Dynamic Airspace Re-configuration for Manned and Unmanned Operations in Shared Airspace

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***Abstract*— In the near future, it is expected that an increasing number of Unmanned Aerial Systems (UAS) will operate at very low level altitudes of up to 500 ft in urban and suburban areas. These new airspace users will have to share the available airspace with manned traffic, and dynamic airspace re-configuration (DAR) has been considered within the Single European Sky Air Traffic Management Research (SESAR) Programme as one of the enablers for the integration of unmanned and manned traffic in non-segregated airspace.**

The SESAR Industrial Research Project AURA investigated requirements for an interface between Air Traffic Management (ATM) controlled airspace and highly automated U-space airspace for large numbers of unmanned aircraft to identify practical segregation methods. ATM U-space Shared Airspace (AUSA) was defined as a generic type of airspace that can be delegated between the two regimes by a process called Dynamic Airspace Re-configuration (DAR). AURA results indicated that DAR processes will need refinement to better streamline communication between all actors. Furthermore, U-space contingency scenarios that were investigated showed that different types of situations need different DAR approaches. Accordingly, automation support levels may also change when different types of contingency are encountered.

The ENSURE project, which is part of the Digital European Sky Programme and started its work in 2023, is expected to address these communication and automation issues in the DAR process and validate the changes through simulations and flight trials.

This paper describes the steps that have been and will be taken by the ENSURE project to improve DAR automation and, in particular, the communication between airspace managers working with DAR support tools to accommodate UAS operations with frequently changing mission requirements, and the fleet managers and UAS pilots carrying out these missions. It will also give an outlook into the different types of simulations planned as well as the operational scenarios considered for future demo flights above the North Sea validating both procedures and developed interfaces between ATM and U-space actors.

Keywords*— *UAS, U-space, air traffic management, dynamic airspace re-configuration, contingencies, NARSIM, SESAR

I. INTRODUCTION

Unmanned Aerial Systems (UAS), in the more recent regulation material also called Unmanned Aircraft Systems and commonly known as drones, have seen significant growth in recent years with many efforts being undertaken to integrate them into the current aviation system [1]. Generally, ideas range from full integration into current traffic flows being managed by Air Traffic Control (ATC) to full segregation of unmanned traffic in so-called U-space airspace.

Full integration mostly concerns Remotely Piloted Aircraft (RPA) with a fixed-wing structure that need to be fully integrated into visual and instrument flight rule traffic patterns around airports under consideration of the conceivable differences in performance and technical equipage [2]. Segregation in U-space airspace has been devised to accommodate unmanned movements of all sorts by offering automated services that need to evolve along the U-space implementation roadmap [3]. That roadmap foresees an increase of UAS traffic beyond the year 2030 and an implementation of U-space that starts with dedicated areas in formerly uncontrolled very low-level (VLL) airspace with altitudes of up to 500 ft. The UAS traffic increase in urban and suburban areas may also be accompanied, though, by a change in use of airspace. It is expected that users will extend their operations to higher altitudes to perform special service missions, such as military inspection flights, or inter-city passenger and cargo transport. Accordingly, they will have to share available airspace resources with manned traffic [3].

Faced with this future constraint, the SESAR Industrial Research Project AURA investigated requirements for an intermediate structure between airspace managed by ATC and highly automated U-space airspace that would cater to the need of safely accommodating large quantities of unmanned aircraft. AURA outlined the concept of AUSA, which stands for ATM U-space Shared Airspace, and can be seen as a generic type of airspace that contains both ATC and U-space controlled airspace volumes which can be allocated between the two regimes through a process called Dynamic Airspace Re-configuration, short DAR [4].

DAR was developed as a human-controlled process to be executed by an air traffic controller (ATCO), and that controller was called DAR Manager. The decision not to implement an automated DAR process was based on the assumption that situations requiring dynamic airspace changes would require too many non-standard considerations and tasks that current automation solutions would not yet be able to accommodate to the level of safety assurance required. Thus, one of the primary objectives of AURA was to investigate the human decision processes for DAR operations.

Several highly-realistic simulation activities with ATCOs in the loop were carried out as part of the AURA project. These results indicated that DAR processes may need refinement in the future to better streamline communication between all actors, particularly between U-space users affected by DAR solutions and the DAR Manager. Another result was that DAR requests needed to clearly categorize different urgency levels to the DAR Manager. AURA developed several simulation scenarios for contingency operations that would necessitate a rapid airspace change, and the feedback from controllers hinted at that requirement. In particular, it was difficult for the DAR Manager to determine whether enough time was available to coordinate a contingency DAR request between all parties and implement it for the ATCOs. Even more so, scenarios with non-compliant traffic leaving the designated areas would lead to situations that left the DAR Manager no other choice than to immediately accept the request and communicate it to all parties without coordination. This aspect clearly touches the subject of human-machine teaming. Based on the urgency of the DAR request, a decision needs to be made how much automation support should be given to the DAR Manager, and whether the DAR Manager should actually be responsible for implementation of all types of DAR requests, or only those that can reasonably be coordinated before implementation [5].

The ENSURE project was started in 2023 and is expected to address any gaps in the current definition of the DAR process and further refine it. It not only makes a distinction between ATC-initiated and U-space Service Provider (USSP) initiated DAR requests (also referred to as "reverse" DAR requests), but it will also look at DAR urgency levels and automation needs by defining processes for high priority DAR requests (and reverse DAR requests). The latter are still under development, though, as are the validation activities for the refined processes and procedures [6]. The validation activities at the Royal Netherlands Aerospace Centre (NLR) will address tactical drone missions carried out above the North Sea inside the Amsterdam Flight Information Region (FIR). Different mission scenarios will be simulated to validate the refined DAR processes and to prepare flight tests carried out together with the Royal Netherlands Navy in 2025.

This paper will describe the DAR processes that were defined by AURA and their implementation into a highly realistic simulation environment, the NLR ATC Research Simulator (NARSIM). The results of the experiments carried out in 2022 will be presented and approaches to address the issues encountered and gaps detected in the concept will be identified and captured. The paper will then introduce the refined details applied to ATC and USSP initiated DAR processes in the ENSURE project. Furthermore, the plans for validating the DAR refinements and improved support tools for the DAR Manager in the context of the ENSURE activities will be described. This includes a number of potential flight trial scenarios that may help gaining a better understanding of the required procedures, information exchanges and interfaces between ATM and U-space to appropriately support both the DAR Manager, ATCOs, and drone pilots when carrying out drone operations with dynamically changing mission requirements.

II. Dynamic Airspace Re-configuration in the AURA Context

A. *Shared Airspace and DAR Management*

In 2021 the AURA project team developed an operational concept supporting a collaborative interface between ATM and U-space that was based on the general idea that airspace can be effectively segregated with reduced risk of conflicts between manned and unmanned aircraft by confining UAS operations to lower altitudes [4]. Manned aircraft typically fly above a minimum safe altitude, especially when flying over obstacles or densely populated areas [7], while UAS typically operate at altitudes below 500 ft in VLL airspace. It was also recognized by AURA, though, that the number of UAS operations will grow and become more varied in the future with a portion of the UAS operations being carried out beyond VLL airspace. For example, special inspection flights may necessitate flying at higher altitudes and within other types of airspace.

In order to account for this, AURA placed particular emphasis on the airspace volume definitions proposed in the CORUS concept of operations [3], in particular the so-called Z-volumes. In these volumes, pre-flight conflict resolution and inflight separation services are provided, with Za-volumes being controlled by ATC and Zu-volumes being covered by U-space tactical collision resolution. When UAS operate in Za-volumes, there are additional requirements placed on both the UAS and its operator. These requirements concern communication and system aspects of the vehicle (e.g. Detect-and-Avoid, DAA) and certification and licenses that the operator must acquire. An approved operation plan is required as well. Za-volumes thus represented regions of airspace with the highest demands on the collaborative interface between ATC and U-space investigated by AURA.

As a consequence, an operational solution for separation between manned operations and unmanned traffic was suggested in AURA that relied on the definition of AUSA (Fig. 1). In AUSA, generally, both manned and unmanned operations can be carried out. However, segregation is achieved by delegating dedicated parts of the AUSA airspace to become either ATC-controlled (blue) or USSP-controlled (orange) airspace via a process called Dynamic Airspace Re-configuration, DAR [4].

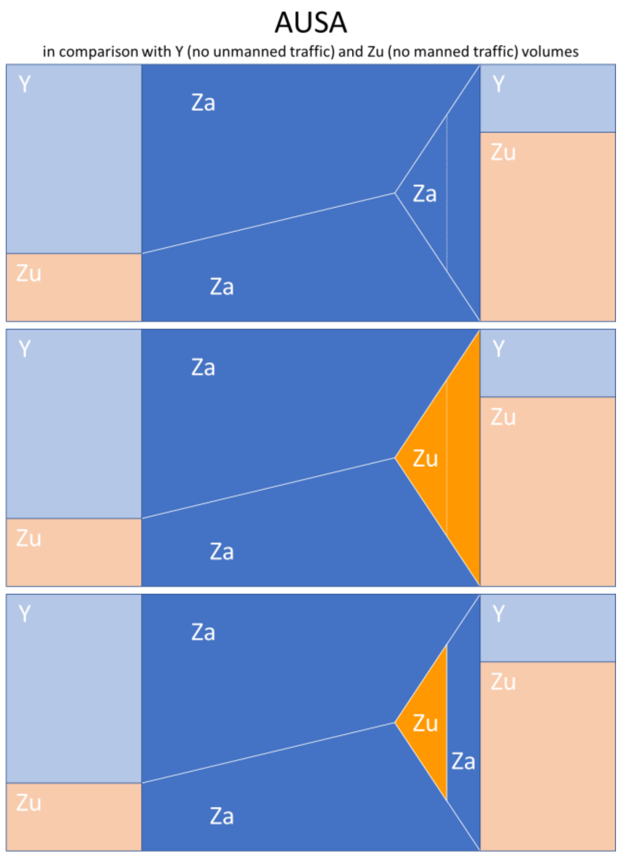

Fig. 1. ATM U-space Shared Airspace Delegation Example.

The DAR solution implemented in AURA was defined in such a way that an ATC appointed DAR Manager received airspace change requests from either ATC or U-space. These could either be strategic requests with planned delegation of airspace volumes several hours before flight execution, or tactical and even contingency requests that required the DAR Manager to quickly implement a solution and coordinate it with the tactical controllers and the USSP within minutes. The DAR Manager thus needed to be an experienced controller with operational knowledge about the very details of the airspace and the area of responsibility.

In the validation activities carried out by Royal NLR together with their AT-One partner DLR, the German Aerospace Centre, in 2022, the geographical environment considered consisted of a small regional airport being controlled by a tower controller (TWR), and a surrounding Control Zone (CTR) being controlled by an approach controller (APP). This meant that the DAR Manager had to coordinate any airspace changes with two tactical controllers and the USSPs of the U-space areas within the area of responsibility. In carrying out that task, the DAR Manager was supported by visualisation tools indicating the necessary changes and restrictions contained in a DAR request [5].

Before getting into the details of the DAR processes applied in AURA, however, it is necessary to take a closer look at the supporting architecture and the interface developed between the ATC and the U-space domains. It should be noted that a large part of the AURA development work was focused on the existing communication infrastructure and the services required to share information about the airspace changes implemented by the DAR Manager.

B. *Interface between ATM and U-space*

In order to enable DAR processes and implement the defined operational concept, AURA needed to specify services for the interface connecting ATM and U-space. Thus, the exchange of information among various actors, roles, and services within AUSA was further developed and described. Detailed information flow diagrams were created, taking into account the specific tasks associated with each role or service. These tasks could be categorized as belonging to either the strategic phase, the tactical phase, or both. One particular section of these diagrams concentrates on the essential components supporting the DAR processes. This section is shown in Fig. 2 and is based on the initial description in the AURA concept document [4] and the refinements made in the consolidated Operational Services and Environment Definition (OSED) document produced at the end of the AURA project [8]. It is currently being revised in ENSURE.

The diagram makes a distinction between manned aircraft operations, overseen by an Air Navigation Service Provider (ANSP), on the left-hand side, and unmanned operations, overseen by one or several USSPs, on the right-hand side. The essential bridge connecting these two domains was defined as the Common Information Service Provider (CISP) situated at the centre. Consequently, the *Dynamic Airspace Management* service on the side of ATC (representing the DAR processes) needed to be defined in AURA for interaction with both *Flight Authorization* and *Tactical Conflict Resolution* (performed by ATC) in case of a DAR request initiated on the ATC side, and for interaction with the CISP for U-space initiated DAR requests. In AURA, the latter included DAR requests that were a result of automated conflict detection (contingencies).

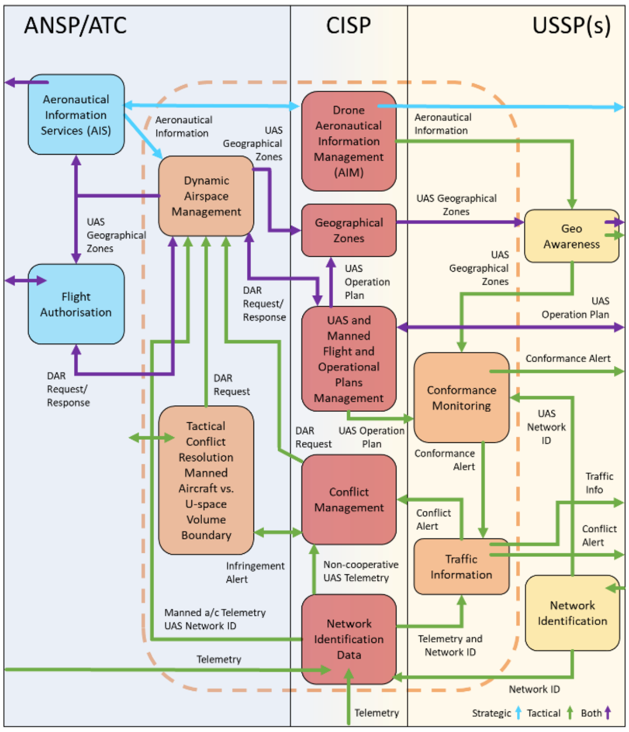

Fig. 2. Collaborative ATM/U-space Interface with Focus on DAR (AURA).

The CISP focuses on providing essential information to ensure the smooth functioning of the ecosystem. Its aim is to ensure that this information originates from reliable sources and maintains high standards of quality, integrity, accuracy, and security. This ensures that USSPs and ANSPs can utilize the information with confidence, trusting its reliability as they deliver their services.

Additionally, the CISP serves as a centralized gateway for all USSPs to engage with the ANSP, positioning itself as the coordinator for data exchanges among stakeholders during both the strategic and tactical phases. Sufficient situational awareness of all involved actors is required, and the CISP therefore needs to disseminate all relevant information received from both ATM and U-space domains. In the context of the DAR concept, this involves consistently transmitting updates on airspace restrictions whenever a DAR or reverse DAR is implemented.

C. *Supporting U-space Services*

The development of a number of basic Information Exchange (IEX) services in support of DAR was also part of the AURA work. The services did not entirely cover all DAR processes as their development took place in parallel to the operational definition of DAR. In particular, generation of DAR requests and the details of DAR request coordination cycles were not included. However, the services represent the required changes in current structures of the System Wide Information Management (SWIM) Yellow Profile regarding information and data exchanges for implementing an airspace change [9].

In summary, the following 5 services for exchange of information and data (see also Fig. 3) between ATM and U-space were developed:

- Operation Plan
- Geo-fence
- Tracking
- Traffic Non-Conformance Monitoring
- Tactical Operational Messages

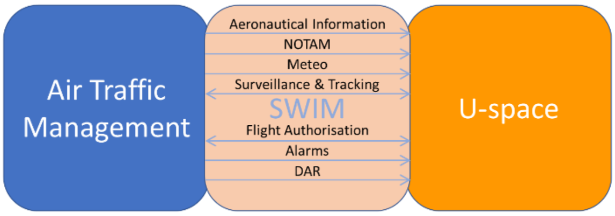

Fig. 3. SWIM Exchange of Data between ATM and U-space in AURA.

The IEX service for Operation Plans is a safety-critical, access-controlled service that manages live operation plans submitted via the operation plan preparation service and checks them against other services. The service manages authorisation workflows with relevant authorities and dynamically takes into account airspace changes. In addition, a part of this data exchange consists of ANSP acceptance or rejection of the plan. The centrepiece of the data being exchanged is the operation plan structure that also contains information about trajectories and operation volumes as well as contingency plans.

The Geo-fence IEX service provides information to UAS pilots and operators regarding any available restrictions at the time-of-flight preparation in order to produce an overview of where drones are allowed to operate. It receives input from NOTAMs and legislation as well as other aeronautical information sources containing information such as restricted and danger areas or temporary restrictions from national airspace authorities.

The IEX service for Surveillance and Tracking Data transfers position (report) data between ATM and U-space domains. It may aggregate mandatory position and altitude data with data on velocity and orientation, if available, and may also contain other related data such as object identification, classification, and priority.

The service for Traffic Non-conformance Monitoring data uses input from the services containing information about the operation plan and the tracking of traffic. The actual position of the UAS is thus compared with the accepted operation plan, and deviations from the plan can be detected. If a deviation of a UAS is detected, a non-conformance alert is sent to the responsible USSP. The idea is that the USSP then shares this information with the ANSP in the same way that deviations of manned aircraft from a flight plan are shared by the ANSP with the USSP(s).

Finally, the IEX service for Tactical Operational Messages transfers operational messages, such as ATC or USSP instructions as well as the corresponding message acknowledgements between ATC and a UAS operator via the involved USSP(s) or between a USSP and ATC.

When comparing the IEX services with the ideas for the CISP expressed in AURA, there are clearly a number of gaps that may have to be addressed in the future. This concerns both the location and responsibilities for some of the services as well as the related communication architecture. In particular, it must be clear whether traffic information and non-conformance monitoring services are provided by a USSP or by the CISP (see Fig. 2).

Furthermore, information needed to request or coordinate a DAR is not fully integrated on the U-space side yet. This means that, in order to understand the challenges of the follow-up project ENSURE, a deeper look needs to be taken into the details of the contents of a DAR request and the coordination options between the DAR Manager and the relevant ATC and U-space actors.

D. Dynamic Airspace Re-configuration Details

As mentioned above, the operational solution developed in AURA for strategic, tactical, and contingency planning of airspace changes and activation of the different airspace elements in AUSA was called Dynamic Airspace Re-configuration, DAR.

As AURA was seen as the first step in defining such a *Dynamic Airspace Management* process, it was decided that an additional ATC role would be added to have responsibility for the different tasks that would otherwise have added to the amount of workload for each of the tactical controllers already affected by the airspace change. The DAR solution thus required the manual intervention of an ATCO, the DAR Manager. This person would be familiar with the operational environment, could oversee the operational consequences of an airspace change, and could thus take decisions in the name of ATC regarding the implementation of the change.

In order to carry out the task of implementing airspace changes, the DAR Manager was supported by visualisation tools that presented the information contained in a DAR request. The tools highlighted the requested airspace change on a radar display and indicated constraints in time and altitude. The DAR Manager was thus responsible for managing the defined AUSA volumes and changing their control domain status depending on the demand for either manned or unmanned operations. The initial state of the AUSA airspace volumes was assumed to be defined via local arrangements, i.e. published in the Aeronautical Information Publications (AIP), but it was generally anticipated that airspace in the vicinity of ATC-controlled airports would also be controlled by ATC initially. In such conditions, AUSA could be reconfigured by the DAR Manager, transitioning the airspace from ATC-managed volumes to USSP-managed volumes wherever required and feasible with the purpose of accommodating an increased volume of unmanned operations alongside manned operations around an airport. Management of the U-space airspace volumes was thus entrusted to USSPs employing the necessary U-space services for safe operations.

Several assumptions were made regarding the DAR process and the tasks and responsibilities of the DAR Manager, as is shown in Fig. 4.

One of the main premises was the need for coordination and agreement between USSPs and ANSPs when making decisions affecting both manned and unmanned operations. Furthermore, it was vital to establish that ATM retains final authority in approving any changes within AUSA to protect manned aviation interests. Another key aspect was acknowledging a wide range of timeframes for re-configuring airspace. Demand fluctuations could vary from being relatively steady, prompting decisions that were more strategic in nature, to being highly dynamic, resulting in airspace configurations that were constantly evolving.

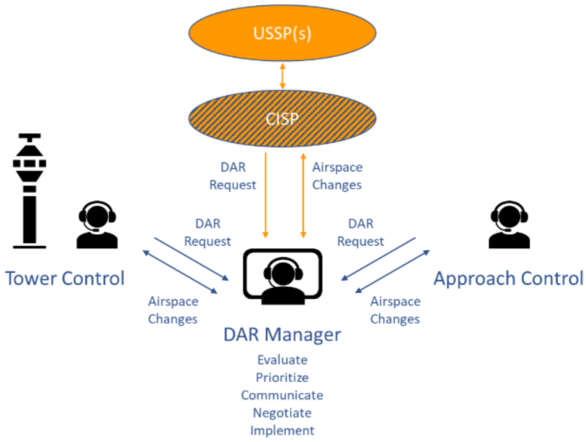

Fig. 4. Simplified Depiction of DAR Manager Role.

Moreover, it was necessary to define the technical requirements for vehicles operating within AUSA areas. The implementation of area restrictions and the confinement of UAS within "orange" zones often depends on the use of geofences and geo-cages. Consequently, this would call for compliant software for unmanned vehicles. Additionally, all vehicles were required to register with the relevant authorities and have Traffic Collision Avoidance System (TCAS) or Detect-and-Avoid (DAA) technology installed as an additional safety measure. Considering these factors, the AURA-defined DAR service provided a secure method to enable the flexible utilization of dedicated airspace areas by both manned and unmanned traffic, ensuring safety and adaptability.

DAR processes are supposed to work for strategic decisions and planning, but also in situations with highly varying traffic patterns. On top of that, some of these variations will be due to contingencies that occur inside U-space airspace volumes. For clarification, AURA defined contingencies as unforeseen events that demand swift resolution, ideally within a few minutes. However, certain contingencies require even more immediate attention, with response times measured in the range of seconds. These instances were referred to as emergencies, as they may breach existing airspace restrictions and pose an imminent threat to manned aircraft operations, asking for rapid intervention by ATC. NLR and their AT-One partner DLR focused their research on such contingency operations, while the consortium partners covered other use cases, as is explained in the upcoming sections.

E. AURA Validation Activities

Within AURA the consortium partners investigated different use cases and scenarios. The following gives an overview of the use cases and what type of interactions were investigated [10]:

- Exercise #1 managed by ENAIRE (CRIDA)

  In this exercise Human-in-the-Loop (HITL) Real-time Simulations (RTS) were carried out in the geographical area of Valencia Airport (LEVC), a mid-sized airport in Spain. For a future scenario, it was assumed that the airport is surrounded by AUSA airspace that is delegated to U-space as much as possible, leaving only a minimum of airspace available for a safe and efficient conduct of manned aircraft operations. One use case considered an emergency helicopter operation leading to a DAR request, initiated by ATC, on the basis of a pre-defined geo-fence structure. Another use case looked at high-priority UAS flights that needed to pass ATC-controlled airspace via a corridor, thus requiring ATC to open a corridor at a specific time via DAR. In both cases the DAR Manager role was carried out by the tower controller. Possible U-space constraints or tools proposing alternative options were not considered. U-space internal processes were also not modelled.

- Exercise #2 managed by Airbus

  This exercise looked at the data transactions between ATM and U-space needed to ensure a safe and efficient traversal of manned aircraft through U-space volumes, i.e. an ATC-initiated DAR request (due to a normal or emergency traversal) was considered. The assumption was that a DAR would be generated by ATC and received by a USSP. UAS would then need to abandon the U-space volume delegated to manned aircraft via DAR. When the manned aircraft had passed, the airspace would change back and become a U-space volume again. This exercise was carried out as a fast-time Monte Carlo simulation and, therefore, could not touch all operational aspects or operator feedback on the details of DAR procedures and interfaces. Instead, it was looking at the details of CISP and USSP processes [11].

- Exercise #3 managed by Indra

  A commercial aerial photography operation was considered together with the interactions needed, between ATC and U-space, to enable dynamic drone flight plan modifications in case of non-nominal conditions, such as UAS flying within a no-fly area after implementation of a DAR. In particular, this exercise thus addressed the exchange of tracking information and presentation of drone movements to controllers for situational awareness, especially in case of non-conformance issues. The exercise was carried out as an RTS in a low-traffic Madrid Barajas Airport (LEMD) environment.

- Exercise #4 managed by Indra

  This exercise, like the previous one, focused on the presentation of drone operations to ATC, in particular an adaptive presentation. The presentation was adaptive in the sense that it filtered the traffic in such a way that only those UAS operations that were considered to be of interest to ATCOs were actually shown to them. It was carried out in the same environment as above. Adaptive presentation was referring to the forwarding of traffic information in cases that would need to raise the situational awareness of an ATCO, such as drone proximity to manned aircraft, alerts being generated due to drone issues (non-conformance, conflict alerts) or non-cooperative drones. Here, the focus was mainly on ATCOs again and the impact that the additional information would have on their workload.

- Exercise #5 managed by AT-One (NLR/DLR)

  The AT-One HITL RTS exercise carried out on the NLR ATC Research Simulator (NARSIM) validation platform [5] in an environment for Rotterdam-The Hague Airport (EHRD) with drone flights simulated in the DLR U-Fly UAS simulator [12] focused on the role of the DAR Manager, the presentation of (reverse) DAR request information to both DAR Manager and ATCOs and the communication between all ATC actors involved. Several use cases leading to a situation where UAS operations in U-space required additional ATC-controlled "blue" AUSA airspace were simulated.

- Exercise #6 managed by SINTEF

  The exercise carried out by SINTEF assessed how U-space resilience can be supported by (semi-) automated algorithms to minimize the impact of disruptions. It addressed the automation of ANSP services and systems and of the CISP to achieve better U-space resilience despite a growing number of operations and more complexity. The simulation did not include human operators, but it simulated traffic in real-time and fast-time in combination with algorithms that modelled operator processes.

In summary, it can be stated that the AURA validation activities covered a wide area of CISP-related aspects, with the more operator focused exercises having been carried out by ENAIRE, INDRA and AT-One. In particular, the AT-One exercise focused on all the communication and coordination aspects required when changing airspace via DAR in both strategic and highly tactical phases, and it also developed a visualisation tool in line with the DAR implementation steps. Most feedback on the DAR operation was thus obtained from the AT-One exercise, with other exercises reaching the same kind of conclusions. The following section will shortly describe the particular aspects in case of contingency DAR requests. This will be followed by a summary of the AURA results with respect to the DAR operation.

F. DAR Management in UAS Contingency Situations

UAS contingency operations were characterized as situations where a UAS encountered an irregular operational state preventing it from following the predefined mission profile. In such cases, a special DAR request was considered necessary. This request was categorized as either a contingency or an emergency, depending on the degree of urgency. Any breaches of geo-fences or geo-cages were automatically treated as emergencies, whereas contingencies allowed for coordination between the DAR Manager and ATC or USSP before implementing an airspace change.

In AURA, use cases for the management of airspace were outlined, distinguishing between contingencies occurring near an airport runway and those taking place within the approach and departure areas (TMA) of an airport [8]. Airspace was structured into predefined AUSA volumes. Around an airport, these were mainly ATC-controlled volumes that could be delegated to U-space. In all contingency situations, the USSP was expected to either receive an automated non-conformance alert via a U-space service or an alert triggered by the relevant UAS fleet supervisor for a detected anomaly or situation that would require the execution of an emergency operation plan.

The USSP would then be responsible for propagation of that information to the common interface. In the simulations an assumption was made that the CISP would be capable of automatically determining the geographical coordinates of the requested airspace volumes (including a safety buffer) around the intended flight path, as was specified in [8], Ch. 6.4. The CISP could thus determine the relevant AUSA volumes that would need to change for segregation of the UAS experiencing the contingency. While this was the vision in AURA, recent developments in ENSURE placed the requirement for this service on the USSP side. For the DAR Manager, however, this question was irrelevant, as long as a request indicating the required volumes was received.

The contingency DAR request issued by the CISP ideally contained information on the airspace volume claimed (identifier, upper and lower altitude limits, start-time and end-time of the reservation), a priority level for the contingency (indirectly indicating whether there is time for coordination), and a motivation for the request (based on the operation plan with the included emergency response, see also [3], Ch. 2.2.4.5 and 4.2.11.4). Submitting the DAR request to ATC was expected to happen within a short time period that depended on the complexity of the situation.

For the Collaborative ATM/U-space Interface for Contingencies (CAUSIC) developed by NLR, this meant that the DAR Manager could visualize the request for evaluation, modify it when deemed necessary, and then propose the change to ATC controllers and the responsible USSP for coordination. Again an assumption was made in the simulations that the USSP side would always accept the request and that this would be made visible to the DAR Manager instantly via automation (Fig. 5). Coordination with controllers was supported by an intercom due to the different physical location chosen for the DAR Manager.

Fig. 5. Preview of DAR Request on CAUSIC Display (NARSIM/NLR).

Finally, the DAR Manager had the authority to use the interface to plan and activate the change. When planned, the change would be activated automatically at the indicated time. Manual activation and plan cancellation could happen at any time.

G. AURA Results for USSP Initiated DAR Management

The results of the validation activities carried out by AT-One have been described in detail in [5], [13] and [14]. The following section summarizes these results again for clarity and in order to point out the main shortcomings and gaps in the current DAR processes after AURA.

Overall, ATCOs (including the DAR Manager) were satisfied that the active U-space volumes (as well as the additional U-space airspace claimed for the emergency/contingency) were visible on their radar displays. The main information needs were met and additional information requirements for contingency situations were elaborated during validation. ATCOs reported that they were satisfied with the following aspects of the user interface:

- Usability (Acceptance) of the interface
- Improvement of Situational Awareness (SA)
- Increased level of Safety
- Increased operational Efficiency

However, there were also suggestions for improvement to make the system even safer, more efficient, and more adequate towards human capabilities. ATCOs recommended the following:

- Adapting the level of detail displayed to ATCO role (APP/TWR controller).
- Immediate (automated) notification of an incoming (reverse) DAR contingency request to draw the attention of the DAR Manager.
- More direct feedback on the actual airspace usage in U-space (in the form of an airspace volume occupancy status or via adaptive/situation-dependent presentation of USSP tracking service information) would allow the return to normal operations earlier and give ATCOs more confidence in carrying out the tasks.

The following remarks concerning the major Human Performance related issues were made:

- ATCOs were satisfied to be able to see the areas requested for contingencies on their radar displays (Fig. 6). It contributed to their SA, which is particularly important in emergency situations. They gave a warning to be careful to provide too much detail on the radar display itself as the increase in SA may be reduced again by a cluttered display. A suggestion was to move additional information in an ordered form (lists) to other display areas.
- Fast refreshers of information for the ATCO will limit the impact on manned traffic and improve the trust of ATCOs in the CAUSIC interface. After all, ATCOs will be better able to respond accurately and at the right moment in time, when they receive continuous and up-to-date information (see also the earlier comment on adaptive display of information). This aspect was linked to the issue of needing to reclaim ATC-controlled areas at airports as quickly as possible in order to reduce the impact on manned operations.
- USSP initiated DAR contingency requests in the airport vicinity can have a large impact on the efficiency of operations and workload of ATCOs (and DAR Manager). As a consequence, there must be careful consideration of the necessity of having AUSA volumes in the immediate neighbourhood of a runway approach and departure area. At all times, it must be clear what the impact of a delegation of airspace means in terms of operational changes for ATC (e.g. keeping aircraft at the gate or on the ground, putting them in holdings).
- The required minimum separation between U-space and manned aircraft has to be defined. This must be clarified in advance, and it must be clear what operations are feasible for each delegated part of AUSA (this finding relates to the previous bullet).

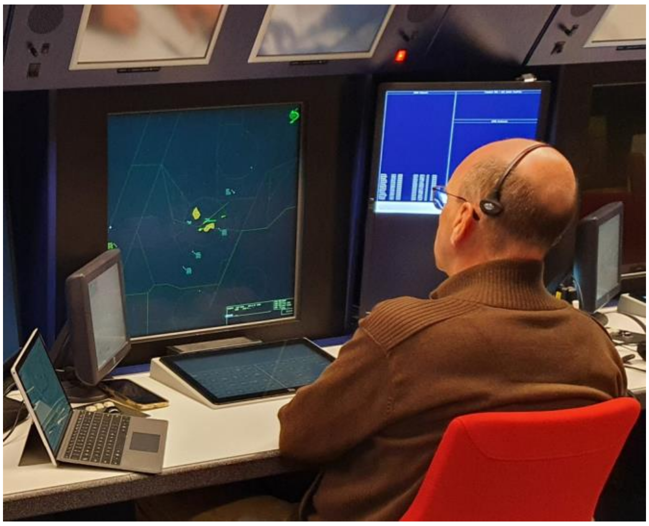

Fig. 6. ATCO Working Position at NLR during AURA Experiments.

H. *Identified Gaps in the DAR Operation*

Two major functionality gaps in the DAR operation were identified in AURA that need to be addressed in future work on the subject (see also [14]):

- For a possible response from the USSP and for further coordination with all actors, the simulations involving human operators made the assumption that the USSP would always agree automatically with an ATC-initiated DAR request or any change to a USSP-initiated DAR request suggested by the DAR Manager. This is not a realistic assumption, especially when looking at the work performed in other AURA validation activities, where a UAS may not be ready in time to leave a U-space volume. The coordination aspect with the U-space side thus needs further attention. Partially, this is also true for the coordination between the DAR Manager and tactical ATCOs. That communication was achieved mainly via an intercom. It thus depends heavily on the local situation and where the DAR Manager working position is located. It is expected that some of that oral communication could be replaced by further automation as well.
- There may also be a need to develop additional automation tools for the DAR Manager to help assess a DAR request and compare and evaluate different re-configuration options for the airspace volumes

These two identified gaps in AURA give way to more open issues that must be addressed in ENSURE to get to a more efficient and practical solution for the DAR Manager role and further automation options. If it is expected that automation will increasingly take over most of the DAR processes in the future, some processes need to be simplified:

- In the case of USSP-initiated requests, the automation will need to transmit (strategically) planned airspace adjustments to tactical controllers well beforehand through the CISP. Displaying that information in a proper way as an integrated part of the current working procedures (and without the intermediate assessment of a DAR Manager) will be a challenge.
- In situations that lead to very dynamic changes of the airspace due to UAS or aircraft contingencies, emergencies, or other high-priority missions that require immediate airspace changes, it may be necessary to directly coordinate the airspace change with ATCOs. This will require additional automation options as well to keep ATCO workload manageable and the entire operation safe and efficient. Adaptive presentation of tracking of information is an important element, but it cannot be the full solution.

Generally, this means that the following topics will be an important part of the operational developments expected from the ENSURE project:

- Airspace definition in a future environment with many UAS movements:
  - What airspace may become AUSA?
  - What are the operational implications on the ATC side for each possible change in AUSA volumes?
  - What does that mean for the business model of an airport?
- Additional automation to separate ATC-initiated DAR requests from USSP-initiated DAR requests:
  - How to separate both types of requests visually?
  - How to deal with concurrent requests from both sides?
- Automation needed for highly tactical operations:
  - What is the process for emergencies (e.g. detected violations of airspace and geo-fences)?
  - How to categorize DAR request types properly to allow for further coordination (i.e. timeframes and priorities)?
  - What kind of automation is required to speed up a coordination cycle?
- Automation versus human interaction:
  - How to allow for an optimal human-machine teaming?
  - Are there processes that could be fully automated?
  - How to keep the DAR Manager informed of fully automated processes?
- Standards and regulations:
  - How to move beyond current regulations and guidance material (EASA 2021/664) [15]?

Over time, DAR management responsibilities will need to transition to systems with greater automation levels. Despite this shift, human operators will remain essential, needing effective support, especially in situations where airspace changes happen swiftly and with limited planning time.

The ENSURE project, that was started when the AURA project finished in 2023, will have to answer many of these questions, with the DAR procedures at the centre of these investigations. The next sections will introduce the work that is currently performed by the ENSURE consortium and some of the plans for further demonstration activities of practical applications of DAR.

III. ENSURE - ATM-USPACE INTERFACE AND AIRSPACE RECONFIGURATION SERVICE

A. *The ENSURE Project*

The recently started ENSURE project that takes place in the framework of the Digital European Sky Programme aims to refine and complete the definition of a common interface and services for U-space and ATM (the CISP and USSP services as described above Fig. 2). This is done in order to continue the development started in AURA of ensuring that an interoperable and efficient interface between the U-space and the conventional traffic domains will be available in the future [16].

Like the AURA project, development activities in ENSURE have been divided into technical and operational solution streams. While the technical stream will extend the IEX services defined in AURA with services that have a standardised data model and architecture and are required on the U-space side and in the CISP to enable DAR operations, the operational stream started working on a refinement of the DAR processes themselves. This is done with the aim to address the detected shortcomings and gaps mentioned above with regard to the DAR procedures and the role and support options for the DAR Manager.

Altogether, the improved processes are expected to lead to further advancements in the AURA concept with simulations being accompanied by an assessment of associated operational risks and mitigation strategies. The end result must be a comprehensive management framework for DAR contingency requests and an assessment of the scalability and long-term sustainability of the proposed DAR services. In particular, the ENSURE project will have to answer questions regarding the categorisation and prioritisation of DAR requests and how to respond to each of them. This also means that human-machine collaboration and delegation of tasks will be at the centre of the investigations.

B. *ENSURE Approach to DAR*

ENSURE started the refinement of services by establishing a baseline from which the different services to be developed could be derived. In this way, several areas were identified as being impacted by DAR and information flow diagrams were established for each [16]:

- UAS Flight Authorization

  The information flow was set-up in such a way that two situations could exist that would require a forwarding of the authorisation request to and approval of ATC, namely an operation of a UAS inside the CTR without high risk and a high-risk CTR operation. The latter meant that ATC authorization would be required due to possible interference of planned UAS trajectories with the planned trajectories of manned flights.

- Emergency Management

  Emergency management would forward alerts between ATM and U-space domains with notification of a DAR request if required. This includes alerts for the end of an emergency situation.

- Traffic Information

  Tracking information from U-space and ATM is aggregated in the CISP and then forwarded to both domains including alerts from conformance monitoring and conflict management.

- Drone Nominal Operation

  For a nominal drone operation, the USSP would monitor traffic information and aeronautical information for geo-awareness to ensure the safe execution of a UAS flight.

- Drone Non-Nominal Operation

  For a non-nominal operation, deviations from the intended UAS trajectory would be detected by the USSP, forwarded to other USSPs, and an alert of non-conformance would be raised and sent to the CISP. The general task of the CISP would be to forward traffic (tracking and alert) information aggregated from USSPs to ATC.

The flow diagrams basically formalized the architecture description of AURA in Fig. 2. The idea of underlying IEX services based on the SWIM architecture was adopted as well. Nevertheless, identified technological gaps in the AURA concept as described and insinuated in the previous sections were affirmed. This especially concerned the standardisation of intra-U-space data exchange, phraseology, and procedure standardisation to allow communication between ATC and U-space operators if required, and potential task re-allocation and clarification for previously unvalidated scenarios. The latter most certainly included the details of the DAR service and associated DAR request contents and information exchanges (see Ch. 8 in [16]).

In that context, it was recognized on the technical side that the creation and submission of USSP initiated DAR requests might need to be formulated into a distinct, separate service that provides input to the DAR service. The procedure for evaluating the request, deciding on the result, and executing it remains consistent for the DAR Manager, regardless of whether it originates from an ATM or U-space actor. As a consequence, the ENSURE consortium decided that the DAR process should encompass both situations (see Ch. 4.3 in [16]). One of the challenges of the project in that regard will be to align development of the DAR service along the lines of the evolution of regulatory material. While the technical side will need to take this material as a basis for development activities, the ongoing operational development of the DAR service will need to be harmonized.

C. Current Status of DAR Management in ENSURE

Notwithstanding the considerations of the dilemma described above, initial steps have been taken in the context of the development of the ENSURE Operational Services and Environment Definition (OSED) document [6]. In that document operations for both ATC-initiated and USSP-initiated DAR requests have been defined. As a first step, these definitions have focused on tactical airspace changes with sufficient time to coordinate requests between all actors. Emergency DAR requests that require more imminent implementation of an airspace change will be looked at later in 2024, amongst others in preparation of operational expert consultations planned by NLR.

One of the assumptions for the new operating method is that the DAR Manager, apart from being an experienced ATCO knowing the ATC-controlled airspace intimately, will also need to have an understanding of how DAR decisions impact UAS operations. To that end, the DAR Manager needs to have support tools available for evaluating and executing DAR modifications that incorporate what-if and what-else functionalities to aid in decision-making. These tools should also allow for rapid implementation of DARs in case of emergencies. Furthermore, the aim will be to have no direct communication between ATCOs and UAS operators.

As one of the major expectations mentioned at the beginning of this paper, future UAS operations may cover altitudes above VLL and reach lower controlled airspace around transition altitudes. In the Netherlands, this would concern airspace starting from 1500 ft (Schiphol TMA) and reaching the transition levels at around 3000 ft. The service definition thus also considered lower and upper airspace boundaries in the DAR request definition.

While traffic on the side of tactical controllers, such as tower and approach controllers, will be filtered using smart algorithms in order not to add to their workload, the DAR Manager must be aware of all UAS traffic and should be able to see it. It is still under discussion, though, whether filters should be applied by the DAR Manager in specific situations, such as contingencies in U-space. The tactical ATCOs will be able to see high-risk flights in the vicinity of airports and also receive alerts in case of deviations. As said before, it still needs to be determined whether a critical situation with a high-risk flight deviating is managed via DAR management services or whether this information will reach ATCOs directly.

One of the DAR operating principles mentioned by ENSURE is that the structure of the AUSA volumes will need to be published in an AIP (without type indications), as suggested by AURA (see also Ch. 3.3.2 in [6]). The different airspace types to be handled by the DAR Manager are mentioned as well. Airspace volumes within AUSA under ATC control are designated as “blue” volumes again and may correspond to manned Standard Instrument Departure Routes (SIDs) and Standard Terminal Arrival routes (STARs). Accordingly, areas within AUSA where ATC has delegated airspace management to U-space are labelled as “orange” volumes again. These could be areas inside a CTR that are more distant from an airport and from manned flight trajectories and would also be free of other obstacles or hazardous objects.

Similarly to what has already been tentatively shown in Fig. 1, “light blue” and “light orange” volumes were now considered to be AUSA volumes that were "blue" and "orange" by default (and thus by local definition). Vice versa, "dark blue" and "dark orange" meant that the volumes were temporarily reconfigured from their default volume type by means of an ATC-initiated and USSP-initiated DAR. As in AURA, "orange" volumes were considered to be geo-caged to prevent UAS from infringing on "blue" volumes, and buffers were assumed to present between the two types of volumes.

What clearly distinguishes the description of the DAR processes in AURA from the ENSURE processes, is the introduction of a special transitioning state introduced as the so-called "amber" state of an AUSA volume. This state starts whenever an airspace volume change in AUSA is initiated and ends when compliance is confirmed, meaning that there are two such states in a temporary delegation as is shown in Fig. 7 (with DAR above and reverse DAR below). The first "amber" state starts when a DAR is published and an advisory alert of an upcoming geo-zone change is transmitted by the DAR Manager and ends with confirmation of compliance. The second state occurs during the period between DAR deactivation and the confirmation of compliance.

During the amber state a caution alert is issued to airspace users, prompting them to vacate the changing airspace volume. This alert should be received with sufficient time for users to exit before the DAR is implemented, taking into account factors such as the distance to the volume boundary divided by the estimated ground speed required to reach it. Under nominal circumstances, the caution alert should be received at least 2 minutes before DAR implementation, while the advisory alert should be transmitted about 10 minutes beforehand (or five times the anticipated time for the caution alert). In that regard it should be noted that further development might lead to different time constraints in the future, e.g., if the process is further enabled by system automation and hence is less dependent on human intervention. Furthermore, the ENSURE OSED team defined the timelines shown in Fig. 7 for short-duration DARs. In case delegation takes longer, it might thus be appropriate to also introduce advisory and caution alerts before deactivating a DAR.

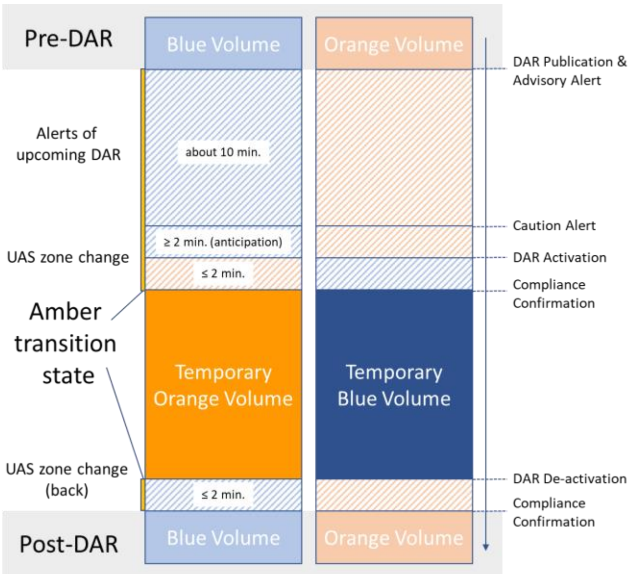

Fig. 7. AUSA Type Transitions and the "Amber" State.

Apart from this very obvious deviation from the AURA DAR definition, several other requirements were formulated. One of the additional tasks to be accomplished by the DAR service is to check whether flight plans or UAS operation plans (also called U-plans) will lead to the crossing of AUSA sectors currently delegated to a different regime and, if this is the case, to automatically send DAR requests.

Risk-based prioritization and the availability of pre-defined prioritization criteria has also been mentioned as one of the operational requirements that was not fully exploited in AURA. On the U-space side this must ensure that operations requiring the highest level of safety are given a correspondingly high priority level and shall account for the presence or absence of passengers onboard the aircraft as well as the emergency status of the aircraft. Generally, though, the concept itself is indifferent to the prioritization criteria that are determined by the regulator.

Another important aspect is a statement in the ENSURE OSED that U-space services will maintain UAS U-plans within the CISP as the "single point of truth" of UAS intentions for all the exchange of information between ATM and U-space actors, wherever the operation departs. Finally, it was highlighted that there is a requirement to quantify the impact of all the decisions to be taken by the DAR Manager on the overall system performance. This means that supporting tools must be available providing this information to the DAR Manager in order to better understand how relevant Key Performance Areas (KPAs) are affected by each decision made, with safety being at the core of the decision-making processes.

D. *The new ENSURE DAR Process Flow*

The message flow for both ATC-initiated and USSP-initiated DARs is described in several phases [6] that are based on outcomes of the AURA project, and in particular the development of the controller support tools of the AT-One exercise that was catering for the different communication processes between ATCOs and the DAR Manager in the simulation set-up [5]. Each phase will shortly be described in the following for both the DAR and the reverse DAR. It should be noted that, at this point, the ENSURE OSED only considers strategic DARs with pre-tactical implementation and accordingly longer timeframes, as shown in Fig. 7.

- ATC-initiated DAR (see also Fig. 8):

  DAR Request Phase. In this phase a manned flight plan is created and submitted. As explained in the previous section, the DAR Manager will use the DAR service to generate the necessary DAR request(s) in case the flight plan indicates that an AUSA U-space volume is passed. What-if scenario planning can be used to evaluate several DAR options considering the relative priorities of operations and the impact that a change may have on all airspace users.

  DAR Proposal Phase. When the DAR option has been elaborated by the DAR Manager, a proposal will be sent to ATC and, via the CISP, to the USSP. ATC will check the viability of options and either declare them as viable or coordinate potential amendments with the DAR Manager. The same viability check will be carried out on the USSP side with inclusion of an indicative timespan needed for UAS movements to vacate the requested area.

That response is forwarded to the DAR Manager via the CISP.

DAR Planning Phase. The DAR Manager will now make a decision on the proposed DAR using the DAR service, which translates the DAR outcome into a flight plan response. The response, which can either be an acceptance (on the condition of a successful DAR implementation) or a rejection (with or without suggested amendments) will be received by the pilot of the manned flight. Any needed amendments can then be further coordinated with the ATC service until the amended flight plan is accepted by the pilot and an acknowledgement message is sent to the ATC service. The ATC DAR Request service then receives the approval of the amended flight plan and translates it into a DAR amendment response. The DAR Manager receives the response and finalizes the DAR using the DAR service.

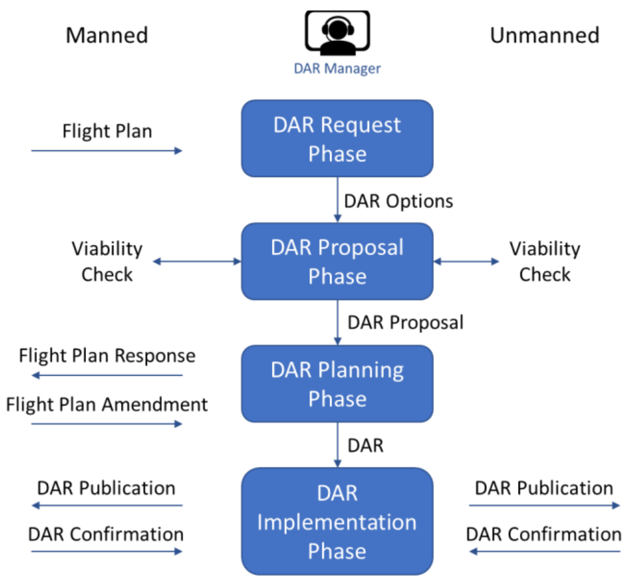

Fig. 8. Basic Process Flow for ATC-initiated DAR.

DAR Implementation Phase. In this final phase the DAR is sent to the CISP by the DAR Manager. In the CISP the DAR is published to the ATM and U-space actors. In the ATC system, the publication will trigger an advisory and subsequently a caution alert to the ATCOs as indicated in Fig. 7. ATCOs will issue instructions to the impacted aircraft and the pilot will follow these instructions. When the DAR is activated, the ATCOs will receive a notification on their working position. ATCOs will then confirm compliance with the DAR activation. This is again indicated in Fig. 7. In parallel, on the U-space side, the DAR publication is received via the Geo-awareness service. The connected UAS Flight Authorization service identifies the impacted UAS operators and sends them an advisory alert (including the DAR details) and a caution alert (in analogy of the ATC system alerts). As airspace volumes need to be vacated by affected UAS operations, a U-plan re-planning and re-submission will take place between operators and the USSP Flight Authorization service. The DAR activation is eventually forwarded to the USSP via the Geo-awareness service and forwarded to the operators. The USSP will monitor (through telemetry reports) whether the required volume is vacated and will then submit the compliance confirmation to the DAR Manager via the CISP. The reception of both confirmations will end the amber state and ATC will guide manned aircraft through the changed airspace volume. At the end of the temporary airspace delegation, ATC systems (resp. USSP(s) via the Geo-awareness service) will promulgate the DAR deactivation and the ATCO will confirm compliance. The time between both actions is the second amber state. As a final action, the CISP will promulgate the confirmation to the UAS Flight Authorization service and UAS operators are notified that they can proceed to use the reconfigured airspace volume again.

Strategic DAR processes will work similarly when initiated on the U-space side.

- USSP-initiated (reverse) DAR (see Fig. 9):

DAR Request Phase. In this phase UAS operators will specify their operational intent and prepare a U-plan proposal that is submitted to the U-space Flight Authorization service. A U-space DAR Request service must be in place to assess the U-plan and the need to create a DAR. Such a DAR request will be promulgated via the CISP to the DAR Manager. What-if scenario planning can then be used again by the DAR Manager to evaluate several DAR options considering the relative priorities of operations and the impact that a change may have on all airspace users.

DAR Proposal Phase. When the DAR option has been elaborated by the DAR Manager, a proposal will be sent to ATC and, via the CISP, to the USSP. ATC will check the viability of options (considering timespans needed for manned aircraft to leave the affected volume) and either declare them as viable or coordinate potential amendments with the DAR Manager. The same viability check will be carried out on the USSP side. The response is forwarded to the DAR Manager via the CISP.

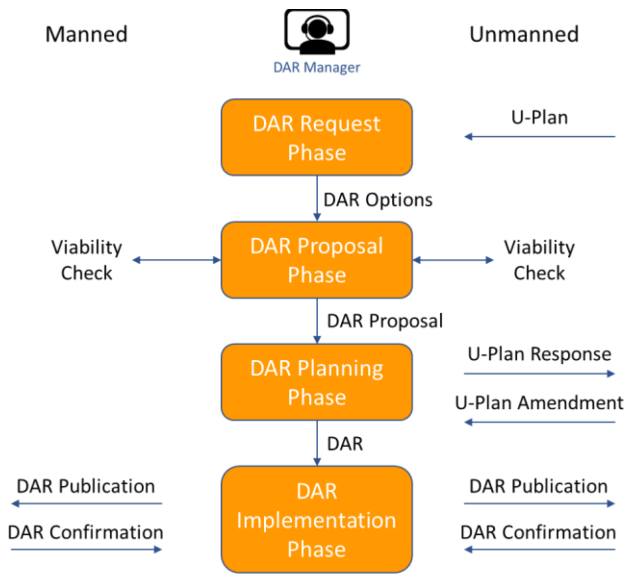

Fig. 9. Basic Process Flow for USSP-initiated DAR.

DAR Planning Phase. The DAR Manager will now make a decision on the proposed DAR using the DAR service, and the outcome will be promulgated via the CISP to the U-space DAR Request service. The service will translate the DAR into a U-space response, and the UAS Flight

Authorization service will then send the U-plan response to the UAS operators. If necessary (i.e. if changes were introduced by the DAR Manager), the U-plan will be updated to adhere to new constraints. UAS operators then have the choice to either cancel or approve the (updated) U-plan. The operator response is received by the UAS Flight Authorization service and the U-plan is forwarded to the U-space DAR request service for translation into a DAR amendment response. The response is finally forwarded to the DAR Manager via the CISP.

DAR Implementation Phase. In the implementation phase the DAR is sent to the CISP by the DAR Manager again. In the CISP the DAR is published to the ATM and U-space actors. Identical steps follow as described for an ATC-initiated DAR with advisory and caution alerts being triggered for ATCOs and U-space operators as indicated in Fig. 7. When the DAR is activated, ATCOs and the USSP (via the CISP) will confirm compliance, and the amber state will end. This time, the CISP will promulgate to the UAS Flight Authorization service that the manned volumes are cleared and UAS operators will be notified by the USSP that they can proceed with their operations in the delegated airspace volume. At the end of the temporary airspace delegation, ATC systems (resp. USSP(s) via the Geo-awareness service) will promulgate the DAR deactivation and the ATCO will confirm compliance. On the U-space side telemetry data will be monitored by the USSP and a clearance confirmation will be received by the DAR Manager via the CISP, ending the second amber state. This time, the final action will be the notification of ATC that the volume is clear of UAS traffic and manned flights can proceed with their operations in the reconfigured airspace volume again.

IV. Conclusions and Outlook

A. *DAR Process Improvements*

This paper has elaborated the current development state of the DAR service in detail, starting from the initial definition in the AURA project, where the DAR service was defined as operational solution for segregation of manned and unmanned traffic in shared airspace volumes (AUSA), to the current state of development. The relevance of additional U-space services and a common interface (CISP) has been explored and stressed. Results of simulation activities for validation of the (reverse) DAR service on the operational side have been presented and the detected gaps in the AURA service definition were highlighted. Recommendations for further research were added.

The assessment of the AURA results was followed by an in-depth study of the development steps taken in the follow-up project ENSURE to refine the DAR service and fill the gaps on both the side of the technical architecture underlying the service definition, and on the operational side where procedures for DAR management must be defined. To that end an overview of the operational assumptions for further DAR refinement was given and the detailed procedures defined for strategic DAR and reverse DAR implementation were presented. These procedures represent an initial step in the further development of DAR and will be the basis for the more demanding tactical DAR changes that will have to be carried out in much smaller timeframes and, accordingly, with more automation support for DAR management.

A short outlook of the activities within the ENSURE project that are expected to be carried out in the 2024/2025 timeframe is given in the following section.

B. *Future Research based on DAR*

In the current plans of the ENSURE project, a number of simulation and demonstration activities will be carried out to gradually develop further the DAR service from lower to higher technology readiness levels (TRL) [17]. While AURA was mainly looking at TRL 4, ENSURE aims to reach levels up to TRL 7.

Airbus will organize a fast-time simulation (FTS) and an RTS. In the FTS, a safety and efficiency analysis of different DAR operational rules for UAS during airspace changes is performed. The RTS will validate strategic and tactical re-planning and authorization processes from a U-space system perspective. The focus will lie on USSP-UAS Operator coordination cycles presented in the previous section.

Another RTS is organized by ENAIRE (CRIDA) and will validate DAR processes to support UAM operations above VLL airspace within the CTR of an airport. These simulations will focus on the tactical DAR procedures needed for maintaining segregation from manned aircraft.

NLR will carry out an RTS as a first step to assess operational feasibility and human performance of DAR processes and human-machine interfaces in strategic (nominal) and tactical (contingency) planning.

Apart from these simulations, three major demonstration activities will be carried out. The Spanish cluster will perform an operational validation of DAR service management within an airport environment. The Italian cluster will investigate the application of the DAR service in support of emergency and special UAS mission management, looking at human performance and safety. Finally, the Dutch cluster activities will build on abovementioned RTSs and will be described in more detail.

As in AURA, NLR will focus their investigations on contingencies, but with a stricter application in a realistic environment where special drone missions are expected to be carried out by NLR together with the Royal Netherlands Navy above the North Sea. The Navy investigates special drone mission profiles that are foreseen for some of their existing tasks currently carried out from boats and ships, from land, or with helicopters. Drones may start their missions, for strategic reasons, from either Maritime Airfield De Kooy (EHKD) close to Den Helder or from specially equipped ships along the coast. The range of drone missions is expected to be large enough to cover even the more remote areas above the North Sea.

The tasks can be summarized as having the character of ISR missions, i.e. missions for Intelligence, Safety and Reconnaissance. Some of the tasks will happen in close cooperation with other organizations, such as the Royal Netherlands Sea Rescue Institution (KNRM), the police and the Netherlands Coastguard, each having their own area of responsibility. This means that some of the missions will also be related to these other organizations. Possible tasks with special equipment for each of the purposes (such as LIDAR, environmental monitoring tools) are:

- Damage assessment (caused by a storm)
- Counter drug trafficking operations

- Environmental inspection flights
- Search for (rescue of) drowning victims (capsized boats)
- Search for lost shipping containers
- European Maritime Safety Agency (EMSA) related tasks

The missions covering these tasks will require to have drones flying towards a certain location or following a certain route or a certain object and are therefore rather flexible in nature. This means that, while it may be possible to strategically plan them, most missions will evolve or change while being executed leading to timing requirements for the DAR processes that are comparable to contingency or emergency operations. Thus, there will be high interest to look at such special situations and special drone missions within the ENSURE project once the DAR management processes have been improved.

Currently, a first idea discussed with operational experts is the division of airspace above the North Sea and along the coastline into smaller blocks of airspace in a structured approach allowing to easily re-configure them when needed via the DAR processes from ATC-controlled airspace to U-space reserved areas (see Fig. 10). This will mostly be a strategic process which can be automated easily with basic monitoring tasks for the DAR Manager to prepare ATC for upcoming changes.

Fig. 10. Sketch of an Airspace Grid in the North Sea Test Area

However, if earlier mentioned changes are more imminent, the DAR requests will more and more look like AURA contingency requests that require more management tasks. One of the exciting tasks of the ENSURE project will be to find out how it will be possible to also automate these more flexible changes. It is hoped that the special UAS missions planned by NLR and the Royal Navy will help accomplish this task.

V. SUMMARY

Between 2021 and 2023 the AURA consortium carried out development activities and simulations for the SESAR Industrial Research Project AURA. AURA defined ATM U-space Shared Airspace, which can be delegated to contain both ATC controlled and U-space controlled airspace volumes for traffic segregation, in order to investigate requirements for an interface between the two regimes. Simulations carried out by NLR focused on contingency scenarios within U-space and the impact of these contingencies on air traffic control and manned traffic. However, they also addressed strategic and tactical aspects of airspace planning and Dynamic Airspace Re-configuration (DAR) request implementation in general.

Several UAS use cases with varying degrees of urgency were carried out to investigate the concept of DAR and the role of a DAR Manager implementing airspace changes to facilitate USSP-initiated DAR requests in nominal and contingency operations.

The results revealed that introducing a DAR Manager role with ATC background and knowledge helps mitigating the impact of the introduction of UAS in ATC-controlled airspace via AUSA delegation and DAR on the tactical control carried out by tower and approach controllers in terms of workload and situational awareness. A prototype of an interface for the DAR Manager and air traffic controllers was developed that helped communicating contingency requests originating from UAS via the responsible U-space Service Provider and an intermediate services layer (CISP) to the DAR Manager and that could further be used for coordination of these changes with ATC.

This initial step in validating DAR Management and U-space contingencies led to the identification of areas for improvement of the operational concept and gaps in the development of the interface. These gaps and shortcomings are addressed in the follow-up project ENSURE. The first activities in ENSURE focus on a more detailed definition of the DAR processes and the elaboration of additional research challenges that need to be addressed in the upcoming development and demonstration activities that are intended to reach a high level of technology readiness (TRL 7).

The NLR work in the ENSURE project will address the shortcomings and gaps mentioned focusing on closer integration between ATM and U-space communication and coordination processes and improving both information content and support options for DAR management. This includes a detailed look at special drone missions carried out in (military) U-space areas above the North Sea that need to be tightly integrated and coordinated with civil air traffic controllers to avoid traffic delays in ATC controlled airspace caused by unnecessary airspace closures.

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The paper has been developed alongside several internal project documents describing, in detail, the simulation planning and conduct of the AT-One validation activities. All documents were written as part of the ATM U-space Interface (AURA) Project (PJ.34 Wave 3) within the frame of the SESAR 2020 Programme and are referenced below. The ENSURE Project that started in the summer of 2023 is part of the Digital European Sky Programme and is currently

developing relevant use cases and scenarios. The descriptions in this paper are part of the internal project planning documents as well as NLR-plans to approach the attributed project tasks within the upcoming years.

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