On the Impact of UAS Contingencies on ATC Operations in Shared Airspace

Jürgen Teutsch
ATM & Airports Department
Royal Netherlands Aerospace Centre (NLR)
Amsterdam, Netherlands
juergen.teutsch@nlr.nl

Co Petersen
ATM & Airports Department
Royal Netherlands Aerospace Centre (NLR)
Amsterdam, Netherlands
co.petersen@nlr.nl

Gunnar Schwoch
Institute of Flight Guidance
German Aerospace Center (DLR)
Braunschweig, Germany
gunnar.schwoch@dlr.de

Teemu Joonas Lieb
Institute of Flight Guidance
German Aerospace Center (DLR)
Braunschweig, Germany
teemu.lieb@dlr.de

Tanja Bos
Safety & Human Performance Department
Royal Netherlands Aerospace Centre (NLR)
Amsterdam, Netherlands
tanja.bos@nlr.nl

Rolf Zon
Safety & Human Performance Department
Royal Netherlands Aerospace Centre (NLR)
Amsterdam, Netherlands
rolf.zon@nlr.nl

***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. It is expected that these new airspace users will extend their operations and share available airspace with manned traffic. Dynamic Airspace Re-configuration (DAR) has been considered as one of the enablers for the integration of unmanned and manned traffic in such non-segregated airspace.**

The Royal Netherlands Aerospace Centre, NLR, together with their partners from the German Aerospace Centre, DLR, carried out simulations for the SESAR Industrial Research Project AURA that investigates requirements for an interface between Air Traffic Management (ATM) controlled airspace and highly automated U-space airspace for large numbers of unmanned aircraft. To this end, AURA defined the so-called AUSA, ATM U-space Shared Airspace, which is a generic type of airspace that can be delegated to contain both Air Traffic Control (ATC) and U-space controlled airspace volumes. The simulations carried out by NLR and DLR investigated U-space contingencies that could have an impact on those parts of the shared airspace controlled by ATC. This included specific UAS missions and related emergency and other contingency situations inside U-space that would require an extension into ATC controlled airspace. The simulations introduced the role of a manager for DAR processes. The DAR Manager received contingency requests from U-space and negotiated them with ATC.

Results have shown that the introduced DAR Manager role and the designed working position supported and improved ATC operations. Negotiations between the DAR Manager and air traffic controllers, however, will only be possible if there is enough lead time - in the range of several minutes - to prepare for airspace changes. Emergency requests that require immediate action should be communicated to the affected controllers immediately by the system.

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

I. Introduction

In the current Single European Sky ATM Research (SESAR) Programme, the Industrial Research Project AURA investigates a collaborative interface between ATM and U-space controlled airspace for medium-term to long-term application, at a time when high volumes of diverse manned and unmanned operations and high levels of automation and digitalization can reasonably be expected.

The developed collaborative interface has been assessed in the second half of 2022 by several AURA consortium partners with regard to operational safety, efficiency and the human performance impact, in particular the impact on future ATC operations. To this end, a number of assumptions had to be made considering U-space and ATM service provision and the way in which airspace is delegated between a U-space controlled and an ATC controlled environment within shared airspace structures. These structures were designated as AUSA, ATM U-space Shared Airspace, where pre-defined airspace volumes can change from being ATC controlled (so-called blue volumes) to U-space controlled (so-called orange volumes) and vice versa.

The process itself to achieve this is called Dynamic Airspace Re-configuration (DAR) and can be carried out by ATC personnel, e.g. in case of strategic UAS mission planning, but is expected to be automated in the future and reduced to indicating planned airspace changes to tactical controllers, hours in advance, via a collaborative interface between U-space and the ATM world. The process will thus eventually entail the delegation of responsibilities to systems with higher automation levels. Human operators will consequently have to interact with such systems and need to be supported in doing so. This is particularly true in situations where changes to the airspace structures happen quickly and with short planning horizons, as is the case for contingencies happening in U-space airspace. For the sake of finding a meaningful definition, AURA considers contingencies to be unexpected events that need to be mitigated by finding a solution that can be implemented within a few minutes. Some of these contingencies, however, will need to be resolved within much shorter timeframes (seconds rather than minutes) as they may violate current airspace restrictions and thus pose a threat to manned operations. These contingencies are then referred to as emergencies requiring immediate attention and short reaction times by ATC.

The AURA validation exercise conducted by AT-One, the European ATM Research Alliance of DLR and NLR, focused on abovementioned contingency and emergency situations originating from U-space within the DAR processes. A contingency was considered to be all activity that does not happen according to the plan, while an emergency was defined as a contingency that requires immediate action from ATC. The AT-One exercise assessed the impact on human performance within a future environment for Rotterdam The Hague Airport (ICAO: EHRD). Several typical UAS mission scenarios that result in unexpected changes to the mission plan or in unexpected UAS movements were simulated. An ATC tower (TWR) and an approach (APP) controller were working on NARSIM, the NLR ATM validation platform, in a highly realistic simulation environment with added Very Low-Level (VLL) U-space airspace (up to 500 ft) above city centers close to the airport. The validated operational solution included the additional ATC role of an airspace manager, called DAR Manager. Introducing such a role may be seen as an intermediate step towards full DAR automation. However, in the case of the investigated contingencies, the objective was to shift the DAR task from TWR and APP controllers to a separate actor due to the expected workload and safety impact on tactical ATC operations. Furthermore, the DAR Manager was supported by a technical solution for contingency DAR process visualization and communication with both U-space and ATM actors. In order to present high fidelity Unmanned Aircraft (UA) movements within the simulation exercises, the NLR NARSIM platform was connected to the DLR U-FLY ground control station. Since U-FLY can be used to both simulate UA movements and control a real UA, one of the scenarios could be carried out performing a UA flight at the National Experimental Test Center for Unmanned Aircraft Systems at Magdeburg-Cochstedt Airport, Germany, that was manipulated to appear flying at Rotterdam The Hague Airport.

II. AURA Concept Baseline

A. *Basic Principles and Assumptions*

The AURA concept for collaboration between ATM and U-space is guided by several basic principles which were chosen in line with existing research activities and regulatory framework developments in Europe [1]. Most of the services developed within that framework are directly addressing safety-related challenges. The AURA concept takes a user-centric approach responding to and trying to balance the needs of user operations without constraints inflicted on them by the current ATM architecture. Finding a balance to comply with the user needs is expected to improve the performance of the whole system. This also implicates that the needs of new airspace users will become more prominent when compared to current regulations. Any development within the AURA concept must consider scalability, so that the system can adopt easily to changing demand patterns (cf. expectations in [2]). Another important principle is that of equity, meaning that access shall be granted in accordance with user needs under the condition that it does not jeopardize the integrity of the complete system. Finally, cybersecure system design plays an important role, not only for the processes inside U-space but particularly for the collaborative interface between ATM and U-space.

The U-space areas considered in the AURA concept and the AT-One exercise were built around the idea that VLL airspace constitutes the most basic option to separate manned and unmanned operations. There are two reasons for this: manned aircraft will usually be flying above a minimum safe altitude, especially above obstacles or densely populated areas, and UAS will usually require airspace for their missions and operations that is confined to VLL airspace. For the medium-term future, it is also anticipated that a much larger part of the unmanned missions will require the UAS to fly at higher altitudes (e.g. for surveillance missions), and thus inside other types of airspace. AURA puts particular emphasis on the use of the Za-volumes, as proposed in the CORUS concept of operations [3]. Za-volumes are airspace that is controlled by ATC, which puts additional requirements on the vehicle in terms of available communication and system aspects (e.g. Detect-and-Avoid, DAA) and on the operator in terms of certification and licenses and an approved operation plan (Fig. 1).

When looking at the four UAS deployment phases as defined by the SESAR Joint Undertaking (SJU), the European public-private partnership for acceleration of delivery of the Single (Digital) European Sky [4], the AURA concept is set between phase U3 (U-space advanced services) and U4 (U-space full services) with certified operations taking place within Controlled Airspace (CAS). UAS operations considered in AURA include passenger transportation (such as air taxis or air ambulances), movement of goods (e.g. medical delivery), visual and data acquisition (for activities like infrastructure mapping and inspection), and other aerial work.

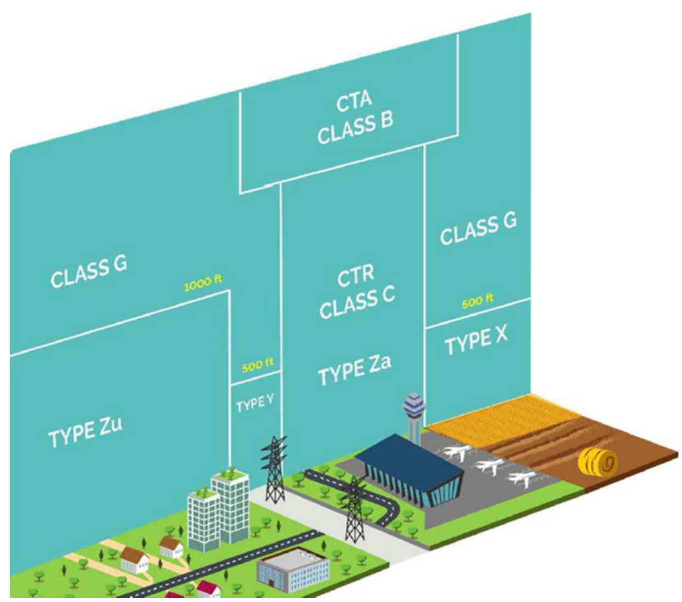

Fig. 1. Airspace Volume Designators from CORUS Concept of Operations [3].

B. Interface for Collaboration between ATM and U-space

The AURA concept is based on a collaborative interface between ATM and U-space, which is driven by U-space services on the one hand, and additional services required for the application of the concept on the other. In an effort to find potential gaps in the current U-space concept, the AURA project defined elements of shared airspace (AUSA) and identified the flow of information between actors, roles and services therein. Depending on the task associated to each role or service, and whether the task is linked to the strategic phase, the tactical phase, or both, a detailed information flow diagram was created. A part of that diagram that can also be found in the AURA concept documentation [1] and has a focus on the relevant elements for DAR processes can be seen in Fig. 2.

The diagram distinguishes manned aircraft operations on the left side, managed by ATC, from U-space operations on the right side, managed by U-space Service Providers (USSPs). The link between both is conceptually enabled by the Common Information Service Provider (CISP) in the center. Cyan arrows depict information flow in the strategic phase, green arrows represent information flow in the tactical phase, and purple arrows are used to indicated where information may flow in both phases. The orange elements are additional concept components required by the AURA concept.

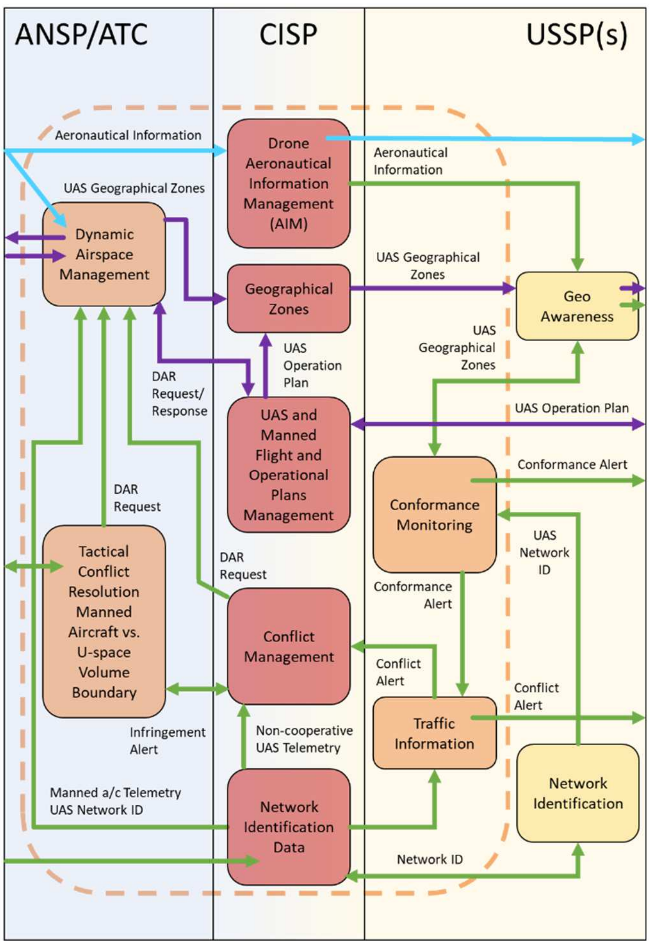

Fig. 2. Collaborative ATM/U-space Interface with Focus on DAR.

For the validation exercise conducted by AT-One, not every CISP service was required or available. Some services were implicitly or explicitly assumed, while others were developed using prototyping software from NLR and DLR. For example, the Drone Aeronautical Information Management service, which enables the aeronautical information required for the UAS flight plan request, was assumed to be present and was realized by data exchange between NLR and DLR prior to the exercise.

On the USSP side, the Conformance Monitoring service was implemented as required to notify the UAS operator of a violation of the mission envelope, if applicable to the scenario. A prototype implementation of the Network Identification service enabled the UAS position reporting to the validation platform elements using an assumed Network Identification Data service of the CISP that was created as part of the distributed simulation set-up. This is described in more detail in section III.D.

On the ANSP side, tactical conflict resolution was part of the general ATC task and was carried out by separating the active and planned U-space volumes from manned traffic in the vicinity of the airport or in terminal airspace (TMA). The Dynamic Airspace Management service was provided by the earlier mentioned DAR Manager. These two elements stood at the heart of the validation activities and were therefore elaborated in detail together with experienced air traffic controllers (ATCOs) who were familiar with operations at EHRD.

C. Operational Environment

The AURA concept based its assumptions, the derived use cases and the required information flow on an operational environment, in which various interactions between ATM and U-space are covered. All possible interactions identified are described in [1]. It should be noted that no strict distinction was made between possible variations of U-space volumes, which span from open airspace with little access requirements to in-flight separation provision in airspace with strict access requirements. These U-space volumes can be referred to by the terms X, Y, Zu and Za as defined by CORUS (cf. Fig. 1).

The AT-One validation scenarios focused on the impact of UAS contingencies in U-space on ATC operations. This means that they cover the scope of the following interactions that are also depicted in Fig. 3:

- Interaction 1: Unmanned operation accessing CAS in a densely populated, urban environment.
- Interaction 2: Implementation of DAR, allowing an unmanned operation within an airport control zone (CTR).
- Interaction 3: Unmanned operation accessing CAS from a U-space volume.
- Interaction 4: Unmanned emergency medical service traffic through a CTR.

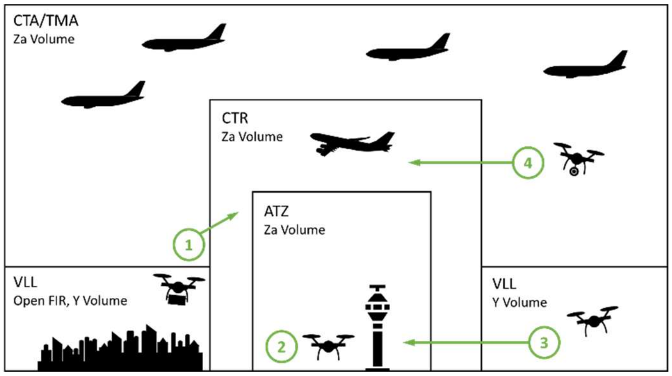

Fig. 3. UAS Contingency Interactions in AURA Operational Environment.

In the validation scenarios, it was assumed that a high level of manned traffic was present in the operational environment as interactions took place in the vicinity of an ATC controlled international airport with a high demand for manned operations under both instrument (IFR) and visual flight rules (VFR) in the CTR. Thus, AUSA was delegated to ATC by default. When unmanned operations requested to operate inside this airspace, a DAR process was carried out and required portions of AUSA were delegated to U-space. These volumes were geo-caged to ensure that unmanned operations were clearly segregated.

D. Human Performance Challenges

The AURA concept describes a situation with full integration of unmanned and manned operations in shared airspace. Therefore, special attention must be given to the roles and tasks of ATCOs who are responsible for the safe and efficient management of traffic movements in those parts of AUSA delegated to be controlled by ATC. They need to be able to perform their tasks to the same level of quality as is generally expected in air transportation.

This is particularly true for ATCOs who are responsible for operations at airports and the control of traffic in the CTR and the surrounding TMA. The impact of UAS operations will be very high in these areas as missions will mostly be performed at low altitudes. with vehicles moving goods or people between inhabited areas or carrying out inspection or surveillance activities. The UAS movements will consequently become a collision hazard for departing and arriving airport traffic in both IFR and VFR regimes.

TWR and APP controllers will need to interact with a U-space system that is expected to be highly automated and perhaps even completely autonomous. At the same time, they need to coordinate manned aircraft movements with a traditional human-centered approach. This leads to two basic changes in the way ATCOs will have to work [1]. First of all, they need to understand the highly dynamic character of speeds and maneuvering capabilities of unmanned aircraft. Secondly, ATCOs will need to interact and collaborate with a highly automated U-space system, which will only be possible if the control actions performed by that system are well understood. This again requires the system to inform ATCOs and communicate any expected change in airspace delegation in a timely and accurate manner.

The same considerations will be true for the UAS operator side. The U-space systems should allow equal access to all types of UAS operations. These could be carried out remotely piloted, partially automated, or even as fully autonomous flights managed by a UAS fleet supervisor who monitors and is responsible for several missions. While the validation exercise was carried out considering such roles and processes on the U-space side, the focus of human performance investigations was still on the ATCOs managing manned traffic and the information they needed from these actors and systems to carry out both their traditional and new tasks.

Considering the above, a number of challenges for human performance with regard to ATC or ATCO tasks, in particular concerning U-space contingencies, may be identified, namely:

- What is the information that is absolutely necessary for the ATCO to perform the tasks and what is the information that is merely “nice to have”? While an answer to this question will certainly depend on the role of the ATCO (TWR, APP, DAR Manager), the encountered situation may also lead to different information needs. Further, ATCOs may need information on unmanned movements that they do not control themselves, which again may lead to challenging situations.
- Are there differences between scenarios and the ATCO information need? In the validation exercise several situation-specific scenarios were evaluated. Therefore, each scenario type may result in different requests and different information demand from the ATCOs.
- Several aspects of ATCO mental workload management are relevant, in particular:
  - Will ATCO workload change when adding new roles and responsibilities? This question concerns the operational feasibility of (new) working procedures (DAR Manager).
  - Will ATCO workload change when adding new human-machine interface (HMI) solutions to the controller working position (CWP)? This question concerns the technical changes and the usability of the implemented technology, i.e. the DAR Manager interface and visualization and negotiation options for TWR and APP.
  - Will the tactical ATCO workload indeed be reduced due to the new operation and technology or will there be new and unforeseen tasks that add to the workload?
- Will the Situational Awareness of ATCOs be sufficient and improved due to the new operation and technology?
- The system needs attention from the ATCO at certain moments whereas, at other moments, the ATCO may have no control over an area because it will be a U-space area. This phenomenon raises questions like: “Is it always clear where the ATCO needs to focus the attention to?”.

- How can optimal information exchange between ATCO and DAR Manager be accomplished? Where is the DAR Manager ideally located, in relation to the ATCOs? Is face-to-face contact needed?
- Do ATCOs have sufficient confidence in the system? Given the fact that ATCOs are used to having 100% control over their own sector, it is interesting to see how ATCOs cope with the fact that they have to "share" their space with U-space.
- Do ATCOs consider the system safe to use? Besides objective safety criteria the impression of the ATCOs regarding safety is important as well for the feasibility of the concept.
- Finally, there is the question of efficiency. Do ATCOs think that they can execute their work in an efficient manner?

E. *Dynamic Airspace Re-configuration (DAR)*

The AURA project describes an operational solution under abovementioned assumptions and environment considerations to accommodate the interactions, use cases and operational scenarios in CAS. This solution relies on the definition of AUSA, which in effect are those areas in CAS where manned and unmanned operations can be carried out. Within AUSA dedicated volumes can be delegated to U-space, if required, and the processes to achieve this represent the operational solution, which is called Dynamic Airspace Re-configuration, DAR.

DAR can be seen as an ATM executed process to delegate responsibility for control of airspace volumes between ATM and U-space based on user demand for either manned or unmanned operations. The default state would depend on local agreements made, but generally, in the neighborhood of ATM controlled airports, it should be expected that airspace is CAS by default. In that case, AUSA is re-configured (from blue to orange volumes) by a DAR Manager, who is an ATM actor, to facilitate a larger number of unmanned operations alongside the manned operations. Orange airspace volumes are assumed to be managed by USSPs using U-space services. While this represents a strict separation between the two types of operation, the proximity of the orange sectors to ATM controlled airports calls for a collaborative approach to management of the airspace and thus several assumptions for DAR and the DAR Manager.

One of the foremost assumptions is that actions affecting both manned and unmanned operations need to be coordinated and agreed upon by the concerned USSPs and ANSPs. Further, ATM must have the final authority on approving the AUSA re-configuration (essentially to protect manned aviation). Another consideration is that there will be a rather wide range of re-configuration timeframes, meaning that variations in demand can be either low, leading to more strategic decisions, or they could be fairly dynamic, causing constantly evolving airspace structures. Other assumptions concern the technical requirements for vehicles in AUSA volumes. Geofences and geo-cages will be used to enforce area restrictions or to restrain UAS movements to orange volumes, which necessitates compliant software for unmanned vehicles. Also, all vehicles need to be registered with the relevant authority and need to carry TCAS/DAA equipment as an additional safety layer. With this in mind, DAR is a safe enabler for flexible use of dedicated airspace volumes by manned and unmanned traffic.

III. Validation of UAS Contingency Situations

A. *DAR Management in UAS Contingency Situations*

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. The latter was the topic of the AT-One validation exercise carried out in October 2022. Together with AURA project partners, AT-One elaborated a concept for DAR contingency requests originating in U-space.

The concept is based on a number of additional assumptions that needed to be made to create an operational environment that was feasible to work with during the validation exercise. Prior to the simulation activities, an ATCO, who had experience in working as an APP controller for EHRD, was contacted to discuss potential operational issues.

During the discussions the following emerged:

- Designated U-space airspace (orange volumes) above the city centers in the vicinity of EHRD should be defined as VLL with a maximum altitude of 500 ft.
- Terminal airspace separation values must initially be assumed (3 NM horizontal, 1,000 ft vertical) between all manned aircraft and the orange (U-space) volumes, unless safety studies have been performed that allow for smaller separation distances.
- For each of the pre-defined AUSA volumes that can potentially switch from blue to orange, the possible consequences for inbound and outbound movements must be determined. Potential limitations in carrying out approach and departure operations at the airport and in the terminal area, must therefore be identified and must be known to all ATM actors.

As a consequence of this, it was assumed that:

- Designated U-space VLL airspace is defined for the cities of Rotterdam, The Hague, and Delft, including the surrounding populated areas and safety studies were conducted determining that all current operations at EHRD can be carried out without limitations.
- The operational consequences at EHRD for each of the pre-defined AUSA volumes becoming unavailable for manned traffic when delegated to U-space are known to ATM actors.

While these assumptions, in the first place, only seemed to concern airport and TMA controllers, it became evident that the DAR Manager, being the ATM actor implementing the airspace changes, had to be well aware of the local arrangements and the consequences for manned traffic, too. This was especially true, if the intended aim of having such an actor was to reduce the workload of airport and TMA tactical controllers in highly dynamic situations, such as contingencies and emergency operations.

Contingencies were considered situations with an irregular operational state of a UAS preventing flight execution according to the defined mission profile [6]. These situations would then necessitate a special DAR request with a contingency or emergency status, depending on the urgency of the situation. All violations of geofences or geo-cages could automatically be considered emergencies, while contingencies still allowed for negotiations between the DAR Manager and ATC or USSP before implementing an airspace change.

AURA defined use cases for management of the airspace with contingencies occurring in close proximity to an airport runway and those occurring in the approach and departure areas of an airport (TMA). Airspace consisted of pre-defined AUSA volumes that could be delegated to U-space. In both cases the USSP was expected to either receive an automated non-conformance alert via a U-space system component 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. The CISP, receiving that information, would be able to determine the required AUSA volumes to be delegated to U-space for segregation of the UAS, experiencing the contingency, from manned traffic and send a request to the DAR Manager. To that end, the CISP must be capable of automatically determining the geographical coordinates of the requested airspace volumes, including a safety buffer, around the intended flight path (as specified in [6], Ch. 6.4).

The DAR request issued by the CISP in case of contingencies ideally contains information on the claimed airspace volume (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 negotiation), and a motivation for the request (based on the operation plan with the included emergency response, see also [3], Ch. 5.1.3.4.3). Submitting the DAR request to ATC is expected to happen within a very short period, but will depend on the complexity of the situation.

The simulations carried out by AT-One looked at one particular situation with a violation of delegated airspace and thus a high priority level. In all other scenarios there was time to focus on the negotiation between the DAR Manager and ATC. For a possible negotiation with the USSP, the assumption was made that the USSP would always agree with any additional change to the DAR request, meaning that this communication aspect may need further research.

While there may be a need to develop additional automation tools for the DAR Manager to help assess the request and, possibly, different re-configuration options for the airspace volumes, the validation exercises were carried out without such tools leaving implementation options open. This forced the DAR Manager and the ATCOs to communicate earlier in the DAR process regarding the impact on manned airspace users and the related safety risk. This risk depended on the experienced UAS contingency situation as well as the feasibility to instruct manned traffic early enough to leave those parts of the AUSA that were planned to be delegated to U-space.

Negotiations between DAR Manager and the TWR and APP controllers concerning the planned re-configuration were facilitated by a Human-Machine Interface (HMI) on each of the Controller Working Positions (CWPs) that is introduced next.

B. Development of a DAR Manager and ATCO Interfaces

The primary concern of air traffic control is safety. The TWR and APP controllers at EHRD need to be able to carry out the work of managing IFR and VFR movements at and around the airport efficiently and without any additional tasks that would increase mental workload and reduce situational awareness, thereby negatively impacting safety of the manned movements. To achieve this, the role of the DAR Manager was added on the ANSP side assisting controllers with any airspace changes that are either due to carrying out a specific UAS mission or a contingency operation.

The DAR Manager needs to have an overview of the situation in order to evaluate DAR contingency requests. The DAR Manager also needs to be able to vary the shape of the requested airspace volumes in both lateral and vertical direction and determine the exact start- and end-times of their use.

In addition, ATCOs have to be aware of any pending changes to the dynamically reconfigurable airspace and need to receive sufficient information about UAS operations in or close to their area of responsibility while continuing to carry out their existing tasks.

During the conducted simulation activities, the DAR Manager received contingency requests from U-space and negotiated them with the controllers. The interface between U-Space and the DAR Manager was largely emulated, meaning that all actions leading to the composition of a contingency request (as described above) were assumed to be working as required on the side of the USSP and the CISP. Further, the DAR Manager was able to see all relevant UAS movements inside U-space on a surveillance display identical to the one the controllers were using.

Based on the contingency request, the DAR Manager was presented with a recommended airspace re-configuration option using a preview setting in the control panel (as shown in Fig. 4). The preview was shown on the surveillance display (Fig. 5) and the DAR Manager observed the actual manned traffic situation estimating the urgency of the contingency.

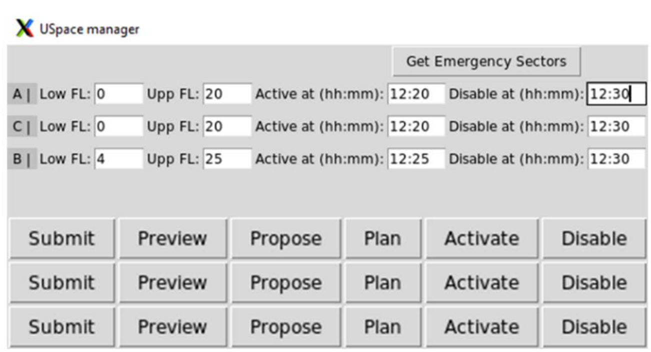

Fig. 4. DAR Manager DAR Request Control Panel.

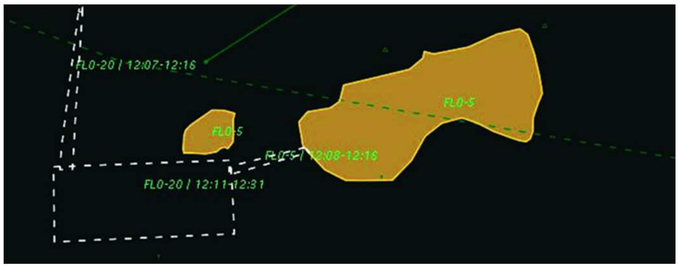

Fig. 5. Preview of DAR Request on DAR Manager Surveillance Display.

The DAR Manager could then leave the request unchanged or choose another option, respectively change the existing option in terms of extension of the airspace and activation time by changing parameters in the control panel. Since the simulations were working with pre-defined AUSA volumes, changing the lateral extension could only be achieved by adding or subtracting different airspace elements.

In the next step, the DAR Manager was free to either directly propose the selected (or revised) change to the affected air traffic controllers (and back to the USSP) or to discuss the situation with controllers via an intercom. Usually, the process was to propose the change via the control panel and to briefly discuss it. Pushing the proposal button made the airspace elements and properties visible to ATCOs on their surveillance display in the same way they were presented to the DAR Manager in the preview (dashed grey contours)

When agreement was reached, ATCOs would start managing all manned operations impacted by the change, instructing aircraft in such a way that the chosen airspace elements would be free of any manned traffic and that future operations would not lead to conflicts between the manned traffic and these volumes.

The change could then be put into effect and be transferred to the planning stage by the DAR Manager. Once that stage was activated, the airspace elements would be displayed with dashed contours in orange color (as shown in Fig. 6) on all surveillance displays and the change would also be communicated via the CISP to the USSP.

A response from the USSP was not simulated as one of the assumptions was that any change of the request would be agreed upon on the U-space side. This assumption may not hold for all situations, so that future investigations should look into this part of the negotiation process as well.

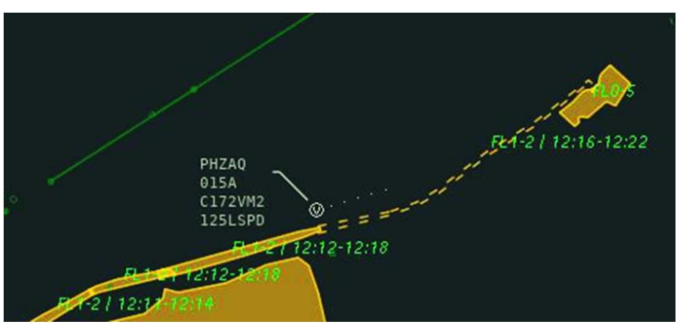

Fig. 6. Active (Solid) and Planned DAR (Dashed) on ATCO Display

Finally, when the activation start time was reached, the airspace elements would be presented in transparent orange and with solid contours (see also Fig. 6). In addition, the DAR Manager had an option to directly activate the airspace elements when needed or to disable them once notification from the UAM fleet supervisor was received via the USSP and the CISP that the UAS contingency situation was solved, so that the airspace could be configured back to a blue volume.

Fig. 7 shows a typical situation with planned and activated (orange) U-space volumes inside AUSA for a UAS safe-and-rescue mission on the surveillance display (CAUSIC) that was used by all ATC actors (with different zoom levels) in the simulation. The main difference between the DAR Manager and the ATCO surveillance screen was that operations within U-space airspace were not visible to the ATCOs, while the DAR Manager could observe UAS movements. The reason for this was to have ATCOs focus on the provision of separation between manned traffic and the orange airspace, while the DAR Manager would monitor and keep track of all unmanned movements inside U-space for a complete overview.

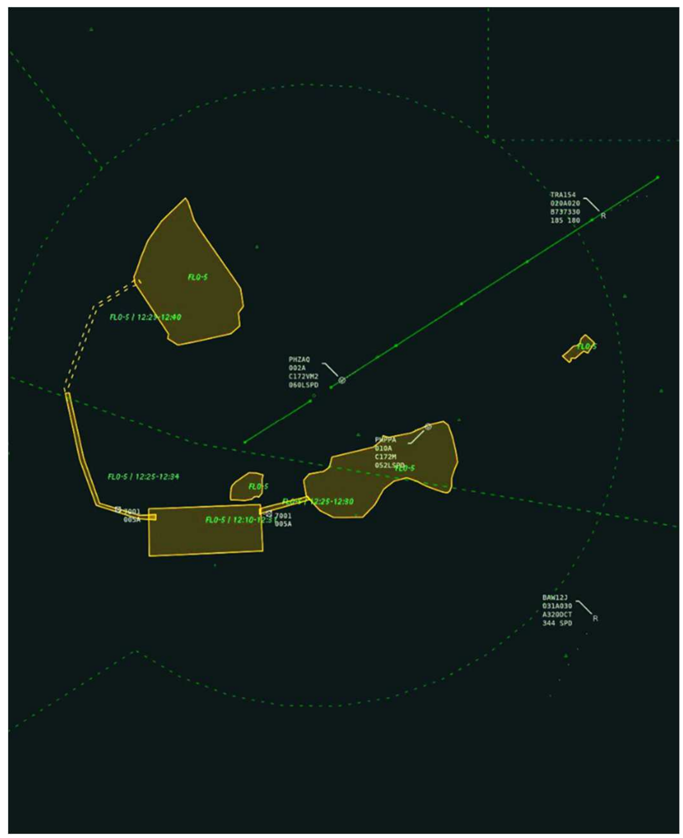

Fig. 7. Surveillance Display used for DAR Manager and ATCOs.

C. *Validation Scope*

1) *Validation Objectives*

In accordance with abovementioned procedural changes and technical development activities, the following basic validation objectives were defined for the simulations carried out by AT-One (see also [8] and [9]):

- Validate that the Collaborative ATM/U-space Interface for Contingencies (CAUSIC) enables the ATC operators (TWR, APP, DAR Manager) and U-space service operators to collaboratively manage manned and unmanned traffic in a safe, resilient and feasible manner in contingency/emergency situations.[1]
- Demonstrate that the DAR process within AUSA during contingency operations does not negatively impact safety and human performance of ATC operators.
- Establish quantitative references for the minimum lead time required to implement dynamic changes and provide clearances within AUSA during the tactical phase of operations, taking into account U-space system performance, UAS vehicle performance, manned aircraft performance and ATM requirements.
- Assess that the exchange process of updating flight plans between U-space and ATM within AUSA during contingency operations does not negatively impact safety and human performance of ATC operators.

The validation activities and the related assessment of Human Performance issues were set up in such a way that these validation objectives could be studied by finding answers to a number of success criteria that were compared to qualitative or quantitative evidence found during the simulations or during de-briefings with the simulation participants.

2) Geographical Environment

As has been described earlier, Rotterdam The Hague Airport (ICAO: EHRD) provided the geographical environment for carrying out the AT-One simulation activities. EHRD is a less complex but important airport serving one of the larger metropolitan areas in the Netherlands. It ranks as one of the larger airports in the Netherlands behind Amsterdam Airport Schiphol, and served some 2 million passengers and about 50,000 flight movements annually in the years prior to the pandemic.

The airport has one runway in NE/SW direction, and is designated as RWY06/24 (see Fig. 8). The runway is 2200 m long in each direction and has a width of 45 m. It has no slope and the thresholds are at an elevation of about -14.5 ft. The apron area lies to the SW end of the runway on the southern side and is connected to the NE end of the runway by a taxiway, TWY V, running parallel to the runway. There are two holding positions for both runway directions and four intersections.[2]

For carrying out the simulations, the runway configuration with south-westerly wind (RWY 24) was chosen. For IFR traffic, this meant that the approach controller received traffic from the upper ACC sector at the TMA borders in proximity of the initial approach fixes (IAF) MASOS and ROT (or sometimes earlier around STD) at or below FL060. Holding areas were located at MASOS, STD and ROT (see Fig. 9).

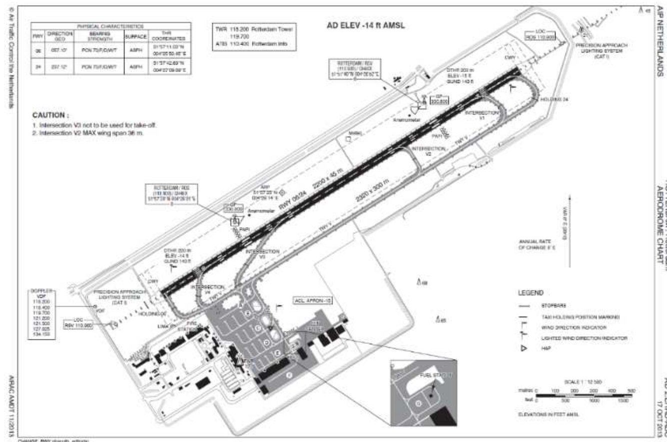

Fig. 8. Aerodrome Chart EHRD, AIP NL, AD 2.EHRD-ADC.

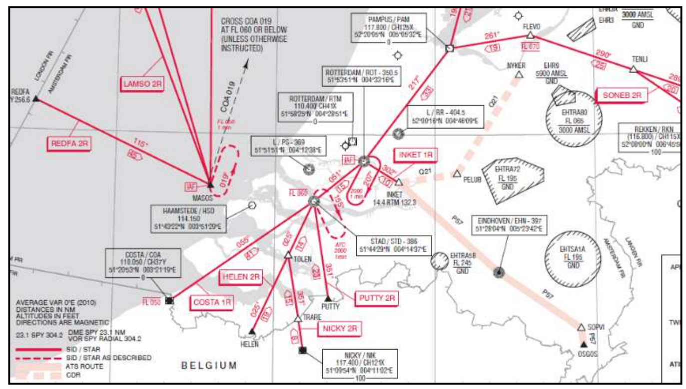

Fig. 9. EHRD STARs and IAF Locations, AIP NL, AD 2.EHRD-STAR.

For arrivals on RWY 24, flights were vectored on all Standard Arrival Routes (STARs) and from all IAF locations towards ROT and continued further for an ILS approach (as can be seen in Fig. 10) towards RTM and down to the runway, RWY24. Fig. 11 shows the Standard Instrument Departure (SID) routes for RWY24.

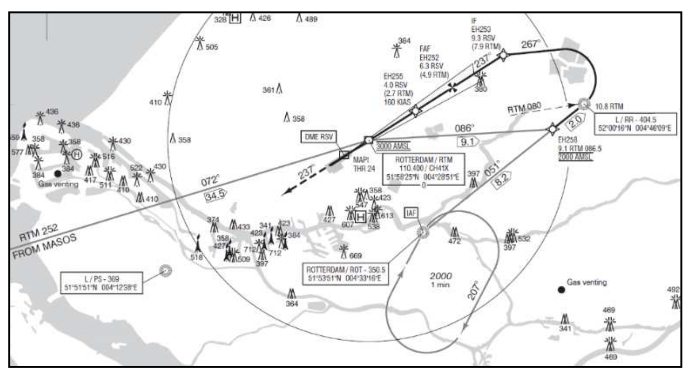

Fig. 10. ILS LOC Approach RWY 24 EHRD, AIP NL, AD 2.EHRD-IAC-24.1.

[1] This included an assessment of the impact of providing adaptive information content on U-space movements to ATC operators.

[2] Note, that the 2013 situation for EHRD designators was used, mainly for being able to compare this simulation to earlier simulations carried out in the same operational environment.

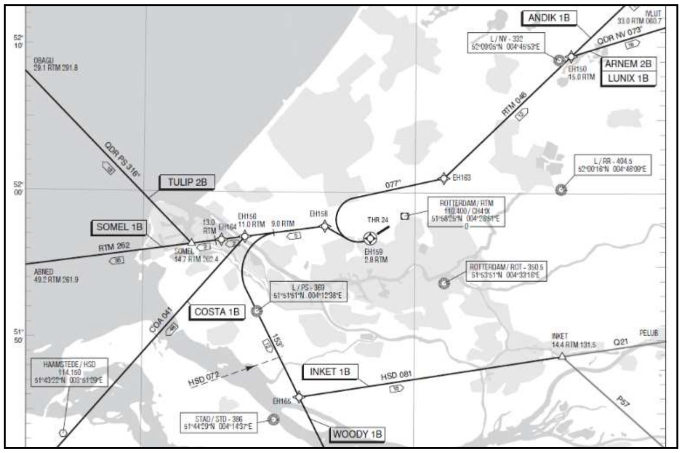

Fig. 11. SIDs for RWY 24 EHRD, AIP NL, AD 2.EHRD-SID-24.

In addition to IFR movements, EHRD has a lot of VFR traffic that was also simulated. For RWY 24, VFR flights entered a right-hand circuit at 1000 ft AMSL, and maintained that altitude until turning to the base leg.

3) *Investigated Interactions*

The general interactions between U-space traffic and manned traffic in CAS were already discussed above (II.C Operational Environment. They concern movements of U-space traffic in the vicinity of an airport. Fig. 12 shows the ATC surveillance screen as used by the DAR Manager and APP and TWR ATCOs.

The choice of distributing U-space areas in that way meant that it was possible to simulate Urban Air Mobility (UAM) movements between the larger populated areas that would cross the CTR of EHRD, infrastructure inspection flights that could enter the TMA from U-space, and unmanned emergency service traffic that could move from one of the hospitals in the orange airspace volumes to a Search-and-Rescue (SAR) area situated within CAS.

Furthermore, unrelated to the choice of pre-defined U-space volumes, other (drone) movements could be simulated at the airport itself.

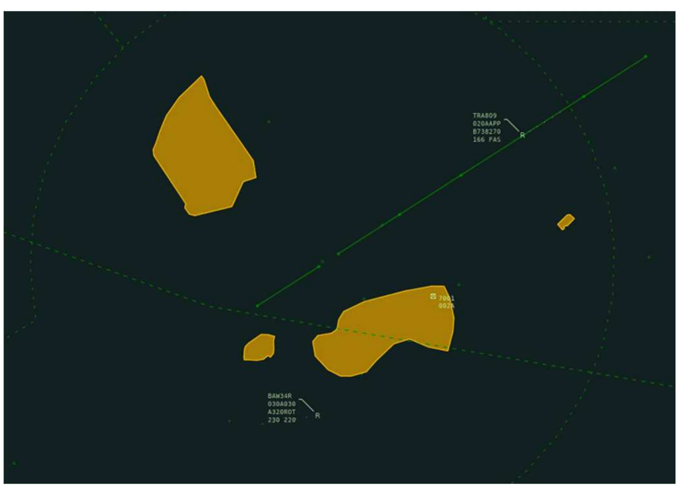

Fig. 12: Pre-defined VLL U-space Areas in the Rotterdam-The Hague Region.

D. *Validation Platform*

1) *NARSIM*

The highly realistic human-in-the-loop real-time simulation and validation platform NARSIM that is located at the Royal NLR premises in Amsterdam was used for manned traffic generation and simulation of all operational front-ends regarding tower (NARSIM Tower) and approach control (NARSIM Radar), as well as the DAR Manager position (integrated in NARSIM Radar).

NARSIM Tower provided the human-in-the-loop simulation for aerodrome tower control (Fig. 13). One of its main features is the full 360-degrees visual system used for different kinds of airport simulations. With NARSIM Tower, it is generally possible to simulate any airport for which 2D and 3D models are available, but it already includes highly realistic models of several Dutch airports, such as Amsterdam Airport Schiphol (for which it is also used as ATC training facility) and Rotterdam The Hague Airport which was used for the AURA simulations.

NARSIM Radar provided the human-in-the-loop simulation for approach control and the DAR Manager (Fig. 14). This easily adaptable and scalable environment offers control positions for en-route (UAC and ACC), and approach and military controllers (TMA) in Dutch airspace.

In the AURA simulations, the TMA approach controller position for simulation of (pre-pandemic) arrival and departure traffic in the EHRD environment was set up and manned with one experienced approach controller. The DAR Manager position was integrated into this environment.

Fig. 13. NARSIM Tower Control Room for EHRD with CAUSIC Display.

Fig. 14. NARSIM Radar with Working Positions for DAR Manager and APP.

In the pseudo-pilot room there were two manned positions for the pseudo-pilots with a single monitor set-up showing the Terminal Approach Radar (TAR) screen and the HMI for interacting with the simulated aircraft. Observers were able to talk to the pilots on these positions and give them instructions. Observers also had an additional monitor showing the traffic situation (on the TAR). The simulation supervisor position was set up in the pseudo-pilot room as well for quick interaction with observers (Fig. 15).

Fig. 15. Simulation Supervisor Screen in Pseudo-pilot Room.

2) U-FLY

In order to carry out precisely controlled drone missions in accordance with the defined use cases and scenarios for contingencies [6], it was necessary to use a UAS platform capable of transmitting the necessary position information to the NARSIM environment. As a consequence, the available U-FLY platform of DLR was chosen for the validation activities.

U-FLY is a configurable HMI for the simultaneous supervision and guidance of multiple highly automated simulated or real UAS. Empirically validated human factors methods were applied in order to design a novel interface that optimally meets the needs of UAS pilots. Furthermore, the degree of abstraction of the presented information is being varied systematically, enabling the UAS pilot to quickly perceive safety-critical system states of all UAS under control.

U-FLY provides input devices for efficient and precise mission planning, high-level flight control (e.g. change of heading or altitude) and simulation of different aerial platforms. U-FLY served as the main mission planning tool for one or multiple UAS in this validation exercise. The main features are the preparation and planning of missions, the prediction of optimized 4D trajectories, the assistance and/or adoption of the communication activities of the pilots with e.g. ATC, the automated conflict prediction with other airspace participants, and the accessibility of further important information such as NOTAMs, weather data or navigation charts.

The map display of U-FLY can be configured to provide the respective validation scenarios (see section III.E) with available geo-fenced corridors and VLL areas for assisted mission planning and monitoring (see Fig. 16).

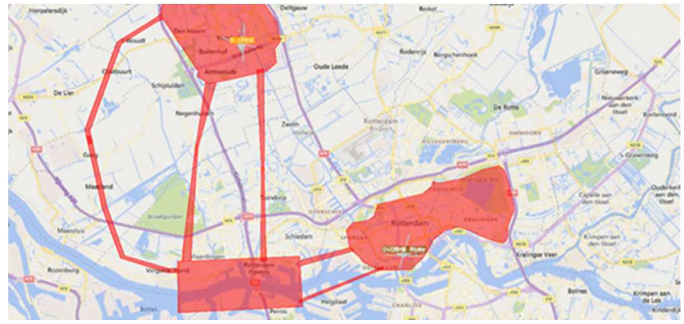

Fig. 16. U-FLY Map Display for "Search-and-Rescue Traffic in TMA".

U-FLY is coupled with the highly configurable UAS drone movement simulator DroneSim, which is based on a modular flight management system for unmanned multicopters, small unmanned fixed-wing vehicles, vehicles used in UAM concepts, helicopters and other vertical take-off and landing vehicles [7]. The vehicle models for the validation scenarios were selected based on availability in DroneSim and requirements of the scenarios.

3) UAS Flight

A real UAS flight was prepared for one of the validation scenarios ("Runway Inspection Drone", see section III.E). For this purpose, the EVO-X8 heavy drone available for flight tests at DLR was selected. The drone was connected to U-FLY by using a 433 MHz datalink. The EVO-X8 heavy has an autopilot that is based on PixHawk 2.1 and can carry up to 20 kg of payload mass. In the setup used during this exercise, an optical camera was attached to the drone (Fig. 17). The reference speed of the drone was 10 m/s.

Specific missions for the UAS flight can be planned using U-FLY and can be uploaded to the drone by using the installed datalink after a coherence check in U-FLY. Uploaded missions can then be activated by a safety pilot, who is monitoring the highly automated flight and who can directly interact with the drone using a remote control at any time, if required.

The UAS flight was conducted in the safe environment of the National Experimental Test Center for Unmanned Aircraft Systems in Cochstedt, Germany, which is operated by DLR.

Fig. 17. EVO-X8 heavy Drone at the German National Experimental Test Center for UAS.

Coordinate transformation translated the actual position data to the positions relative to the geographical environment of EHRD (see III C.2) as required for the validation exercise.

Video acquisition was not a focal point of the exercise. However, the mission parameters were selected such that the recorded video was suitable for online or offline assessments. In this case, the mission altitude was set to 30 m (around 100 ft) above ground level, and the mission speed was set to the aforementioned reference speed of 10 m/s.

4) Simulator connectivity

To connect the validation platform components, a common architecture was agreed on that allows the necessary data exchange. The ground control station U-FLY communicates with the UAS directly via the MAVLink protocol or with the (various) fixed or rotary wing simulations via a proprietary network protocol and a data broker middleware. During a real flight with a UA, U-FLY can send position and status data received via MAVLink to the middleware to facilitate other clients, such as traffic visualization or conflict detection.

During the UA simulations and the UA flight exercise the position data of the simulated or real UAS needed to be visible on the DAR Manager interface. Data exchange was based on the SimNet library that consists of a set of pre-defined messages in JSON format and a set of functions to exchange these via the open source message broker RabbitMQ. The RabbitMQ server was deployed locally for testing. For cross-facility connectivity during the validation exercise, a server reachable from the public internet was provided. A connector software sent UAS position updates from the U-FLY setup to the RabbitMQ server. By means of a SimNet based software module, NARSIM could read the messages and distribute them to its clients.

E. Validation Scenarios

In order to validate the DAR procedures, the technical interfaces and the related operational situations, several typical traffic scenarios and use cases were devised. All validation scenarios were carried out with a comparatively high traffic load for EHRD. Traffic was tuned in consultation with operational experts in order to have a good balance between IFR and VFR traffic in both TMA and CTR. In total, 14 departures and 15 arrivals per hour (on one runway) were simulated with roughly a quarter of the traffic being VFR.

The two basic operational environments investigated with respect to contingencies originating from U-space were an aerodrome (EHRD) and its immediate surroundings being controlled by a TWR controller and the approach operation of that aerodrome being controlled by an APP controller. For each environment two use cases were described that could typically occur. A contingency in U-space would then lead to a situation in which an Emergency Response Plan (ERP) needed to be executed and facilitated by ATC.

In a baseline or reference situation, AUSA was available and dedicated for specific missions, but communication between UAS fleet managers and ATC in case of a contingency had to be achieved via a telephone line to either TWR or APP controllers.

For the scenarios that represented the operational solution to reduce the impact on ATC, the DAR Manager role was introduced and communication was achieved via the CISP and the previously described HMI (section III.B) for planning, negotiating and implementing the DAR.

The use cases investigated and scenarios produced for the aerodrome environment focused on the role of the TWR controller and the management of the airport runway and taxiway systems. It was assumed that it was a busy day with both IFR and VFR traffic in operation and that AUSA was implemented within the airport CTR to facilitate U-space operations within controlled airspace in pre-defined volumes and volumes related to the execution of a particular mission.

The two use cases below describe the relevant U-space missions and contingency situations close to the runway:

- Runway Inspection Drone

A mission was assumed, in which a drone needs the entire runway surface area as temporarily delegated (geo-fenced) U-space airspace to perform a runway inspection. The drone is based in the apron area. While performing the runway inspection the drone has a malfunction resulting in an emergency landing on the runway. This means that more time is needed to reserve the airspace to solve the problem. The extension of the reservation leads to operational consequences for both controller roles (TWR and APP) considered.

- UAM Movement to a City Vertiport

A UAM taxi flight with passengers on board takes off from a vertiport in the city of Rotterdam (south of the airport) in existing VLL U-space airspace and needs to cross the airport (at VLL altitudes) to move people to another U-space area in the city of Delft (north of the airport) in a dedicated geo-fenced airspace corridor delegated to U-space. During that operation a medical emergency occurs and the UAM needs to make an emergency landing in the apron area of the airport.

The investigated use cases for the approach operation focused on the role of the APP controller and the management of approaching and departing traffic in the TMA. It was again assumed that it was a busy day with both IFR and VFR traffic in operation and that AUSA was implemented within the TMA to facilitate U-space operations within CAS in pre-defined volumes and volumes related to the execution of a particular mission.

The two use cases below describe the relevant U-space missions and contingency situations in the TMA:

- Infrastructure Inspection Drone

In this scenario, the mission of an inspection drone is to take pictures along motorway A20 in the North of the Rotterdam VLL, running in parallel with the EHRD runway south of the airport. This area is pre-planned in AUSA and is segregated from manned traffic in the TMA. An emergency occurs (system failure), forcing the drone to leave the pre-planned U-space airspace and make an emergency landing (or move to a loiter point) via a geo-fenced area. It is expected that this operation has a particular impact on TMA movements.

- Search-and-Rescue Traffic in TMA

This scenario consists of two different mission profiles and either profile could potentially involve humans. A SAR drone takes off from a hospital vertiport and flies through a geo-fenced airspace corridor (that needs to be delegated to U-space for the contingency) in the TMA towards a SAR area in the Port of Rotterdam area. In another part of the scenario, an unpiloted SAR helicopter leaves the SAR area towards a hospital. It is expected that all operations will have an impact on TMA movements.

More details regarding use cases and scenarios, especially regarding the different steps in communication and negotiation between ANSP and USSP actors and entities can be found in the AURA Consolidated OSED [6].

F. Data Collection and Human Performance Assessment

In order to address the validation objectives, qualitative and quantitative data gathering techniques were applied during the real-time simulation execution, namely:

- Data logging: data regarding system performance and for quantitative evaluation of human performance and safety KPIs were collected.
- Observations
- Questionnaires, debriefings and interviews

Questionnaires were completed after each simulation run and after each simulation day as well as the end of the complete simulation period. After a simulation run, standard tools for workload and SA were applied (SASHA, Bedford scale, AIM-L/S) as well as ad-hoc operations-related questions, addressing what the human actors experienced during the run.

The questionnaires elicited ratings on the global user perception of the concept and qualitative information, such as positive and negative implications of the concept under assessment according to the direct experience of ATCOs.

The idea of gathering data from data loggings, observations, questionnaires, and debriefings altogether allowed for a comprehensive judgement of the concept. Assessing objective and subjective data for the same aspect led to a more reliable outcome. The contingency situations were simulated with and without the additional role of the DAR Manager, which allowed for the comparison of the quantitative ratings between the two operations in a within-subjects analysis. Due to limited availability of ATCOs, the runs with and without the DAR Manager took place on different days. As a result, the sequence of runs was not structurally counterbalanced, which should be considered when interpreting the outcomes.

IV. Validation Results and Conclusions

A. General Observations

Overall, ATCOs were satisfied that the U-space (as well as the extra U-space claimed for the emergency/contingency) was visible on their radar displays. The main information needs were met and additional information requirements for contingency situations were elicited.

At a general level, one can say that ATCOs reported that they were satisfied with:

- Usability and acceptance of the user interface
- Improved SA when using the interface
- High level of safety when using the interface
- Maintained operational efficiency when using the interface

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

Again, at a general level, ATCOs recommended:

- Avoid clutter by adapting the level of detail depending on the ATCO role.
- For the DAR Manager, the first notification of a U-space claim for a contingency/emergency should draw the attention of the DAR Manager immediately.
- More direct feedback on the actual usage of U-space would allow the return to normal operations earlier and give ATCOs more confidence.

B. Concept Clarifications

The simulated scenarios raised discussions. ATCOs seemed to find it unacceptable that UAS emergency or contingency movements were interfering with large commercial planes. Additionally, the U-space emergencies and contingencies were presented as a fact without any coordination with the DAR Manager or the ATCOs, which was contrary to their expectation. This also had the consequence that, particularly in situations where not much negotiation time was left or an infringement had already taken place, a quicker response might have been needed from both the DAR Manager and the system.

ATCOs mentioned to have no idea about the intention of the UAS in case of U-space emergencies or contingencies and were unsure whether the drones would move beyond the boundaries of the designated U-space airspace. As the simulation introduced a new role (DAR Manager), both the roles and skills as well as new interfaces were under investigation. The roles were not worked out clearly enough. ATCOs seemed to agree that the DAR Manager should have ATCO skills, and that it would be preferable, in case of a contingency, that a few more options for U-space claims would be generated by the system for the DAR Manager to evaluate and choose rather than having the DAR Manager change DAR parameters (altitudes, times, or shapes).

The required minimum separation between U-Space airspace and manned aircraft has to be defined in order to evaluate loss of separation. With U-space airspace active in the vicinity of the airport, general assumptions were made as well as individual assumptions for certain U-space airspace corridors that were located within 3 NM lateral or 1,000 ft vertical of approach and departure routes. With regard to these assumptions, no loss of separation occurred in any of the simulations. All manned traffic operating in the vicinity of the airport will be impacted by separation minima to U-space airspace. This is seen as a prioritization of U-space that may not be acceptable for other airspace users.

In the U-space emergency scenarios, there was no lead time and the DAR Manager had to immediately activate the proposed airspace re-configuration. In each contingency scenario lead times were determined and evaluated. The evaluation of the proposed airspace re-configuration by the DAR Manager and the communication with the ATCOs took approximately between 1 and 2 minutes. A few additional minutes were required by the ATCOs to prepare for the airspace re-configuration.

C. *HMI and Automation*

The basic information requirements were met. ATCOs were satisfied to be able to see the areas claimed for contingencies and emergencies on their radar displays. The expected start-times, end-times and altitudes for using the delegated airspace are important information, however, care should be taken not to provide too much detail in a limited area on the CWP and also to optimize the level of detail presented in accordance with the controller role (TWR or APP).

The average responses regarding ATCO Situational Awareness (SA) shown in Fig. 18 were slightly more positive in the solution runs than in the reference situation, which is likely due to the presence of the DAR Manager who provided additional information with respect to the airspace changes (i.e. location, duration, altitude, affected manned aircraft) and the presentation of that information on the TWR and APP controller interfaces.

The average ATCO rating for confidence in the concept (shown in Fig. 19) was rather high, with a tendency towards higher confidence in the runs with the DAR Manager when compared to the reference runs. However, ATCOs mentioned that they were unsure whether unmanned traffic would stay within the newly claimed U-space airspace in case of an emergency. This was particularly true for the APP controller who had to separate arrival and departure traffic flows from the delegated volumes, resulting in lower confidence ratings for the solution runs. While this is not a factor that could be attributed to the system, it might undermine trust in the system.

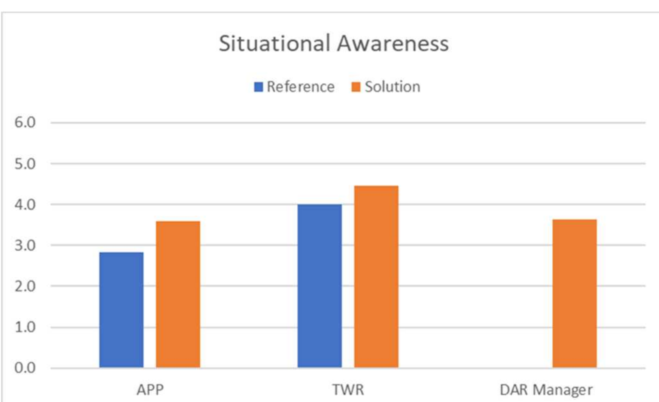

Fig. 18. SA (SASHA) Ratings in Reference and Solution Conditions.

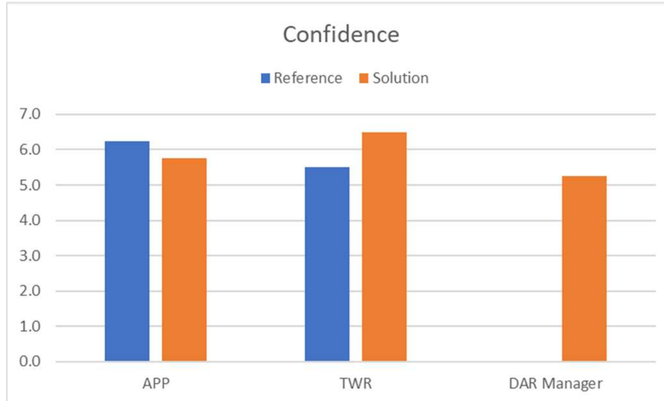

Fig. 19. Confidence Ratings in Reference and Solution Conditions.

D. *Human Performance*

ATCOs felt that they were able to perform their work in an accurate, efficient and timely manner. In the solution runs there was a higher level of agreement than in the reference runs, which indicates that the TWR and APP controller appreciated the DAR Manager role as an intermediate actor to relieve them from some of the mental workload that is likely to be caused by contingencies and, in particular, emergencies.

The perceived level of workload (shown in Fig. 20) was not negatively impacted by the DAR process. The level of workload was rated similar in the reference and solution runs, and average values were slightly lower when working together with the DAR Manager, in particular for the APP controller, who experienced the highest overall workload.

The APP controller rated the perceived level of safety (shown in Fig. 21) higher for the condition where the DAR Manager role was included in the different simulation runs than for the condition where the DAR Manager was not present. For the TWR controller that difference was less obvious, but the overall level was already rated very high. This can be explained by the fact that some of the scenarios simply required the TWR controller to stop operations at the airport, while the APP controller, who experienced comparatively higher workload levels already, had to manage a sequence of flights that could not land.

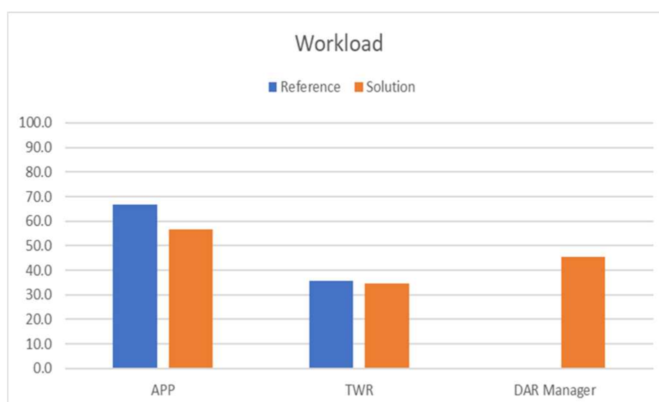

Fig. 20. Workload Ratings (NASA TLX) in Reference and Solution Conditions.

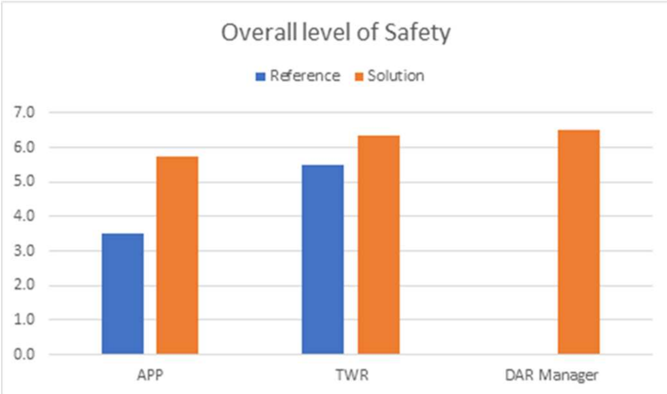

Fig. 21. Safety Ratings in Reference and Solution Conditions.

E. Concluding Remarks

Overall a few Human Factors related concluding remarks were made by ATCOs and researchers.

- ATCOs were satisfied to be able to see the areas claimed for emergencies on their radar displays. It contributed to their SA, which is particularly important in emergency situations. They gave a warning to be careful with too much detail as the increase in SA may be reduced again by a cluttered display.
- Fast refreshers of information for the ATCO will limit the impact on manned traffic and improve the ATCO's trust in the system. After all ATCOs will be better able to respond accurately and at the right moment in time, when the receive continuous and up to date information.
- Emergencies arising out of U-Space in the airport vicinity can have a large impact on the efficiency of operations and workload of ATCOs (and DAR Manager).
- The required minimum separation between U-Space and manned aircraft has to be defined. It must be clarified in advance and it must be clear what operations are feasible for each delegated part of AUSA.
- The presence of a DAR Manager has added value; it increases ATCO SA during contingencies and emergencies.
- Impact on manned traffic can be reduced by accurate and up to date information about U-Space airspace claims. This will also positively improve the trust of ATCOs in the system.

Further the following gaps were identified that need to be addressed in future work on the subject:

- For a possible response from the USSP or further negotiation with all actors, the assumption was made that the USSP would always agree with any change to the DAR request. This aspect needs further research.
- There may be a need to develop additional automation tools for the DAR Manager to help assess the request and, possibly, different re-configuration options for the airspace volumes
- Due to limited availability of ATCOs, the runs with and without the DAR Manager took place on different days. As a result, the sequence of runs was not structurally counterbalanced. This could be improved in future research.

V. Summary

The Royal Netherlands Aerospace Centre, NLR, together with their partners from the German Aerospace Centre, DLR, carried out 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. The simulations focused on contingency scenarios within U-space and the impact of these contingencies on air traffic control and manned traffic.

Several UAS use cases with varying degrees of urgency were carried out to investigate the concept of Dynamic Airspace Re-configuration (DAR) and the role of a DAR Manager implementing airspace changes to facilitate U-space contingency requests.

The results reveal that introducing a DAR Manager role with ATC background and knowledge helps mitigating the impact of the introduction of UAS in CAS via AUSA delegation and DAR on the tactical control carried out by TWR and APP controllers in terms of workload and situational awareness. A prototype of an interface for the DAR Manager and ATCOs 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 negotiation 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 that will need to be addressed in follow-up work. It is recommended to resolve these issues before taking steps to fully automate DAR Management and communication aspects between USSPs and ANSPs.

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The paper has been developed by AT-One, author of this paper, 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.

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