complexity of the multiple ATM systems currently deployed in the EUROCONTROL Network Manager (NM) area, the development of solutions to accommodate new entrants will need to consider both national and regional State responsibilities. With forecasted traffic exceeding 40 000 IFR flights for a busy summer day in this area by 2030 [1] and Air Traffic Flow & Capacity Management (ATFCM) delays reaching already critical levels with current levels of traffic, solutions need to be developed for enabling a seamless accommodation of these new operations without further jeopardizing the current capacity limits of the Air Traffic Control (ATC) centers. These solutions will need to provide a paradigm shift, moving away from the segregation of today's pioneer new entrants' operations to a more dynamic, automated and integrated mode of routine daily HAO based on the principles of cooperative traffic management and 4D operating zones.

HAO represent one of the most profound changes to the aviation environment for many decades. The number of space operations, HAPS, supersonic and hypersonic vehicles is set to steadily increase in the years ahead [2]. Due to the wide range of trajectories of very high-speed vehicles and the lack of precision in altimetry at high levels (up to 4000 ft difference between barometric pressure altitude and geometric altitude) HAPS operations can result in a requirement for large areas segregation due to uncertainty in trajectory prediction [3]. It is imperative that such operations continue to take place safely, efficiently and without a disproportional impact on more conventional air traffic operations. Change is needed to evolve from how we work today to fully support the new HAO and space activities so these operations can fully achieve their economical and societal benefits in Europe.

This article provides the essentials of the European concept of operations developed for HAO within ECHO SESAR 2020 funded project. Section II provides an overview of the present situation of the European airspace organization and how the space domain and its operations are governed today. Section III offers a short characterization of the types of HAO, their operational differences, and a demand analysis per each category. Furthermore, it describes the target concept, while the key characteristics are underlined in Section IV, focusing on the Civil Military Cooperation and matters related to airspace planning and structure. Section V summarizes the salient elements and draws conclusions, paving the way for future activities.

## II. Current Environment

Within European airspace, traffic density varies across Europe as shown in Fig. 1. In the ATM context, traffic complexity refers to the number of simultaneous or near-simultaneous interactions of trajectories in a given volume of airspace that generates additional workload for the Air Traffic Controller (ATCO) to resolve before a conflict would occur. Trajectories refer to the flight paths of individual aircraft, and interactions occur when these trajectories come into close proximity or conflict with each other. Complexity of the traffic and flows have a major impact on definition, scoping and execution of Air Traffic Service (ATS) provided in today's airspace environment.

Figure 1-Traffic Flows in Europe

ATS is provided by more than 60 Area Control Centers (ACC) and by more than 30 Air Navigation Service Providers (ANSPs) where Class C airspace has been published from FL195 up to FL660. Above FL 660 in some States no classification is published, while some have published Class G airspace to unlimited and consequently a basic ATS should be provided see Fig 2 (e.g. Flight Information Service and Alerting). It should be noted that today there is little, or no surveillance and communication capability provided by ANSPs above FL660.

The management of the European ATM network has been built on strong cooperation between all stakeholders based on the Collaborative Decision Making (CDM) principle (e.g. airspace users, service providers, regulators, the EU and its agencies, international organizations, etc.). It has been supported and codified by a coherent set of EU regulations which confers clear responsibilities on all actors involved. Hence, the management of the network is an essential component of the European ATM system and by extension for HAO which are an integral part of network operations and where the airspace is seen as a continuum.

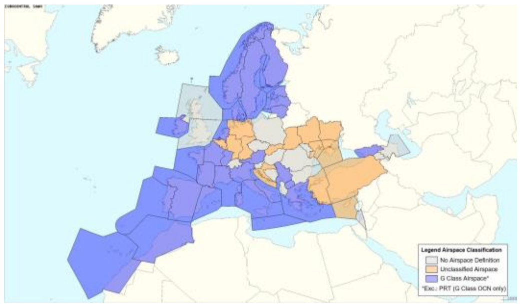


Figure 2–Airspace Classification above FL 660

On the other hand, space as an operational environment differs significantly from the operational constraints as they apply to airspace. There are no borders and national territories to be considered. Outer space can be freely explored, and no nation or State can restrict another State's lawful access to outer space for peaceful purposes. The Outer Space Treaty is the basic international treaty defining the framework under which operations in space should be performed. As there is no state sovereignty in space, the Convention on Registration of Outer Space Objects has the effect of establishing a crucial component of state sovereignty. A State's right to exercise sovereignty over space objects is dependent on that State entering its launched objects in a national registry. Additionally, States are absolutely liable for damage their space launches cause on the surface of the ground, or damage to aircraft in flight.

Global space activity has experienced a massive growth since 2013. 5681 spacecraft were launched between 2012 and 2021, which 1849 of those being in 2021 while only 110 spacecraft were launched in average per year between 2000 and 2012. The launch of so-called "mega-constellations", starting in 2019 with several operators, is expected to bring launch activity and satellites disposal to another level. Forecasts suggest that the deployment of mega-constellations, which have already started, will contribute to an even bigger increase in global space activity in the coming years, with 500 to 700 satellites to be launched per year by 2023 and tens to reenter at end of life.

## III. Higher Airspace Operations

HAO offer a unique opportunity to promote an operational vison that, from the outset aims to address some of the structural elements that in the past have required significant time and effort to improve. Perhaps one of the most familiar examples, the airspace organization and structure across the NM area, has been subject to constant developments to reduce fragmentation and improve interoperability. Such improvements have required a bottom-up approach and several decades to be fully implemented across the network. The lessons learned from this experience should be taken into consideration and the development of HA should start with a new approach.

Currently space operations are rapidly developing both in terms of the number of potential spaceport locations, proposed launches and launch methods. They can take place from land, sea and air with reusable components that return to the surface. Traditionally large airspace volumes are reserved for a considerable time to enable a launch or return to take place safely, thus preventing other traffic to utilize this airspace leading to flight inefficiencies or even cancelations. However, with the increasing number of expected launches, their impact on the European aviation network will significantly grow as the frequency of HAO operations could be even daily by 2040, while commercial traffic will continue to grow. Certain types of operations, such as commercial space, will require the expansion of existing operational interfaces and tools already available between the aviation and space domains.

Therefore, new processes and procedures at European network level are needed to mitigate the impact of such launches, reducing the need for segregation, and to prepare for both planned and unplanned returns.

Accommodating very high-speed operations, such as space launches and re-entries or hypersonic flights, will require cross-border procedures and system capabilities that are able to deal with non-nominal events that may extend across multiple national borders. Matching the operational requirements from all categories of new entrants with the specificities of the European ATM environment is therefore now essential. Also relevant in the context of network operations and HAO is the operational interface between aviation and space which requires a new approach that combines national, regional, and global perspectives to deliver the intended solutions for the future when the sharing of airspace becomes critical. The interface between the ATM domain and space traffic management domain (STM) will be determined using elements related to planning, contingency management and traffic management which will take all key factors into consideration. In the next part, a categorization of the HAO vehicles based on the operational altitude is given.

## A. *Types of HAO*

*Sub-orbital*

A suborbital flight may be described as the intentional flight of a vehicle system that reaches high altitudes above those reachable by conventional air-breathing aircraft, but which is not able to reach and maintain orbital speed around the Earth or able to escape from the Earth. Based on this general definition a suborbital flight may be either a flight with a ballistic or boosted phase above atmosphere, or it may be a trans-atmospheric flight, where the vehicle transits through the atmosphere up to high altitude continuously using air-breathing propulsion or the aerodynamic forces to control the flight, usually in hypersonic regimes. A suborbital operation is the whole set of ground and flight activities related to a suborbital vehicle system.

Two different types of suborbital operations can be identified. The first type is A-to-A suborbital flight, in which the launch/take-off area coincides with the return/landing area. They may be considered as regional operations. The second type is the A-to-B suborbital flight, in which the return/landing area and the launch/take-off one, are located at a great distance, typically intercontinental. Moreover, an additional classification can be made considering the mode of take-off and landing which characterizes the suborbital vehicle systems: horizontal or vertical.

The main challenges associated to suborbital flights, many of which are common with the other types of HAO, concern the technology, the regulation, the performances and trajectories, and the security and defense issues. From the technological point of view the challenge is the improvement of the reliability of the suborbital vehicle systems, especially the propulsion system, in order to increase the overall safety of the suborbital operations, especially for the occupants onboard.

Regarding the regulation, the main challenge consists in defining adequate overall safety objectives and systems' safety targets, to protect the occupants onboard, the third parties on the ground, in the air and in space, including the other airspace and higher airspace users. The level of safety will have to be established according to the principle of safety continuum (coming from the traditional aviation), considering the variety of the vehicle configurations with different level of risks and different scope of operation. This may be done by defining proportionate and performance-based requirements to be complied with through specific consensus standards able to support the evolution of the technology. It is clear in fact that establishing e.g. a single level of safety aligned with today's Commercial Air Transport (CAT) aircrafts and operations may not be appropriate for many types of HAO, even in the long term. Precise safety and related reliability requirements play an important role in the strategic phase of the operations because they affect the probability to have a contingency, or an emergency and the hazard areas involved in these occurrences.

A suborbital flight typically is intended to reach altitudes around 100 km. A-B flights may also have a range of thousands of km reaching supersonic or even hypersonic speeds. These characteristics pose two types of issue, namely (i) the need to develop specific surveillance and tracking systems and algorithms able to follow those speeds up to those altitudes, and (ii) a security and defense issue due to the fact that these types of vehicle, that can be confused with weapons, are able to overfly different States at altitude where the State's sovereignty might not be clear based on the current international treaties. Furthermore, especially for long range A-B suborbital flights, which may reach altitudes higher than 150 km, proper interface and coordination between ATM and STM are required.

*Orbital*

Orbital operations that generate HAO in non-segregated areas are re-entry vehicles transiting from orbit to ground and de-orbited satellites in end of life. Re-entry vehicles can either be ballistic or boosted, like A-to-B vehicles, but enter in atmosphere at speed that can exceed Mach 25. Soon after aero breaking in upper atmosphere, the re-entry vehicle operations can be assimilated to A-to-B suborbital operation. Main difference relies in absence of take-off prior to HAO because re-entry vehicle could stay days, months or years in orbit before return to ground. This changes the way to prepare the operations and implies even deeper STM and ATM coordination.

De-orbing of satellites designed to demise is ballistic. Start of the operation could be controlled or not. Because of speed, fragility and steepness of the dive in atmosphere, satellites are vaporized before airspace and ground, but they generate risk of collision in HAO. Other vehicles or objects returning with payloads to be recovered and under controlled re-entry will also have to be accommodated safely. Here again the main challenge concerns STM and ATM coordination.

*HAPS*

High Altitude Platform Systems (HAPS) represent a class of low-velocity and economical aerial vehicle, characterized by their constrained maneuvering capabilities, which can operate in the stratosphere for extensive periods of time spanning days, weeks and months. The viability of these operations derives from the solar irradiation as a primary energy source, keeping the equipment functioning at these elevated altitudes.

Three types of HAPS emerge based on their locomotive mechanism: motorized Heavier Than Air (HTA) HAPS category, distinguished by small propulsion systems and reliance on convective airstreams for ascension together with gliding capabilities for descent; the motorized Lighter Than Air (LTA) variant, characterized by utilization of fluids lighter than air for controlled elevation changes apart from the motors to control speed and maneuverability; and Balloons, which are the group more limited in terms of maneuverability, using wind predictions and other fluids to control the position.

The main applications of HAPS cover domains such as communications, earth observation and scientific exploration, among others. These platforms can be orchestrated into fleets to facilitate broader application scope and extended coverage. Projections suggest and anticipated deployment of 1000 HAPS in Europe annually before the close of the current decade, reaching an estimation of 1500 to 2000 flights per year in the 2030s.

Nevertheless, HAPS must address some challenges to achieve their entrance at scale in this new era of aviation. Transition of HAPS from

Lower to Higher Airspace is crucial without impacting and ensuring minimal disruption to traditional air traffic flows. Furthermore, operations may cover several Flight Information Regions (FIR) from different countries, thereby a standard regulation and flight authorization protocols are required. Lastly, among other challenges, the enhancement of meteorological forecasting assumes a relevant paramount for these types of vehicles.

## *B. Potential Demand*

Higher Airspace has been utilised almost entirely by military actors and as transit for space vehicles in the past. Challenges posed by new entrants and the underlying conditions of their operations will lead to an increase in interactions among HAO and between HAO and conventional air traffic in the airspaces below. Assessing the demand for HAO is critical for the evaluation of future operational means to ensure a safe and practicable use of airspace. Within the ECHO project, a thorough demand analysis has been conducted, including the development of specific demand scenarios and an impact assessment of new entrant's operations. The collected results are summarised in the following paragraphs. [2]

HAPS services must be expected being utilised predominantly for telecommunications in low to medium densely populated areas. In addition, HAPS can be used, among other things, for maritime surveillance and border security measures. European regions with apparent potential for HAPS deployment are therefore peripheral areas like Scandinavia or the Mediterranean. Unfavourable environmental conditions, e.g. at higher altitudes or during winter season however pose significant hurdles for current technology. Due to the limited manoeuvrability and low speeds, the transition through the ATS Airspace is a critical flight phase for HAPS. Blocking large volumes of highly utilised airspace for a considerable amount of time like in the core area must be assessed and particularly minimised regarding the potential impact on the entire network.

Frequently operated sub-orbital operations in the network area are currently taking place in the form of sounding rocket launches (almost exclusively in Scandinavia). Future demand is expected for the UK as well. (Touristic) A to A flights may be launched in the UK and Italy. Supersonic A to B flights could be revived, presumably only connecting major city pairs though. Primary destinations would therefore be London, Paris, Amsterdam, Frankfurt, and Istanbul.

Orbital launch activities are expected to surge in Europe with multiple start-ups progressing in the field of the so-called micro-launchers. Scandinavia and the United Kingdom will offer launch services in the short to medium term future. The first UK spaceport, Spaceport Cornwall has been certified and is operational since 2023, when the Virgin Orbit air-launched Launcher One on 9 January 2023.

Additionally, a variety of launch sites/spaceports are designated, with initial launch intentions announced (e.g. SaxaVord Spaceport, Andøya Spaceport, German Offshore Spaceport). Air-launches operations are also possible from Grottaglie spaceport. From orbit operations of the Space Rider could use Grottaglie in southern Italy as landing site in the future, Sierra Space Dream Chaser approaches into Cornwall and Italy are under consideration as well. An overview of proposed launch sites/spaceports for orbital operations in Europe is depicted in Fig. 3.


Figure 3–Proposed spaceports with orbital operations in Europe

Within the scope of ECHO, four distinct European focus regions have been picked in an attempt to estimate HAO demand. These regions are Scandinavia, UK-Ireland, FABEC and the Eastern Mediterranean. The regions were selected considering a wide coverage of the following four characteristics: Geographical location (i.e. latitude), population density, fragmentation pressure, and air traffic density.

The demand estimation was stated per HAO type, namely the frequency of super-/hypersonic flights, continuous HAPS operations, the maximum number of HAPS transitions through ATS airspace per day, sub-orbital launches per year, and orbital launches per year. Assumptions for sustained operations were considered, i.e. assumptions have been made regarding the minimum launch frequency or number of operations required in order to achieve economic viability.

The following key statements summarise the range of demand for HAO as estimated in ECHO [2]:

In the short term,

- more than ten HAPS may operate continuously,
- A to A sub-orbital flights may launch every two months[1] or even more often in the future[2],, and
- orbital operations may take place on a monthly basis.

In the long term, demand may evolve to

- more than 100 HAPS operating continuously,
- multiple daily supersonic (and hypersonic, but only in the very distant future >2040) flights,
- A to A sub-orbital flights may launch up to twice a week, and
- orbital operations may take place twice a week.

In order to assess the impact of future HAO on the European network, fast-time simulations were used. Methodology and results are

[1] Not counting sounding rockets

[2] In June this year, Virgin Galactic has started monthly operation in the US from Spaceport America and expect to increse up to four operations per month in the future.

described in the following paragraphs. [4][5] Input variables were the alleged launch sites in Europe, the dimensions of closed airspace volumes as per real-life operations in other parts of the world (e.g. rocket launches in the U.S. or NZ), already planned operational volumes, and estimates based on available expertise and research. European network air traffic data of the peak day in 2019 was used to model the conventional traffic as well as EUROCONTROL traffic forecasts.

The impact of HAOs on the conventional air traffic has been modelled using a fast-time simulation environment and measured i.e. using the following flight efficiency parameters: Total flight distance, total flight duration, total fuel consumption, and number of re-routings necessary due to HAO activity. Out of the four focus regions assessed in ECHO, simulation activities were limited to the UK-Ireland FAB due to the most mature data for this region (real-world operations data from the Virgin Orbit launch as well as a number of spaceports and the various launch intentions already announced). An overview of all operational volumes modelled is shown in Fig. 4, including vertical launches from the Shetland Islands and Northern Scotland, southern and northern bound air-launch trajectories south-west and north-west of Ireland, HAPS transiting zones in south-west of Scotland and southern Ireland, an A-A sub-orbital launch area in the southwest of England and a hypersonic ascend corridor over the North Sea east of England. Out of these volumes, three daily scenarios were created, reflecting the ECHO HAO short-, medium- and long-term demand estimates.

Figure 4–Operational volumes of simulated HAO scenario

The results of the study (see Tab. 1 and 2) show that HAPS could potentially cause the vast majority of network impact for conventional air traffic among all types of HAO. This can be explained by their large operational volumes as shown in Fig. 5

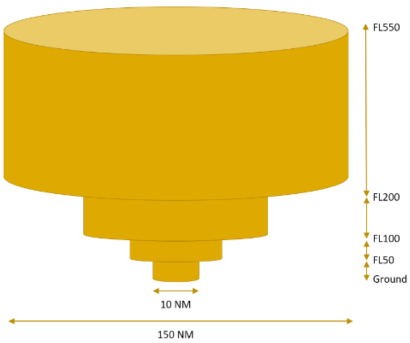


Figure 5–Model for a HAPS operational volume [6]

(the upper segment of 150NM diameter was subdivided in six 60° segments, with only one of the segments active at a time). Additionally, these volumes are active for long durations of multiple hours due to slow speeds of the vehicles, thus affecting a large number of flights. Considering individual flights, launches cause the highest average impact per flight. The respective closed areas around the launch area and for rocket stage and fairing drop zones are only operative for a maximum of one hour though, hence affecting less flights causing a relatively lower network impact compared to orbital operations. A finding worth noting is that under the parameters of the study, vertical launches caused several times less network impact compared to orbital air-launch operations. A-A sub-orbital flights cause significantly less network impact due to their relatively small footprint and short mission durations as opposed to A-B suborbital flights that would have cross-continental footprint.

TABLE I. AVERAGE VALUE FOR FLIGHT EFFICIENCY PARAMETERS PER USE CASE [6]

| Use Case | Additional flight distance [NM] | Additional flight duration [min] | Additional fuel consumption [kg] | Number of rerouted aircraft |
|---|---|---|---|---|
| HAPS | 7.08 | 0.93 | 96.20 | 308 |
| Launcher | 30.41 | 3.95 | 271.45 | 11 |
| A to A | 4.80 | 0.77 | 40.37 | 3 |
| A to B | 9.50 | 1.30 | 53.87 | 1 |

TABLE II. TOTAL VALUES FOR FLIGHT EFFICIENCY PARAMETERS PER USE CASE [6]

| Use Case | Additional flight distance [NM] | Additional flight duration [min] | Additional fuel consumption [kg] |
|---|---|---|---|
| HAPS | 2182 | 286.72 | 29,628.55 |
| Launcher | 334.50 | 43.42 | 2985.90 |
| A to A | 14.40 | 2.30 | 121.10 |
| A to B | 9.50 | 1.30 | 53.87 |

To conclude the findings of the study, peripheral locations as well as off-peak launch / take-off windows for HAO are needed to facilitate acceptable levels of network impact. The results illustrate that especially HAPS transitions must be located in areas with relatively low air traffic density and during off-peak times to ensure acceptable levels of network impact.

## C. *Target Concept*

The ECHO ConOps develops and outlines a desirable and aspirational state as a target for the integration of HAO in the European context. The individual target concept elements are summarised in this chapter. [5]

Managing HAO in the European ATM network will be based on the principles of collaborative decision-making (CDM), which includes air situation awareness and strategic collaborative de-confliction which forms part of trajectory-based operations (TBO). The concept will be applied to both individual vehicles, flying according to their agreed trajectories, and to operating volumes, which are called 4D operating zones.

A 4D operating zone is understood to be a volume of airspace typically used by vehicles associated with higher levels of uncertainties for their movements. It is allocated to one or several specific vehicle(s) and separated from other airspace users. It is a 4D volume of airspace moving alongside a 4D trajectory profile. Inside the 4D operating zone, vehicle(s) are free to operate as required as long as they stay inside the defined 4D operating zone. Separation for vehicles inside a 4D operating zone may be provided by additional separation service providers and/or self-separation capability. Building on key elements of the SESAR DMA Type III concept, the 4D operating zone expands the characteristics due to the capability of dynamic expansion and other vehicle's ability to join, extending the volume and resulting in potentially multiple 4D operating zones merging into one.

The European concept aims to set out operational means and approaches on how to enable managing operations with a large variety of velocity and trajectory profiles in an already highly congested airspace environment, building upon the established strategic, pre-tactical and tactical ATM planning phases.

Operators share their flight intent via extended flight-plan information and provide their desired 4D-trajectory and any other relevant information for the safe execution. The information is incorporated in the network planning process. Operators will receive information from supporting service providers. Within the planning phase, the operator supports a continuous CDM process based on all information exchanged with the NM. The Network function may look to balance the desired trajectory flows and initiate a trajectory negotiation.

It has to be determined if a flight will require airspace segregation or if it can be handled by its 4D-trajectory. An airspace segregation might be either a static airspace volume activated at a specific time and duration or a dynamic airspace volume representing the amount of uncertainty associated with this specific type of operation.

The ascent to and descend from HA through ATS airspace is performed in accordance with the accepted and maintained flight plan. Separation is ensured by ATC based on established separation criteria using available surveillance information and information provided by the operator. Separation criteria are dependable on the vehicle class and its associated performance capabilities. Based on deviations and environmental or performance conditions, or operator intent, the agreed trajectory may be updated. If those updates require modifications to constraints or an optimisation of the flight, a revision of the agreed trajectory might become necessary and trigger an in-flight trajectory negotiation process. In case of an emergency, predefined emergency procedures are activated.

Operations in the HA are conducted based on the agreed trajectory or 4D operating zone, acting as a dynamic airspace reservation. Size and duration of an airspace reservation is determined through a CDM process between the relevant operational stakeholders and the NM. Long endurance flights or possible uncertainties during the operation may lead to a requirement to modify the flight profile, resulting in an evolution of the agreed trajectory or 4D operating zone until a definitive revision becomes necessary. If the operators flight intent changes, it generates a new desired trajectory which ideally considers existing operational constraints and resource contentions or otherwise engages in collaboration on the trajectory or 4D operating zone.

Strategic de-confliction is applied as far as possible to ensure conflict-free flight execution of operations in HA already through the planning phase. This includes a variety of airspace route structures such as entry/exit routes for hypersonic flights, launch/re-entry structures for space operation or dynamic airspace volumes for HAPS.

Inside the 4D operating zone reserved for HAO operations, new approaches may be used to avoid collisions using AI, machine learning or other evolving technologies which use information-sharing to enable safe operations within the reserved airspace. Furthermore, once the protective volume has been established, the organisation and management of the operations is the responsibility of the agreed entity through the planning process. The operator is responsible for the evolution of the 4D operating zone over time and providing the information to all stakeholders. To maintain consistent situational awareness and predictability of operation, operators share changes to their intent, enrich surveillance information where necessary by additional information like telemetry data, maintain awareness of their operational environment and flight intent of other operators and participate in collaborative coordination measures.

The lower boundary of HA is not necessarily defined as a fixed level throughout European airspace. Certain types of HA vehicles operate at levels where other types of traffic routinely operate. For example, nominal trajectory profiles of balloons or HAPS might require operation potentially down to FL550. On the other hand, conventional aircraft may reach altitudes above FL550 such as high-performance business aviation but participate in HA only via a specific trajectory coordination process and are not considered HAO. Supersonic flights may as well operate on trajectories that also utilise a similar level band.

High-altitude vehicles which need to operate at the lower levels require a dynamic airspace to ensure separation management. This requires the establishment of a 4D operating zone for HAPS, while the IFR traffic is cleared to ensure separation. Rules are established for priority of the different operations. The access through airspace where both operations are foreseen to interact is strategically managed through CDM processes.

The responsibility for tactical separation within the 4D operating zone is allocated to a recognised entity. This entity may not be the service provider managing the IFR traffic. Separation assurance of IFR traffic against the 4D operating zone is the responsibility of an ANSP.

When the operational profile of an HA vehicle and the flight intent of its operator result in a trajectory extending beyond HA and entering the space domain, it requires not only separation from other operating vehicles in ATS airspace and HA, but also from active and passive space objects. During the planning phase, the operator extends the coordination of its intended trajectory beyond ATS airspace and HA, using services provided by STM or other additional service providers. The planning of the re-entry of a vehicle from space takes place as part of the flight-planning process. The re-entry of a space vehicle may already be part of the initially planned flight trajectory. However, the re-entry of an orbital or interplanetary mission can also take place after a considerable time; its exact time can be determined only in the course of the mission. Planning of re-entry operations considers the aspect of limiting unnecessary interactions and impairment of other traffic participants and is thereupon likewise reviewed and coordinated with the NM. It is considered that the flight phase of the re-entry is irreversible after it has been initiated and that the resulting flight phase can be associated with the need for prioritised execution.

Within the execution phase, deviations from the planned trajectory must be checked for their impact in both domains and appropriate measures must be initiated with the help of the respective processes of ATM and STM. STM service providers maintain situational awareness and support the vehicle operator through means of SSA.

Specific HA vehicles such as space vehicles during launch or re-entry may require efficient segregation procedures, protecting other airspace users. Areas along their flight trajectory, for which sufficient levels of safety cannot be assured by other means, will be segregated as the vehicle moves along its trajectory through this airspace region. Further along its flight trajectory, the vehicle is separated from other airspace users by operating within a 4D operating zone which also considers the level of uncertainty associated with the individual type of operation. Below their flight trajectory, airspace regions that would be endangered in case of non-nominal situations, but which can be cleared of other airspace users on time to prevent any collision with resulting debris are protected by dynamic aircraft hazard areas (AHA) using real-time monitoring and data-processing capabilities. Dynamic AHA complements the use of 4D operating zones and DMAs to separate the operational volume of the vehicle itself. The use of 4D operating zones covering the space vehicle in real-time minimises the need for static airspace segregation. This is achieved based on the real-time provision of all necessary information to all involved stakeholders allowing dynamic adaptation to non-nominal events, supported by higher levels of automation.

## IV. Key Characteristics

### A. HAOSP

When strategic de-confliction is no longer possible, tactical traffic information and monitoring, as part of ATM services, may be required to support operators in their separation provision task or provide a separation service for HA users that are unable to fulfil a separation task for themselves. This service may be provided by a higher-airspace operation service provider (HAOSP).

### B. Civil Military Cooperation

Civil-military relationship has three levels of interaction, from collaboration through cooperation and finally coordination, a process aimed to provide the framework within which the civil and military organizations can conduct their specific activities by maximizing the use of the airspace as a common resource with minimum impact of each other operations.

Collaboration is taking place basically at the strategic level, where long term agreements are concluded in order to establish certain portions of airspace with priority allocation to one or another stakeholder, rules for access to airspace, Letters of Agreement (LoA) for coordination procedures, requirements for data exchange, contingency principles and procedures.

Coordination is addressing primarily the pre-tactical and tactical phases of operations. It refers to exchanges of information for plans and applying specific procedures for real-time operations of new airspace users.

Regarding the HAO process, military are both airspace users and empowered with specific tasks related to national sovereignty, like air defense. As airspace users, there are military activities, especially surveillance and communications that will use platforms evolving in higher airspace but travelling through ATS airspace. To date there are in place comprehensive arrangements on information exchange and cross-servicing with civil aviation organizations for airspace up to FL660 (called ATS airspace). In the future similar procedures and practices are required for higher altitudes of flight operations, subject to resolving legal aspects of activities conducted beyond current ATS airspace upper limits.

For the military to be able to fulfil their national commitments for air defense, a complete set of data are required to be made available for the detection, identification and tracking of the flying objects. This data comprises but is not limited to planned 4-D trajectories, SSR/IFF codes, specificities of the mission (e.g. with/without re-entry components, footprint and altitude of protected areas, space debris status). All this information can be conveyed using existing systems and procedures in place for the ATS airspace enhanced with additional features suited for higher altitudes and new type of missions.

Military have a major role as airspace managers where robust mechanisms comprising institutional arrangements and coordination procedures are already in place. They are based on the FUA concept which allows effective airspace management from strategic level down to tactical in the day of operation. Although the existing arrangements work very well for classic civil aviation operations, the advent of new entrants conducting space operations of a different nature will challenge the current paradigm.

The collaborative decision making (CDM) between civil and military will broaden its scope to bring new actors in the process, Thus the solutions and tactical decisions will take into considerations the full spectrum of needs and requirements of both civil and military stakeholders.

Contingency is another field where military organizations have a role to play adapted to the new challenges posed by HAO. Military must be part of the contingency planning process and develop the subsequent procedures and competencies to ensure safety and security of air operations.

### C. Airspace Planning and Structure.

HA with its vast expanse is to be considered as a shared resource. The airspace will be organized and managed in a manner that will accommodate all current and potential new users of HA. Access to HA must be on a fair and equitable basis, with users being able to enter HA either vertically from the current ATS airspace volume below, from space above or horizontally from adjacent regions. Therefore, the design of HA needs to follow the already established airspace continuum principle, being driven by the new users' needs and with operations following a single planning process. Fair and equitable access will rely on a regulatory framework to include safety, security and environmental considerations.

### D. Comparing the Concepts for integrating Higher Airspace Operations in Europe and the U.S.

The operational concepts for higher airspace in the U.S. and Europe have been developed independently. Due to the global nature of most HAO and diverse operational types, which both concepts recognize, standardization through cross-border coordination and interoperability will be essential for a successful operational implementation. The following paragraphs give an overview of common principles between ECHO and the U.S.'s Upper Class E Traffic Management (ETM) ConOps as well as some divergent principles: [5]

The concept of Trajectory Based Operations (TBO) is an integral part of both concepts for the integration of HAO. ECHO builds on TBO and complements it with the novel concept of 4D operating zones. ETM mentions 4D information and flight intent sharing including "flight trajectories and volumes". Shared intent directly connects to TBO, enabling shared situational awareness. ECHO describes a CDM process based on TBO and shared flight intent. The corresponding element of ETM are the Cooperative Operating Practices (COPS).

During transit through ATS airspace, ECHO defines the ANSP as responsible for separation and for managing HAO in relation to IFR traffic. This includes operations at the lower boundary of HA, where separation again is the responsibility of the ANSP for managing IFR traffic against 4D operating zones. Within HA, the HA vehicle operators are responsible for carrying out their operations - including LRO's - providing all necessary information to other stakeholders to ensure safe operations. 4D operating zones may develop over time, with the HA vehicle operators again responsible for the evolution of the volumes. Separation provision inside a 4D operating zone may be provided by an operator or a service provider other than the operator (e.g. airborne function, dedicated service provider). While the focus is on strategic conflict-free flight planning as far as possible and the operators providing their own separation, tactical monitoring and traffic information is also provided, supported by ATM services. A novel type of service provider, the HAOSP, may fulfil the separation task in case operators are unable to do so for themselves.

In ETM, due to the Class E classification of the HA, the ANSP will provide separation to IFR flights, including the separation of IFR aircraft from the so-called cooperative operations. ANSP separation provision for IFR flights therefore extends into HA, contrasting the situation in Europe. Using operative services like the Central Altitude

Reservation Function (CARF) for the early implementation phase of HAO, in the long-term, operator-responsible cooperative separation measures shall be developed. Cooperative separation is understood to be a community-based separation provision, where operators are responsible for the coordination, execution and management according to the rules set by the FAA.

The implementation and integration of HAO is foreseen both in ECHO and ETM to be through an evolutionary path, adapting to operational needs and avoiding a specific timeline. ECHO mentions three regimes of implementation from a short-term environment with current ATM capabilities, to a medium-term scenario and ultimately the long term "target concept" (see chapter III C). Similarly, in the U.S., existing ATM resources are used to accommodate early operations. With the expansion of operations, a phased implementation process is suggested.

Space Vehicle Operations are incorporated in the ECHO ConOps, whereas the integration of space operations in the U.S. is addressed in a separate Commercial Space Integration into the NAS (CSINAS) ConOps, though the difference is assessed to be generally programmatic rather than operationally significant.

Operations near the lower boundary of HA however are handled differently in ECHO and ETM respectively. In ETM, between FL500 and FL600, a "flexible floor" may extend cooperative operations into Class A airspace, and operators must obtain ATC approval to cooperatively separate in the given area. IFR can either avoid the area or file a conflict-free trajectory. In ECHO, 4D operating zones may be utilized in Class C airspace below HA altitudes, and IFR traffic would be strategically separated via a CDM process with separation assurance finally being the responsibility of an ANSP. Restrictions may apply to 4D operating zones in Class C airspace to ensure equal access to airspace for all airspace users.

Finally, airspace classification is handled differently in Europe and the U.S. The U.S. designates all airspace above FL660 as Class E with no specified upper limit. The underlying airspace is classified as Class A. The airspace structure in Europe was already discussed in chapter II.

## V. Conclusions and Further Steps

So far, the approach to define CONOPS has been described. The analysis of demand for each identified category of vehicles has allowed to set sound basis for the CONOPS. Accordingly, such analysis has provided clear evidences of the different development and exploitation timespan, rising the needs of designing CONOPS considering short, medium and long term. Where stratospheric and hypersonic platforms seem to progress in maturity in the next ten years highlighting the need of a quicker seamless integration in the national airspaces, other platforms such re-entry vehicle will be massively operated by longer term.

The CONOPS has been validated by means of workshops involving relevant stakeholders of the higher airspace operation value chains from manufacturers to national air service providers. They have encountered a common agreement, and next steps have been identified considering the market needs.

Each result and related assumptions are to be validated.

Validating Concepts of Operations (ConOps) for higher airspace operations involves ensuring that the proposed concepts align with the intended goals and are technically feasible, paving the way towards the operational integration of HAO in ATM, on three layers:

1. Space Launch Real Time Monitoring Module and associated working station for the European ATM Network Manager for increased situational awareness at Network level, supporting Air Traffic Flow Management as well as crisis and contingency management.
2. Procedural Package covering specific ground and air-ground operational integration issues (including for communications, navigation and surveillance means) associated with the integration of High-Altitude Platform Systems (HAPS) operations into ATM
3. Procedural Package covering specific ground and air-ground operational integration issues (including for communications, navigation and surveillance means) associated with the integration of supersonic, hypersonic and suborbital vehicles operations into ATM.

Such layers will thus feed the validation exercise, which will consist of :

**Defining Detailed Operational Scenarios:** Develop a set of detailed operational scenarios, including off-nominal ones, that the higher airspace operations ConOps will address. These scenarios should cover a range of use cases, from routine operations to emergency situations.

**Performing Risk Assessment:** Conduct a thorough risk assessment to identify potential hazards and challenges associated with the proposed concepts. Consider factors such as collision risks, communication breakdowns, technical failures, and environmental impacts.

**Assessing Technical Feasibility:** Evaluate the technical feasibility of implementing the proposed concepts. Consider the availability of necessary technologies, infrastructure requirements, interoperability with existing systems and equipment, also assessing potential limitations to be overcome by new technology developments and/or procedural approaches and communication protocols.

**Performing Simulation and Modeling:** Utilize simulation tools and modeling techniques to test the proposed concepts in a controlled environment. Simulate various operational scenarios to assess their performance, safety, and efficiency.

**Defining and applying Performance Metrics:** Define key performance metrics that will be used to measure the success of validation activity. Metrics could include efficiency gains, reduction in delays and safety enhancements.

**Implementing Iterative Feedback Loop:** Continuously engage with stakeholders and subject matter experts to gather feedback on the ConOps. Use their input to refine and improve the concepts.

**Guaranteeing Regulatory Compliance:** Ensure that the proposed concepts adhere to relevant aviation and new *ad-hoc* HAO regulations and standards. Work closely with regulatory bodies to address any compliance issues.

**Performing Pilot Testing:** Conduct pilot tests of the validated concepts in a controlled environment or limited operational setting. This will provide real-world insights and allow for further refinement.

In order to ensure safety, the new entrants' operational behavior will need to be validated. Validation activities and further research is currently envisaged in SESAR3 ECHO2 project to move the current theoretical concept of operations (TRL 2) closer to daily operational use (up to TRL 6) by providing NM with real time mission monitoring capabilities, cross-border validated trajectory data from HAPS test flights and enhanced network simulations, airspace and continency management procedures. Based on the gained operational experience from these real and virtual flight trials, it will be decided what airspace structure, types of services are required in the HA, and whether new separation requirements and rules of the air should be adopted.

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