

Advanced Controller Interfaces for U-space Initiated DAR Requests above VLL Airspace

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Abstract— The ENSURE project is a fast-track project that is part of the Single European Sky Air Traffic Management Research (SESAR) Programme. It addresses the strategic domain of U-space and Urban Air Mobility and seeks to standardize a common interface and core services bridging traditional Air Traffic Management (ATM) with U-space for unmanned traffic. Main deliverables include a unified data model and architectural framework, as well as an operational methodology for dynamic airspace delegation, supporting safe traffic segregation and reducing the risk of close encounters between manned and unmanned aircraft. Dynamic Airspace Re-configuration (DAR) has been identified as the main enabler for a more efficient and dynamic use of shared airspace volumes. The Royal Netherlands Aerospace Centre (NLR) examined a range of use cases involving state actors, such as the Royal Navy of the Netherlands, requiring access to airspace volumes in proximity to the approach areas of Amsterdam Airport Schiphol. These use cases pertain to the execution of sovereign tasks, including asset protection, the provision of emergency services, and disaster relief operations. The focus of this paper is on the development of Human Machine Interfaces for different air traffic controller roles, i.e. the airspace manager responsible for implementing U-space DAR requests in proximity of Schiphol and the Schiphol Approach controllers.

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

I. INTRODUCTION

In the near future, a growing number of Unmanned Aerial Systems (UAS) are anticipated to operate at very low level (VLL) altitudes, up to 500 ft, particularly within urban and suburban environments (cf. preamble of [1]). In parallel, state actors, such as the military, are expected to conduct high-priority operations at higher altitudes, extending up to 5000 ft within designated airspace volumes. Certain volumes are likely to be situated in close proximity to civil airspace, thereby potentially affecting the efficiency of civil flight operations in and out of airports [2].

Several initiatives were started as part of the Single European Sky Air Traffic Management Research (SESAR) Programme in the early 2020s to investigate the integration of unmanned and manned traffic in non-segregated airspace, such

as the SESAR project INVIRCAT that looked at integration of fixed-wing drones into the operations of a regional airport [3]. Another project, called AURA, took a different approach. The project played a crucial role in defining ATM U-space Shared Airspace (AUSA), which is a generic type of airspace that can be dynamically delegated between Air Traffic Control (ATC) units and highly automated U-space airspace [4]. Essentially, that meant that non-segregated airspace was replaced by airspace that can be shared using a flexible segregation method called Dynamic Airspace Re-configuration (DAR). DAR processes were defined and a software prototype for management of requests (initiated on the U-space side) to an airspace manager, called DAR Manager (DARM), was developed. These developments served as an enabler for the necessary flexibility by enhancing communication among all involved actors, i.e. drone pilots, U-space Service Providers (USSP), Air Navigation Service Providers (ANSP) and Air Traffic Controllers (ATCO). Additionally, the investigation of U-space contingency scenarios revealed that different situations require tailored DAR approaches [5].

The DAR concept is currently being further developed within the ENSURE project of the SESAR 3 Industrial Research Programme by building the required services and interfaces for both U-space Service Providers (USSPs) and Air Traffic Control (ATC) to enable flexible airspace management procedures for strategic, tactical and contingency use cases. One of the tasks of the Netherlands Aerospace Centre (NLR) in that project is the investigation of high-priority operations and the dynamic allocation of shared airspace between manned civil traffic and unmanned military missions [6]. This paper describes the different steps taken by the NLR validation team for the ENSURE project when developing the ATC interfaces for the DARM and the ATCOs working in the Schiphol Terminal Manoeuvring Area (TMA). It starts with a summary of DAR concept development [7], and then elaborates on the difficulties that the Human Machine Interface (HMI) design inhibited, leading to improvements for the final prototypes. The HMIs will be used by NLR to carry out demonstration flights with a UAS above the North Sea between September 2025 and March 2026.



II. DYNAMIC AIRSPACE RE-CONFIGURATION

A. Initial Concept

The SESAR Industrial Research Project AURA [8] aimed at finding a solution for dynamically separating manned and unmanned traffic involved in interactions near medium-sized airports with UAS operating in VLL. AURA defined a new airspace category called ATM U-space Shared Airspace (AUSA). AUSA airspace refers to portions of controlled airspace (CAS) where both manned and unmanned operations may take place. These airspace volumes are predefined and structured in such a way that ATCOs can clearly understand the operational consequences of delegating them to U-space. Accordingly, AUSA should only be implemented in areas where it is operationally meaningful for manned and unmanned traffic to share airspace resources.

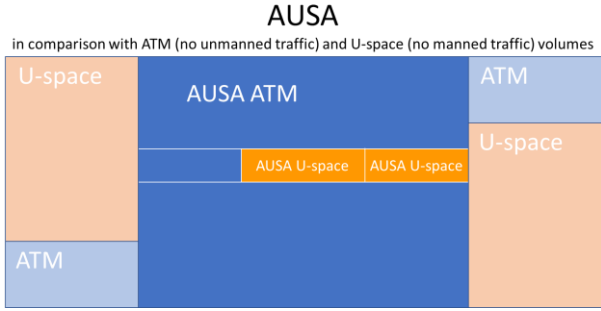


Fig. 1. Delegated AUSA U-space Corridor.

DAR was consequently developed as an ATM process that dynamically delegates control of AUSA airspace volumes between ATM and U-space (Fig. 1), based on demand from manned or unmanned operations [9]. The AURA concept introduced a DAR Manager (DARM) role to oversee these changes, thereby intending to reduce tactical ATC workload and a possible impact on the safety of manned operations. DAR had to provide finer granularity and adapt flexibly to traffic demand, enabling unmanned traffic access to airspace that would otherwise be restricted. Through DAR, predefined AUSA structures could switch between ATC control (blue volumes) and U-space control (orange volumes). Since airspace management is about allocating airspace volumes to meet demand, AUSA sectors were considered to have a default status, with delegations applied only temporarily.



Fig. 2: Preview of DAR Request for ATCO and DARM (NARSIM/NLR).

The AURA project assumed that airspace changes would occur only occasionally and for a limited number of unmanned flights. NLR then conducted real-time simulations with experienced ATCOs in a realistic regional airport setting for Rotterdam The Hague Airport and its TMA [10]. These simulations examined scenarios where delegating airspace to U-space disrupted manned operations under Visual (VFR) and Instrument Flight Rules (IFR). In each use case, the delegation was triggered by a contingency or emergency situation. The DARM would see the predefined VLL U-space volumes on the surveillance display and when triggered by an incoming contingency request would evaluate the proposed airspace changes and start a negotiation process with ATCOs controlling the traffic at EHRD. During that process the DAR proposal was communicated via an intercom system, but could also be submitted to be shown on the ATCO surveillance screens as proposed and planned changes (Fig. 2).

As the communication process turned out to be lengthy and increased the workload for the ATCOs, it was concluded that the DARM should be able to assess the impact of the DAR without consulting the ATCOs. The DARM could make specific alterations to the DAR request based on feedback from ATCOs or personal insights and observations and initiate a feedback loop with the USSP. As a result, the negotiation process and its efficiency were considered suboptimal [6].

In summary, the information requirements for ATCOs included geographical details with altitude data and the current status of the DAR (e.g., soon to be activated, activated, etc.), preferably presented visually. It was also noted that ATCOs would need at least ten minutes of advance notice, where possible, to plan manned traffic accordingly. For the DARM, in addition to the information requirements for the ATCO, a capability to assess the impact of a request was identified as an important feature. This requires a visual representation of the requested DAR in relation to traffic flows, ideally supported by an extrapolation function to evaluate the potential impact of an airspace delegation to U-space. As mentioned, NLR focussed on emergency and contingency operations (in addition to planned DARs). The prioritization of DAR operations was also considered important, particularly when multiple DAR requests with varying levels of urgency or importance are received simultaneously.

B. Concept Improvements

While the AURA project provided a solid basis for the DAR concept, several gaps were identified and discussed at the start of the SESAR Industrial Research Project ENSURE. The main issue was process efficiency: allowing the DARM to alter requests was seen as unnecessary for USSP-initiated requests. The concept had to be scalable as well, allowing for more UAS missions while still being manageable for the DARM. As a consequence, aggregation of strategic and tactical DAR requests on the USSP-side before transmission to the DARM was seen as a necessity. ENSURE aimed to support both strategic planning and tactical changes while keeping the DAR Management efficient and ATC situational awareness intact.



Fig. 3: Sketch of an AUSA Airspace Grid in the North Sea Test Area.

Within ENSURE, NLR again focussed on investigations concerning USSP-initiated requests, as these usually had a larger impact on ATC operations. The following topics were addressed:

- DAR operational concept scalability regarding increasing numbers of UAS and more complex UAS operations
- DAR concept improvements with an emphasis on process steps and operational stages, duration and frequency, operational response times, strategic DAR planning, and use of DAR in tactical and contingency or emergency situations
- Airspace Design (AUSA) and the more complex issue of managing a (smaller) group of volumes relating to the same UAS mission (Fig. 3)
- Support tooling for DARM and ATCOs concerning DAR information content, DAR communication, DAR impact assessment, DAR decision making, and visualization of UAS movements
- Human performance aspects on the ATM side
- ATM environment (working position and location)
- Communication between systems and actors

Further details on the system elements and architecture developed by ENSURE industry partners can be found in [7].

A more important aspect of the NLR investigations, though, concerned the development of support tools for DAR management and for ATCOs impacted by airspace changes. close to their areas of responsibility above VLL. Workshops with operational experts were held to find acceptable solutions and a working method for the planned real-time simulations. The most appropriate cases concerned military surveillance missions along the Dutch coastline having an impact on Amsterdam Airport Schiphol (EHAM) approach operations. NLR collaborated with the Royal Netherlands Navy (RNLN) to define AUSA volumes above the North Sea on the basis of a test and training area already in use (red grid in Fig. 3). In addition, they developed several use cases illustrating how DAR could be applied by a military USSP.

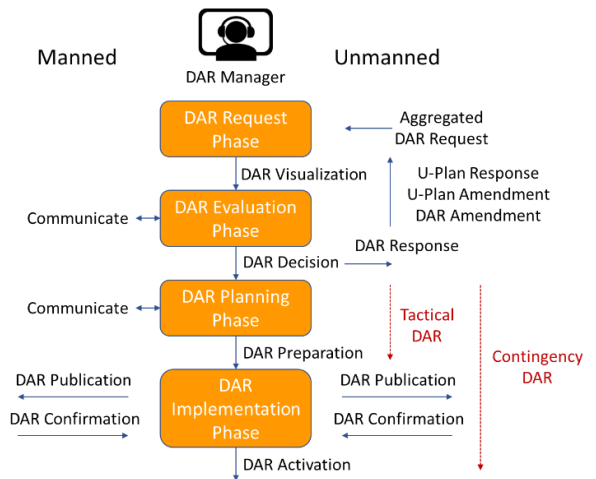


Fig. 4: DAR Process Flow for USSP-initiated DAR Request.

Concept improvements were jointly elaborated with ENSURE partners with scalability of the operation as a guiding principle. The concept also incorporated airspace planning at both the day before operation (D-1) and the day of operation (D0), leading to a clear distinction between strategic, long-term DAR planning and more dynamic, tactical requests. The existing procedures for USSP-initiated (reverse) DAR requests from AURA were changed and refined and the process flow was divided into specific phases (as is shown in Fig. 4). The details for each of these phases have been described in detail in [11] and the reader is encouraged to consult this paper for more information on USSP procedures.

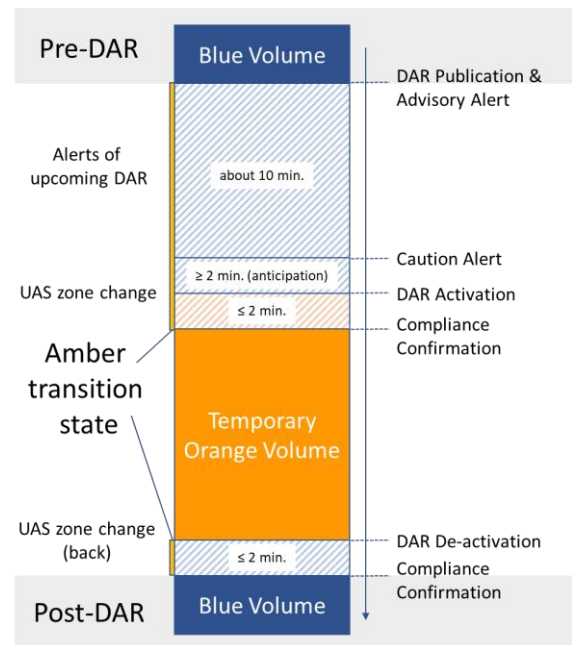


Fig. 5: DAR Implementation Phase (USSP-initiated).

The most important phase for a deeper understanding of DAR is the implementation phase which starts about 10 minutes before DAR activation. It follows a very strict process (Fig. 5).

Caution alerts are issued 4 minutes before activation, marking the start of the “amber” transition state [7]. Both USSP and ATC must confirm compliance and once activated, UAS operators may use the delegated airspace volume. Deactivation essentially follows the same sequence. After deactivation, and once the volume is confirmed clear of UAS traffic, manned flights may resume operations.

As noted above, the duration of each phase depends on the type of DAR and the related planning horizon. A strategic DAR has a longer planning phase and becomes available on D-1, with its impact being re-evaluated by the DARM (or a supervisor) at the start of D0. In contrast, a tactical DAR, which is requested shortly before or even during UAS operations, is evaluated immediately and either accepted or rejected. If accepted, it is published without delay.

Contingency operations, which may be unexpected missions with urgency or high-priority emergencies, are following a non-nominal workflow. When mitigating measures such as an Emergency Response Plan (ERP) are activated, a DAR may be generated automatically, but only if there is a deviation from an active DAR. In such cases, the contingency DAR is presented only to the DARM, who confirms reception for activation on ATCO displays. The DARM should engage with ATCOs early to anticipate traffic adjustments. When airspace is infringed (i.e. on violation of an internal buffer) without knowledge of any mitigating measures, UAS positions from the network identification service (Article 8 in [1]) are displayed on ATCO surveillance screens to support separation.

III. DAR APPLICATION AND USE CASES

A. Application Areas

The DAR concept can generally be applied in areas where UAS operations in U-space occur close to manned operations, especially when flexibility is required to execute UAS operations in ATC-controlled volumes. Smaller volumes allow greater flexibility and typically reduce the effect on manned traffic. The concept is analogous to military operations, where flexible use of airspace (FUA) procedures coordinate military and civil airspace demand [12]. Consequently, if military airspace for drone test and training exercises is considered a specialized U-space, DAR procedures can be applied in the same way [13].

B. Specific Missions and Use Cases

In order to identify relevant use cases for operations in the Netherlands, NLR collaborated with the RNLN, who are developing UAS missions for tasks currently carried out from ships, land, or with helicopters. For strategic reasons, missions are typically launched from Maritime Airfield De Kooy (EHKD) near Den Helder or from specially equipped ships along the coast. The range of UAS operations is expected to cover even remote areas above the North Sea [13], up to 3,000 ft. Applying DAR to these missions was expected to improve efficiency and convenience for both RNLN and ATC The Netherlands (LVNL), particularly for military airspace claims near manned operations at Schiphol Airport.

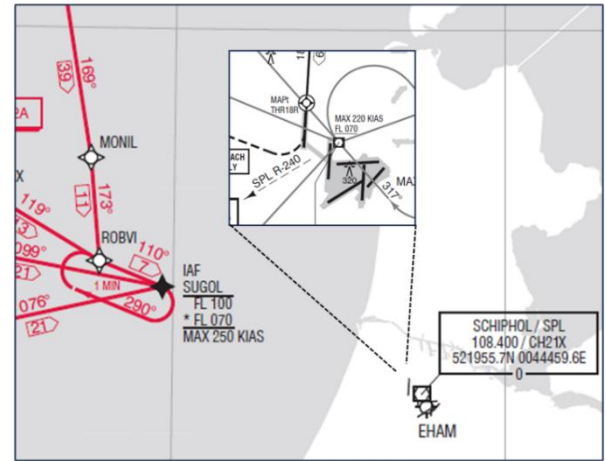


Fig. 6: Excerpt of EHAM Arrival Chart with Runway Locations [14].

The largest impact was expected in the southern sectors of the UAS Test and Training Area (TTA) shown in Fig. 3. Arrivals are particularly affected by DAR operations in this area, as they descend from FL 100–070 at Initial Approach Fix (IAF) SUGOL down to 3,000 ft on the downwind leg for runway 18R (Fig. 6). The following basic use cases (UC) were defined for USSP-initiated DAR requests [7]:

- Strategic Planning/Execution of a UAS Mission (UC1)
- Tactical Change of a UAS Mission (UC2)
- Contingency Operation with Execution of ERP (UC3)
- Contingency Operation with Infringement (UC4)

C. Simulation Sessions

The focus of the first simulation session with ATCOs in March 2025 was on the first two use cases presented above, but also addressed the two contingency use cases in debriefings and during interviews. It is described in detail in [11]. Based on the feedback from this session, a second session took place at NLR in July 2025 providing ATCOs with updated HMIs. This session led to further changes in the presentation.

IV. HMI CONCEPTS AND FEEDBACK

A. Initial HMI Concept for DARM and ATCO

For the first session, NLR set up a real-time human-in-the-loop simulation of the ATC environment for the Schiphol DAR Manager and TMA controllers using the NLR ATM Research Simulator (NARSIM). The NARSIM Radar software replicates key ATM functions, including realistic surveillance data, aircraft behaviour, and interfaces familiar to ATCOs. Additional tooling supported DAR management at the DARM position, and the changes due to a DAR implementation were visualized on ATCO displays. Simulated manned traffic was controlled by pseudo-pilots via radio/telephony. To simulate a military drone movement, NARSIM was connected to the ArduPilot Mission Planner, the same interface that will later be used for live trial flights.



Fig. 7: DAR Impact Assessment Tool (DARM Working Position).

The tooling for the DARM consisted of two components (Fig. 7): the DAR Communication Tool (DAR-CT) and the DAR Impact Assessment Tool (DAR-IAT). DAR requests were presented in the DAR-CT, indicating an identifier, the DAR activation time, and a descriptive name for the DAR. The main component of the DAR-IAT was a time slider that projects all AUSA volumes contained in the request together with their start- and end-times on the DARM surveillance display. In addition, when moving the slider, the future situation regarding the activated AUSA U-space volume and manned traffic was shown in a “ghost” view, i.e. ghost radar blips were indicated with letter “G”, and both AUSA volumes and ghost flights were presented in a teal blue colour.



Fig. 8: DARM Surveillance Display after DAR Request Acceptance.

On acceptance of the DAR request, the DAR was activated and presented in another colour (amber) on the DARM surveillance display (Fig. 8).

The only elements added to the ATCO surveillance display for the Schiphol TMA (Fig. 9) were the active or soon to be active AUSA (military) U-space volumes. The active DAR volumes were presented in orange, volumes for which the caution alert phase (4 min. before activation) had already started were shown in yellow, and volumes for which the publication

phase had started (10 min. before activation) were presented in green. Volume names and altitudes were also indicated inside the volumes. A timer was given to indicate the duration until activation (or de-activation) turning to red one minute before reaching zero.

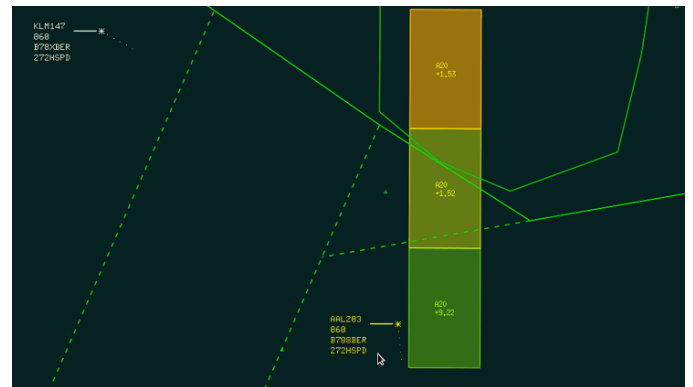


Fig. 9: ATCO Surveillance Display with AUSA U-space Volumes.

B. Changed HMI Concept for DARM and ATCO

The second session had a comparable set-up as the first session addressing the same use cases and more challenging scenarios regarding UAS traffic volume and contingency situations. While this meant that results between the sessions were not comparable, the overall result was expected to show differences regarding usability of the working environment.

A first change concerned the presentation of the TTA itself. As can be seen in the previous chapter, all available AUSA volumes were shown continuously, making it more difficult for the DARM to observe Schiphol traffic (real or ghost). As a consequence, only the volumes affected by a request were presented, and all other unconcerned AUSA volumes would not be shown on the surveillance display.

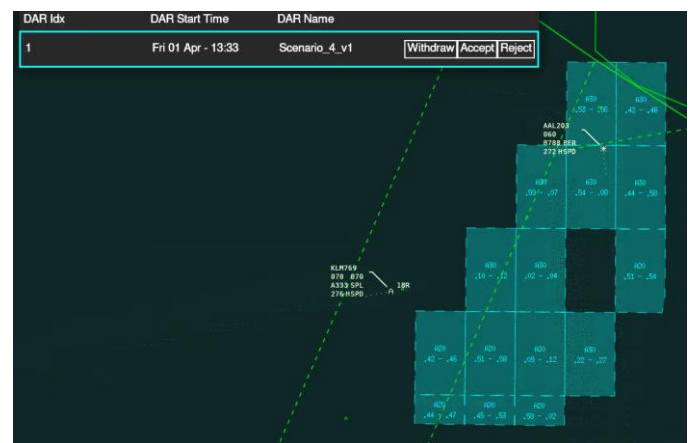


Fig. 10: DARM HMI without Unplanned AUSA Volumes.

A comparison between Fig. 7 and Fig. 10 shows that manned traffic is much better visible for the DARM when the AUSA volumes that are not planned for use are not shown on the DAR-IAT surveillance screen.

Feedback from the DARM after the first simulation session mainly concerned the presentation of DAR requests or request types that are received simultaneously or as an update of an existing request. While this might not affect operations in case of a single request at the beginning of D0, UAS mission changes leading to a tactical DAR request on D0 would definitely lead to refinements in the visualization concept, as the DARM would want to compare requests and evaluate the impact of the changes. It was therefore decided, to present different requests in different layers, using the DAR-CT as a selection tool for each of these layers.

The following figures explain the new layered display concept for receiving DAR requests.

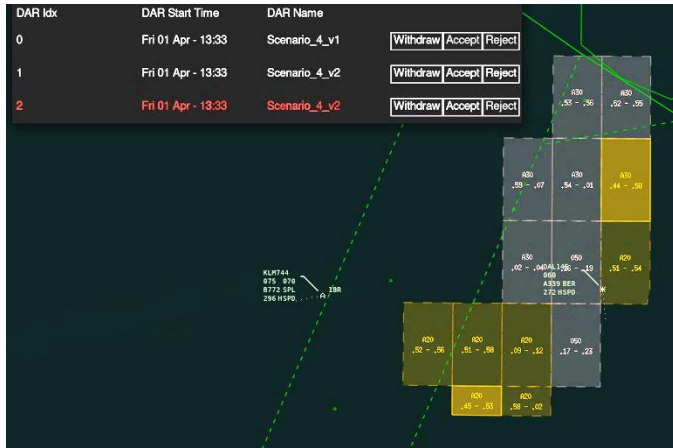


Fig. 11: DAR HMI without Layer Selection.

Fig. 11 shows the DARM surveillance screen together with the DAR-CT without selection of a specific layer. This corresponds to the presentation of the tool used in the first simulation session, with the exception that priorities were added depending on the type of DAR request that is received.

In this particular case the currently implemented DAR is shown in orange, as usual, with the active volumes highlighted, and a (slightly rose-coloured) contingency DAR request (third row in the DAR-CT, in red) is layered on top of the implemented volumes due to its absolute priority.

Together with the contingency request, a new (pending) DAR request is received (second row in the DAR-CT) that is not visible as the implemented DAR will not be changed. This choice has been made for clarity of the presented example. This also means that the pending DAR request is to be found in the layer underneath the implemented DAR.

When selecting a specific layer in the DAR-CT, each layer becomes visible facilitating a better understanding of the situation and enabling the DARM to compare the different DAR layers regarding potential changes in activation times or altitudes for each of the airspace volumes.

The different layers are shown below for the implemented DAR (Fig. 12), the pending DAR request (Fig. 13) and the contingency DAR request (Fig. 14).

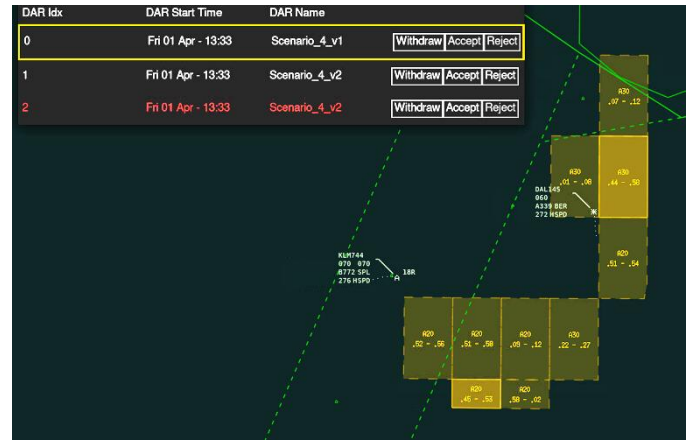


Fig. 12: DARM HMI with Selection of Implemented DAR.

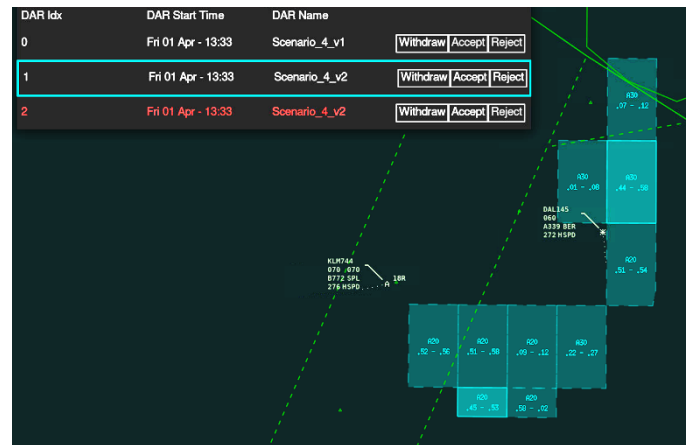


Fig. 13: DARM HMI with Selection of Pending DAR Request.



Fig. 14: DARM HMI with Selection of Contingency DAR Request.

Feedback on the presentation of implemented DARs on the ATCO surveillance display only concerned the chosen colours of the volumes. Each of the colours in Fig. 9 represented a different phase of the DAR implementation (as given in Fig. 5). Orange, yellow and green were considered to be overly salient

colours on the rather dark surveillance screen. Thus, HMI designers and ATCOs agreed on a number of changes that would render the volumes and their statuses less dominant while retaining the signalling effect.

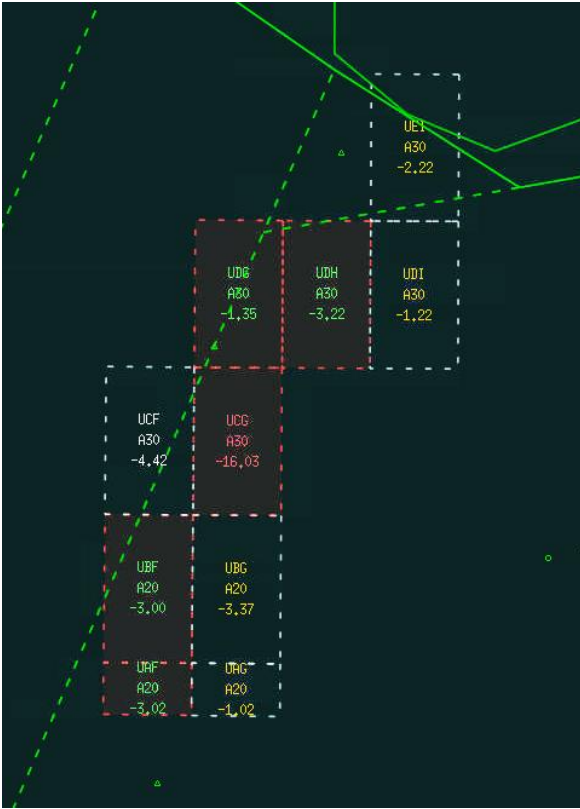


Fig. 15: ATCO Surveillance Display with Changed Colour Statuses.

This is shown in Fig. 15. The following applies:

- All volumes have a dashed outline starting from their publication (i.e. the implementation phase)
- The publication phase starts with a white outline and timer (usually 10 min. before activation)
- For a caution alert, the timer changes to an orange colour less than 4 minutes prior to activation
- On activation, the volume outline turns red and the timer colour depends on the activation time left
- The timer colour inside the activated volume remains red until 4 min. prior to deactivation, then turns green

V. VALIDATION METHODS

As mentioned earlier, the DAR concept was validated in human-in-the-loop real-time simulation experiments. In both cases, three former air traffic controllers participated in a one-day experiment. The day started with a briefing about the concept and a familiarization run of about 20 minutes. At least two runs per use case were carried out (with exception of the infringement use case only being carried out once) with short debriefings and with a final debriefing at the end of the day.

The three working positions described above were simulated: DARM, TMA West Controller (TWEC) and Arrival Controller (ARR, this role is receiving the separated traffic from the TWEC and lining it up for RWY 18R). ATCOs needed to make an assumption regarding the separation of manned traffic from AUSA U-space volumes. In analogy of what is currently used for military airspace, a separation distance from airspace boundaries of 1.5 nm horizontally and 1000 ft vertically was chosen. The DARM was an experienced controller and capable of making decisions in line with TMA working methods.

The participants were asked to fill in questionnaires after each run and at the end of the day to assess the experienced workload [15], situational awareness [16] and teamwork aspects [17]. Since the aim was to assess differences between the mentioned scenarios and between the two HMI designs, participants were asked to remain in the same working position/role during all simulation runs.

VI. VALIDATION RESULTS

While a direct comparison between traffic scenarios was not possible due to the increase of traffic in the TTA in the second session and only overlapping use cases for UC2 and UC3, a number of important human performance observations could still be made that were corroborated by the debriefing results and in interviews with the operational experts.

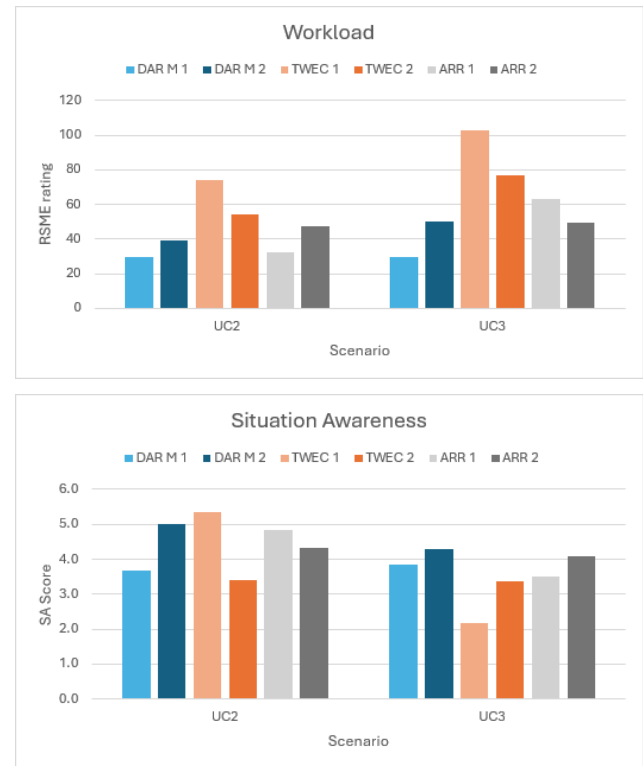


Fig. 16: Human Performance Ratings for UC2 and UC3.

Looking at the scenarios with a tactical change of the UAS mission requiring a rapid change of airspace (UC2 in Fig. 16), the DARM reported only slightly higher workload values than before and situational awareness remained on a high level,

despite having to work with a more complex interface, and having no possibility of tracing individual UAS missions based on the DAR request received. While the now layered concept was appreciated, it was still considered insufficiently intuitive to be used for more than two or three DAR requests a day.

No general suggestions for improvement could be made, as it was assumed that the layered presentation was the best option to present the differences between DAR requests. Nevertheless, it was also indicated there might still be a better option to highlight a change with all layers superimposed. In the current set-up there was a difference in priority, meaning that the current DAR was placed on top of the requested DAR. This was obviously not problematic for added volumes, but disappearing volume claims were hard to spot. The option to reject a DAR request with a rationale was also appreciated. While the standard reasons for rejection that could be selected were valid, a custom text field was still considered necessary, as sometimes there could be several reasons with several different grades of significance. This should only be communicated to UAS pilots (via the USSP) with the free-text option implemented in the tool.

In the case of contingency DAR requests (UC3 in Fig. 16), which were not sufficiently tested in the first session, the second session again led to a small increase in mental effort for the DARM. Situational awareness, however, dropped to lower values, which reflected the confusion of having an additional layer with a requested DAR as replacement for the current DAR in the superimposed view. While it was clear that the contingency had the highest priority, any other simultaneously requested changes should automatically be rejected.

Generally, after having carried out several runs with the layered presentation, the DARM considered the option to be able to select and superimpose layers with a fixed priority as clear and acceptable, given the suggestions for improvement made. Still, it should be clear that any changes of a DAR operation during D0 should be exceptions, not routine. While this would be true for contingency DARs anyhow, tactical changes should only occur in sequence and be separated by at least the time between DAR publication and the end of the airspace volume delegation to U-space. The DAR requests could thus be accommodated once, twice or perhaps three times a day by a supervisor taking over the role of a DARM, but not more. Even with a dedicated DARM role, there should not be many more changes to the DAR implemented at the beginning of D0.

For the ATCO (in this case the TWEC, since the ARR was only indirectly impacted by volume changes) using the new and agreed presentation of DAR volumes on the surveillance screen, mental workload remained high in case of contingencies (UC3 in Fig. 16). This could be expected due to the urgency of the implementation and reduced time to react by changing traffic flows. In the case of a tactical change with more relaxed implementation times (UC2), the effort was lower and only increased again to comparable levels as a contingency if the DAR led to more complicated situations, e.g. additional outbounds that had to avoid a DAR volume, or arrivals that needed to be vectored around a DAR volume and then be added

into the sequence again. Generally, the presentation of the volumes on the ATCO displays was considered clear and acceptable, more intuitive than in the first session, and generally less intrusive. Teamwork aspects were consistently rated high.

One particular case was highlighted, though, that caught the attention of scenario developers and operational concept developers alike: in some situations, in which the DAR volumes were delegated back to ATC, they suddenly reappeared and became active again shortly afterwards. This was in line with the DAR request from the USSP, and was based on the U-plans of the UAS flights considered. However, ATCOs expected that the USSP, when aggregating the U-plans, should also consider minimum re-delegation times. This means that volumes that are only re-delegated to ATC for a short time, should stay delegated to U-space, either for at least 10 minutes (in line with the publication time), or from the first until the last reservation of that volume in the accumulated DAR request. It should be noted that similar arrangements are already in place for FUA operations, e.g. at the EUROCONTROL Upper Area Control Centre in Maastricht (MUAC), where military areas that are not in use for less than two hours will not be opened for civil traffic.

Finally, it was mentioned that higher altitudes (of up to 5,000 ft) would complicate the operational picture close to the TMA and, under specific operational conditions, would lead to difficult sequencing and separation tasks. In such situations, it was expected that traffic into Schiphol would be regulated and reduced accordingly. Since this is undesirable for a more flexible operation such as DAR, prioritisation and availability of certain volumes and altitudes becomes an important factor in AUSA volume definition and the conditions for delegation.

VII. CONCLUSIONS AND OUTLOOK

While it is hard to compare the operational scenarios tested in both simulator sessions, the changes in the DARM HMI and ATCO presentation of DARs were considered acceptable. Despite the more complex DAR requests, ATCOs were capable of understanding the situation and changing traffic patterns for adapted sequencing of aircraft into Schiphol Airport. Nevertheless, acceptability of the DAR operation will depend on several considerations:

- Assumptions that are made for separation between manned traffic and U-space volumes: this could have a large impact on the operation if AUSA volumes are located very close to TMA traffic flows.
- Scalability of operation: many more movements are possible, but will complicate the DAR request. It will thus be necessary to smooth out any short-lived irregularities, considering both DAR timing and altitudes.
- Prioritisation of movements is always a decisive factor. Current feedback from controllers has shown that, in general, AUSA volumes in close vicinity of the approach operations and with challenging altitudes are undesirable for delegation and should only be permitted for UAS flights with the highest priority.

The latter becomes a political debate if impact on a hub operation, such as the one at EHAM, is concerned and a decision has to be taken how much impact a DAR may impose on an approach operation. If there are clear regulations, these could eventually be included in the characteristics of an AUSA volume, e.g. a particular volume close to the downwind operation of RWY 18R at Schiphol during Independent Parallel Approach (IPA) operations may only be used up to an altitude of 1,000 ft. This is currently seen as an important factor for further DAR automation.

Since the simulations showed that an acceptable prototype for DAR processes and approach operations is available, the next step will be the integration of a real UAS flight into the NARSIM environment. To that end, a demonstration flight will be carried out for the described use cases within a designated airspace volume for test flights. On NARSIM, it will be presented as flying in the vicinity of the approach area of EHAM applying a coordinate transformation. A first test flight was already executed at the NLR Drone Centre in September 2025 for verification of the transformation algorithms and validation of the presentation in the DARM and ATCO HMIs. The final flight is expected to allow identification of real-world challenges that may arise when receiving and implementing a DAR request. In addition, the aim is to carry out a more quantitative analysis of operational capacity and safety impacts.

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