ATTENTION GUIDANCE FOR TOWER ATC USING AUGMENTED REALITY DEVICES

Dipl.-Ing. Jürgen Teutsch, Ir. Tanja Bos, Ir. Marcel van Apeldoorn, Lansenou Camara (BSc)
Royal Netherlands Aerospace Centre (NLR), Amsterdam, Netherlands

Abstract

In 2021 Royal NLR carried out innovative technology experiments on their high-fidelity real-time air traffic control simulation and validation platform, NARSIM. These experiments were part of the SESAR 2020 project Digital Technologies for Tower (DTT). The technology option that was investigated focused on advanced HMI interaction modes for aerodrome tower controllers. More particular, Attention Capturing and Guidance strategies with an Augmented Reality device, the Microsoft HoloLens 2™, were evaluated inside an aerodrome control tower environment for Amsterdam Airport Schiphol, one of the major European hub airports.

The NARSIM environment consisted of a realistic but downscaled presentation of the airport with two tower controller working positions emulating current tower systems. Such a set-up allowed researchers to focus their work on the application of Augmented Reality with the introduction of (virtual) aircraft labels as well as special symbology and auditory cues for capturing and guiding tower controller attention in the case of critical events. Several typical attention-critical events that may occur at an airport, such as go-around operations and runway incursions, were orchestrated by a team of NLR experts and presented to the tower controllers while they were operating traffic as usual. Human performance and ATC operational experts observed and analyzed the simulations.

This paper describes the steps taken and the challenges encountered when integrating the HoloLens inside the NARSIM Tower environment. Furthermore, it explores the proposed operational concept for Attention Capturing and Guidance with the HoloLens and how it was realized inside the device. The results of the technical evaluation activity with two experienced air traffic controllers are described in detail. These results came to the conclusion that the device in combination with the concept was a favorable addition to the controller working environment. While desired technical performance improvements, mostly related to user comfort and general adjustments, depend on further vendor development, the used HoloLens was seen as a technically useful device for implementing prototype applications for Attention Capturing and Guidance with aural and visual cues.

In the final sections of the paper, an outlook into the expected future use of Augmented Reality devices in conventional control tower environments is given.

Augmented Reality Technology

AR Developments

In recent years Augmented Reality (AR) has become one of the major focus points of user interface development. With the rapidly increasing computing power and developments in software and hardware applications during the last two decades, it has moved from theoretical approaches towards industry-wide application and mass production.

The technology used for AR combines virtual elements generated by a computer with the real world. Early developments from the military in the second half of the last century used Head-up Displays (HUD) to improve weapon aiming, but soon moved on to general piloting, displaying basic aircraft state parameters in the field-of-view. More complex interface developments based on HUDs were taken up by the gaming industry some twenty years ago, but lacked the sophistication of current devices in terms of many technological developments, such as power sources, display and sound elements, and gyros for orientation. Nevertheless, such portable computers represented a major step from a simple display of data towards the inclusion of 3D-images in the real-world view.

Developments in handheld computing devices, and eventually mobile phones and dedicated AR devices, such as the Microsoft HoloLens, opened up the world of AR computing to a myriad of developers and, among others, gave us Pokémon Go in 2016.

Developments at Royal NLR

Royal NLR has been working on applications for the use of head-mounted devices in the aerodrome tower ATC environment for more than a decade now. The first device of such kind was tested in 2010 on the NARSIM Tower platform, the NLR in-house developed environment for highly realistic real-time simulations of tower operations. It was a head-mounted display (HMD) from NVIS called nVisor ST™, and we used that device as a demonstrator displaying basic flight strip information either as static information or dependent on the direction of view. Feedback from controllers suggested that, apart from the ergonomic discomforts (heavy device, unpleasant to wear, connected with cables etc.) and concerns about the accuracy and availability of (sensor) data, the concept of enhancing visual information using the HMD looked promising.

Figure 1. HoloLens 2 AR Device

In 2016 we integrated a Google Glass™ device (currently marketed as Glass™) in the same NARSIM environment with the aim to demonstrate further capabilities with less discomforts. The device was used to stream video feeds from remote cameras. Selection of the video feed displayed on Google Glass could occur automatically, depending on the user's direction of view of, which was continually tracked. In that way, we were able to suggest and demonstrate applications to our local ANSP LVNL (ATC The Netherlands) that would allow a tower controller to look beyond physical objects constraining the view from the tower towards some of the apron areas. Invited controllers again pointed out the promising capabilities, but still saw some limitations in the way that the glasses incorporated the virtual elements. The video feeds were conceived as an additional monitor on the side, rather than an integrated element of the outside view.

When the Microsoft HoloLens 2™ entered the AR device market at the end of 2019, Royal NLR purchased two devices (Figure 1). Some experience in the use of a HoloLens had already been acquired by our experts between 2016 and 2019 in other areas, such as aircraft maintenance and repair training, simulation debriefings, and projection of the results of model simulations onto aircraft components. The AR device had not been used before by NLR in the context of Air Traffic Control, though.

SESAR 2020 Experiments

Background and Environment

In line with the developments mentioned above, NLR participated in a consortium for a project being part of the SESAR 2020 Programme called Digital Technologies for Tower (DTT) and being funded by the EU Horizon 2020 Programme. The DTT project (also known as PJ.05 Wave 2) started at the beginning of 2020, just before Covid-19 restrictions hit Europe, and looked at two different so-called SESAR Solutions. A SESAR Solution refers to new or improved operational procedures or technologies that are expected to contribute to the modernization of the European and global ATM system. The solution relevant for our work on AR devices was called SESAR Solution 97: HMI Interaction Modes for Airport Tower. It was devised to carry out experiments for tower control in the fields of VR/AR, air gestures, and automatic speech recognition [1].

Figure 2. NARSIM Tower Validation Platform

While we initially planned to carry out several experiments with different AR elements (aircraft label information, video feeds at the gate, traffic density warnings), the circumstances in 2020 regarding partner contributions changed such that we needed to focus on a specific context, though, namely the use of an AR device for Attention Capturing and Attention Guidance (AC&G) for tower controllers.

As originally intended, we then decided to use the acquired HoloLens 2 as AR device inside the NARSIM Tower environment (Figure 2). The NARSIM Tower platform consists of 9 fully equipped controller working positions emulating the workplace of LVNL tower controllers. The projection system has a field of view of 360 by 40 degrees and its diameter is 11 meters. The outside view is very realistic and, if desired, different atmospheric conditions can be simulated.

In the control room of the NARSIM Tower facility displays for a system engineer, runway and ground movement controllers and observers are available. The supervisor (or experiment leader) can leave the control room and still monitor the simulation runs by accessing streamed video from the supervisor cameras installed in both the control room and the pseudo-pilot room.

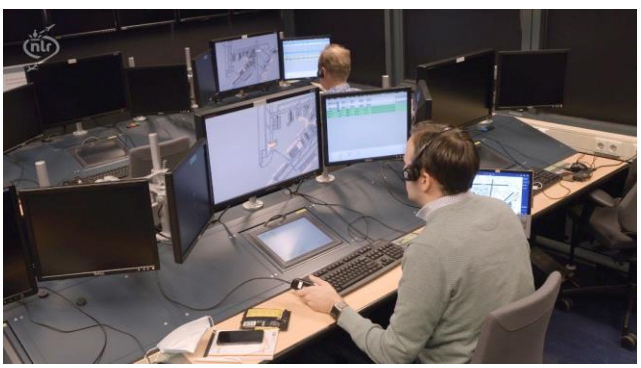

Figure 3. NARSIM Pseudo-pilot Control Positions

The pseudo-pilots controlled all aircraft in the simulation and communicated with ATC. They used standardized control positions providing radar pictures and HMIs for interaction with the aircraft. At NARSIM, there is workspace for up to 15 pseudo-pilots, but due to the limited scope of our simulations only two positions were occupied (Figure 3). Observers were able to talk to the pilots on these positions and gave them instructions (e.g. to cause an event that triggers a safety net response).

Amsterdam Airport Schiphol (EHAM) was chosen as the operational environment for demonstrating the developed concept for AC&G. As was already mentioned, the scope of our simulations was limited in order to investigate the introduction of the technology without adding the complexity of multiple roles and responsibilities inside the Amsterdam control tower team.

Figure 4. Tower Controllers with HoloLens

Only two controller positions were considered in the set-up: a tactical controller on the measured position being responsible for all aircraft movements and an assistant who would observe and support the tactical controller (Figure 4). Still, the chosen runway configuration and the traffic complexity allowed to increase the possibilities for evoking safety-relevant events.

Technical Integration Activities

In order to integrate the HoloLens into the NARSIM environment, it was necessary to align its own internal model of the world with the real world, which consisted of the simulation on a screen (tower outside view) and the controller working positions inside the simulated tower cabin [2].

Technically, there had to be a communication link between the HoloLens and NARSIM as a first step. The NARSIM platform itself runs on a client/server event driven middleware. The simulation of the Tower ATC system consists of a collection of components with (the software design principle of) strict separation of concerns. For the HoloLens application to function in the intended set-up, different kinds of data were required, such as time-ticks, the location of the tower viewpoint, aircraft positions and data, attention items (related to aircraft positions and/or related to runway/taxiways) and their associated data.

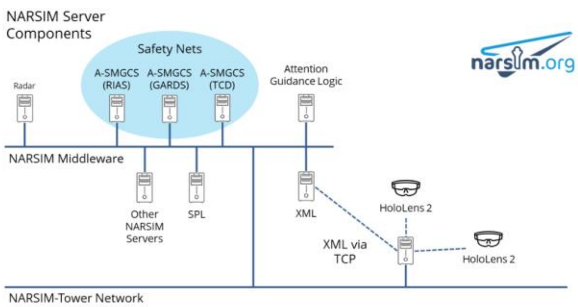

Figure 5. Network Communication Architecture

The HoloLens application was integrated through a dedicated connection where, on the NARSIM end, a component called XML-sender collected all abovementioned data and forwarded that data formatted as XML messages via TCP/IP to the HoloLens application (Figure 5).

To create a HoloLens model of the environment around it, its World Anchoring system was used. The HoloLens scans the real world in real time, and pieces of this information can be used to align the device with the real world. After an anchor point was created near the center of NARSIM, all that had to be done was to align that anchor point perfectly with the real world. The virtual anchor was tweaked to the correct position and height at the center of the NARSIM tower cabin platform. The final step was to find out where north was in the simulation, so that the visualizations pointed in the right direction.

The HoloLens application then used abovementioned NARSIM data in its world model to generate the necessary visualizations. Further attention had to be given to the correct alignment of the augmented data with the simulated world in the outside view, representing another part of the real world that was projected onto a 360-degree circular screen. While the positions in the simulation were known, the HoloLens had to project the positions onto the circular plane of the screen. Aircraft movements on the taxiways were used as a reference to further tweak the visual elements in the HoloLens for perfect alignment with the simulated world.

Attention Capturing and Guidance Concept

The operational concept for AC&G in the AR device was based on visual and auditory cues. In order to find relevant events that would trigger the attention capturing and guidance process, two existing Schiphol runway controller alerting systems were considered, the Runway Incursion Alerting System (RIAS) and the Go-around Detection System (GARDS). Both systems were also available in NARSIM. Furthermore, we added an experimental algorithm for Taxiway Conflict Detection (TCD) in order to also be able to elicit alerts with lower priority that could be perceived as nuisance when compared to the runway alerts that usually indicate a high-impact risk.

A team of Simulation and Human Performance experts at Royal NLR elaborated the basic AC&G operational sequence for safety-relevant events and designed the necessary cues inside the HoloLens to be presented to the tower controller for each of the alerts [2]. They consisted of different types of symbols for information display and user guidance. Different shapes and colors were tested, but also different information content. Aircraft labels generated by the A-SMGCS servers inside the NARSIM environment were also visualized inside the HoloLens and were used as attention getters and as guidance elements, increasing the Situational Awareness of the tower controller.

Figure 6. AC&G Logic Sketch for Start of Event

Generally, the operational sequence was as follows: when any of the A-SMGCS safety net servers detected an event, it relayed that information to the attention guidance logic and a non-intrusive text element was displayed in the center of the HoloLens field-of-view indicating the type of alert and the most important information for that event (Figure 6). The event, and thus the attention capturing activity, had to be acknowledged by the user and both an intrusive (air gesture) and a non-intrusive (direction of view detection) method were tested to that end. At the same time, a pointer guided the user towards the area in which the event was taking place (depending on the type of event that could have been an approach area, a runway, or a part of the movement area) and the callsigns of the involved subjects were highlighted in boxes resembling aircraft labels on a radar display.

Figure 7. AC&G Logic Sketch for Event in View

The boxes were connected to the subjects in question (i.e. an aircraft, vehicle or tow) in a so-called rubber band mode, meaning that they would be drawn towards their subjects until they reached the end of the display. This mode alone already guided the user towards the area of interest. When the user looked towards the location of the event, the callsign boxes snapped to their respective subject and their outline changed to indicate alignment of view (see also Figure 7 with the indicated event focus). Furthermore, the attention capturing process was accompanied by an auditory cue, which was a simple ping sound for the alert and, depending on the type of event, a synthesized speech element announcing the location of the event (as already present in the RIAS).

Updates of the event would occur after a given time interval. They depended on acknowledgement of the user that the event had been noted, the direction of view of the user (i.e. whether the user followed the guidance cues or not), and the severity of the indicated event (or conflict). In case of an update, different cues were used with the interface to raise the attention of the tower controller to a higher level. This meant that different, more pronounced symbology and aural alerts were used. This is tentatively indicated by the arrow in Figure 8. For the eventual set-up, the pointer symbol for each event was highlighted and started blinking. Different settings for the mentioned time interval and the severity of the event were tested.

Figure 8. AC&G Logic Sketch for Event Update

Experiment Arrangement

The test programme, that was designed in accordance with the SESAR-adopted European ATM research methodology for validation [3], consisted of several events and combinations of events (with different or equal priority) that happened while two experienced tower controllers carried out routine work in the NARSIM environment for Schiphol airport. Pseudo-pilots were in control of aircraft movements and communicated with the tower controllers. Traffic scenarios being similar in configuration and traffic volume were used to compare working with and without the HoloLens.

In the reference scenario, ATCOs were working with traffic that was comparable to the traffic used in the scenario including the technical solution, but they were not using the AR device and the symbology that was developed for AC&G. Alerts from the A-SMGCS servers were shown on the Traffic Situation Display (radar screen) instead, resembling the alerts which are currently presented to controllers at Schiphol Tower. The only apparent difference from the current working procedures at Schiphol was the fact that paper strips were used instead of an Electronic Flight Strip (EFS) system that has been in operation at Schiphol tower for about two years now. This was done in order to further reduce complexity of the operation.

The results of the reference scenario were used for comparison between ATCO behavior and performance with the scenario including use of the AR device, the so-called solution scenario.

In all developed scenarios, the ATCO was confronted with a busy traffic situation that would require most of the attention. For the solution scenario, it meant that the ATCO would still need some time to familiarize with the AR device and the traffic situation, even though training runs had been carried out. Traffic scenarios were already running for several minutes (mostly more than 10 minutes) before a first alert situation could be elicited. After a while, the ATCO would be fully engaged in controlling the traffic and was talking to the pilots. At that point, an event that required the immediate attention of the ATCO was created by an observer instructing the pseudo-pilots (such as shown in Figure 9 and Figure 10 below).

Figure 9. Example of a Go-Around Event (AC&G Symbology for event that is not in view)

Figure 10. Example of a Go-Around Event (Snapped callsign on RWY 36R THR)

As mentioned above, generated events consisted of go-around situations, runway incursions with entering or crossing of a runway without permission, and potential taxiway conflicts. The latter were considered less urgent alerts and were therefore mostly used to cause nuisance or distractions.

Results were gathered by using questionnaires after each test run and performing debriefings and interviews. Questionnaires included a set of standardized rating scales to assess ATCO workload, Situational Awareness, system usability and acceptability (Bedford, CARS, SHAPE, SUS). Dedicated questions with a specific operational context were also formulated to retrieve detailed information from the ATCOs about how they appreciated the Attention Guidance cues and what could or should be adjusted.

The experiment structure was based on 14 different events offered in pseudo-randomized order for both ATCOs and conditions. Pseudo-randomized refers to the fact that first all sessions with a single event were completed, and then more complicated situations followed where the ATCO was additionally distracted by other events or had to prioritize between events.

Experiment Results

Our experiment showed that the developed operational concept for capturing and guiding the attention of aerodrome control towers with an AR device can be considered feasible, despite a reduced operational scope and the fact that feedback for improvement of elements of the chosen concept was given. These improvements mainly concerned the symbology and timing of attention guidance cues. In general, though, this result also means that the concept can be seen as a solid basis for continuation of the development work.

Technical Integration

No technical integration issues were experienced in the simulated tower environment, which does not mean that there will be no such issues in a real tower environment. However, the results we obtained boosted our confidence that other experiments planned for real towers in later stages of the SESAR project will come to similar conclusions.

The AR symbology correlated accurately with the objects in the simulated outside view and tracking labels followed the aircraft without noticeable deviations. We assume that this may be different in a real tower environment with less perfect surveillance information, but we also know from our experience with the device that there are methods to improve such imperfections. Further, visibility of the symbology was sometimes competing with reflections of light coming from the surroundings, but it was also considered that such issues might be more prominent in a simulator due to the low light intensity and contrast in the out-the-window view. Finally, the AR attention guidance module received information from the alerting system inside the NARSIM environment and communicated with the AR device as expected.

Operational Analysis

Apart from operational and technical feasibility, the experiment also looked at Human Performance and Safety being the two relevant SESAR Key Performance Areas (KPA) addressed by the operational solution [4].

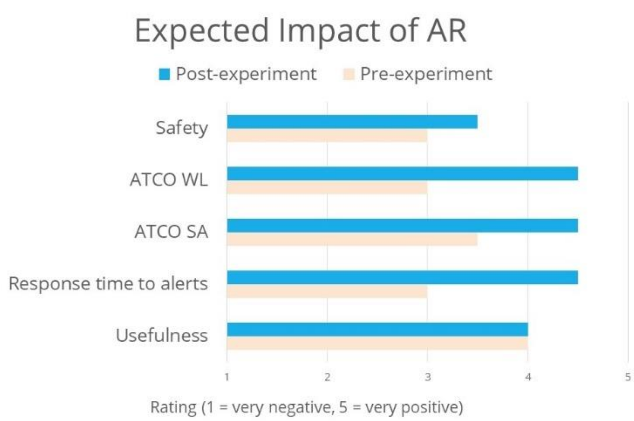

Figure 11. Expected AR Impact (Mean Values)

Controller workload, was rated “positive” to “very positive” after the experiment with respect to the impact of the AR device, both during normal operations and in case of an alert being given (see also Figure 11 above, showing mean questionnaire results). The post-run ratings of workload, however, showed no significant differences between baseline and advanced condition. This could be attributed to the fact that controllers were already working in a smaller operational scope with comparable traffic volume levels under both conditions. Future investigations should therefore concentrate on experiments with larger controller teams for Schiphol or smaller airports with higher levels of diverse traffic to find corroborating evidence for workload reduction.

The impact of AR on controller Situational Awareness (SA) was rated “positive” to “very positive” as well after the experiment, both during normal operation and in case of an alert. Again the post-run ratings of SA showed no significant differences between baseline and advanced condition. While it is thus safe to say that a sufficient level of SA could be maintained, the positive outcome at the end of the experiment could not be corroborated. The fact, though, that controllers stated during debriefings that it was a substantial improvement that they did not have to search for information about the location of the conflict and the relevant aircraft callsigns, indicated that they were indeed anticipating such improvements. The absence of controller errors when using AR may support this argument. Again, different environments with a larger operational scope or more complex traffic situations may help to find more compelling evidence.

The ATCO ratings of expected influence on the response time to alerts was neutral before the experiment and rated “positive” to “very positive” at the end of the experiment. This was substantiated by the ATCOs during the debriefing. ATCOs stated that reaction times might decrease when using AR guidance, because controllers would not have to look down onto displays for information. While this was not objectively measured in our experiment, ATCOs commented that it was efficient and convenient having callsigns in view and not being constrained by information displayed on the TSD or the flight strips which would force them to work in a head-down mode.

After the experiment, the expectation was that safety will increase because controllers could give instructions more efficiently when using AR device (based on the information received from the safety nets). No negative effects on workload or SA were found during the experiment. Furthermore, the outcome of the experiment did not give reason to believe that using AR would have a negative effect on controller error rates due to the consistency of the information provided in the AR device.

While the subjective evidence thus supported the assumption that AR had a positive impact on the work of the tower controller in terms of performance and safety, the current prototype did not reach a development stage yet that would have been sufficient to gain a stable level of automation trust or acceptance ratings from the controllers. Accordingly, the measured system usability scores were low (between 40 and 52.5 on the SUS) and acceptance ratings ranged between 1 and 7, as one of the controllers made several assumptions regarding the potential for improvement of the prototype. Generally, the reasons given for the low ratings concerned the presentation of the alert notification, which was considered too intrusive, the inappropriate re-appearance of alerts in some of the alerting conditions and some of the hardware limitations (restricted field of view, visor reflections, low contrast in simulator).

General Feedback and Summary

Generally, the two experienced tower controllers participating in our experiment, described the device in combination with the concept as a favorable addition to the controller working environment. While desired technical performance improvements (mostly related to user comfort and general adjustments) will depend on vendor development, the HoloLens was considered a technically useful device for implementing prototypes for AC&G with aural and visual cues. According to the controllers, the AR device has a high potential, and definitely deserves more attention.

In the described experiment a rather generic set-up was validated. For example, no distinction between runway or ground controllers was made, while in fact both roles may require another, more customized way of presenting the necessary information. Furthermore, team working aspects and coordination activities between different controllers or controller roles were not considered yet. Notwithstanding these circumstances, which made it impossible to find objective evidence showing operational improvements, the controllers still had a favorable opinion about controller workload and situational awareness improvements and rated both aspects positively. Accordingly, the more efficient and timely presentation and understanding of safety-relevant events was expected to have a positive impact on safety. Similar conclusions concerned head-up and head-down times. While we could not measure them objectively, an increase in head-up time was rated very likely, in particular in alert situations. Controller errors due to the use of the device were not noted.

Recommendations

In summary, the experiment with our prototype led to two issues that should be considered when designing an updated version. They concerned the re-capturing of controller attention and the symbols used. In the original designs, techniques were applied to see if the controller indeed immediately responded to an event as expected by the designers. If that was not the case, the system would repeat the alert and try to capture and guide the attention of the controller again. For the situations chosen in the scenarios this seemed to be a distracting and superfluous step in the concept.

Controllers stated that, once they had been alerted of a serious event, such as a runway incursion or a go-around, they would not need to be alerted again for the same event. What they did need, and what was offered in the current designs, was solid guidance as soon as the event was detected. In a nutshell, controllers do not like support from a system that monitors their own actions, which is not surprising at all.

Accordingly, some of the symbols were considered as distracting with too much interference. This can be changed easily in a different set-up but may lead to different results in a real tower environment due to the different lighting conditions.

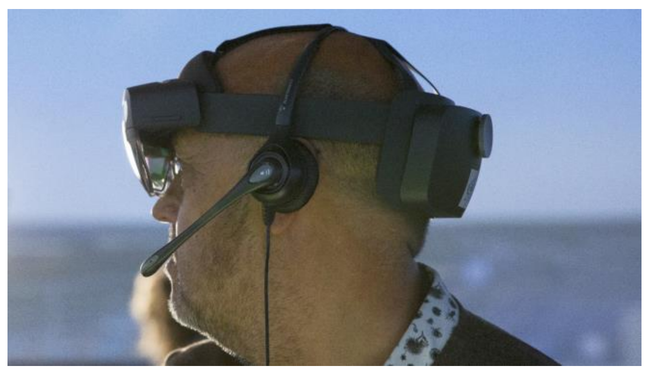

Figure 12. Combining R/T with an AR Device

A large number of the issues that need to be solved in order to allow operational application of the technology comes from hardware constraints, though. Vendors should look at the weight of the device (although improvements were already made here), the size of the screen, which definitely has constraints in the periphery and which leads to difficulties in adjusting the device, and the coating that reduces visibility and is comparable to wearing sun-glasses in a dark simulator room. In addition, the use of R/T together with the HoloLens was simply solved by wearing earphones on top of the device during the experiments (see Figure 12). While speakers are already integrated in the HoloLens (they were used to give aural alerts to the controller), these speakers were not used to communicate. The same goes for the microphones. While they can be used to capture user feedback, they were not tested. As a result, another recommendation for additional experiments was to test the integration of the voice communication service into the AR device.

Further ideas discussed with the simulation participants led to statements about possible development steps in the future and, perhaps, a vision on controller work with AR devices. The recommendation was to not solely focus on alerts related to high impact events. Other means to enhance SA, reduce workload, and share knowledge with the intent to increase ATCO efficiency and capacity should be considered as well. Possibly, a next step could be to focus on increasing tower controller awareness concerning specific airport and approach operations. By studying the kind of information that controllers look up every now and then and offering that information in a more intuitive way (on a silver platter, so to speak) controllers will build their SA with less effort.

A final recommendation was to provide clear guidelines about when and how to use the system. It must be clear in which situations the system should be used, what information is redundant with other sources of information that already exist within the tower, and when using the system is voluntary.

Vision

For a future vision regarding the use of AR devices in the control tower environment, several possible development paths for aerodrome tower control should be discerned. There are clearly very different existing approaches and applications of technology that would reduce the potential of AR or even eliminate its use in tower operations in the first place.

The latter would lead us towards full automation of tower controller tasks and so-called AI algorithms that will completely eliminate the human operator from the tower environment and thus the need for an out-the-window view. While such developments are taking place, we would see them in the context of automation work that still needs to progress in several areas of human perception and cognition.

Figure 13. Using AR Devices in the Future Tower Environment

The impact of further digitalization and remote operations, however, is not really under development anymore and is here to stay. It still requires human operators, but already includes different means for visualization of the outside world and integration of relevant information for tower controllers as part of the visualization concept. Set-ups obviously vary in scope and size, depending on the complexity of the operation that is carried out. For smaller airports or operations, the additional system support and information provision will already lead to benefits reducing the number of controller roles or to improvements regarding work efficiency. However, if more than one controller is supposed to work with the outside view and if that controller would require to see different information content in the outside view, AR devices could help and offer alternatives to additional screens on the remote tower working position or on additional smaller working positions added to the remote set-up (such as can be seen at the Budapest or Fort Collins remote tower centers). Advantages might even become bigger if attention capturing and guidance mechanisms are added, not only for single remote tower set-ups, but to a perhaps larger degree for multiple remote tower set-ups, where one or more controllers need to maintain a mental picture of the operational situation at two different airports. Clearly, AR technology alone would not be enough to improve the situation, but it will certainly offer additional possibilities in combination with planning and alerting features.

If visual operations from existing tower buildings will continue to exist and need to be improved, AR will certainly play a big role in these environments as it offers the possibility to add relevant information to the outside view of a particular controller without adding further equipment to, or forcing the controller to look down at, the working position (Figure 13). Furthermore, it could lead to a new definition of controller roles and responsibilities, where the AR logic determines (or is fed with) the sequence of operations and the course of actions that need to be carried out by a particular individual in the tower. Obviously, such novel arrangements would require a high degree of automation and a clear delegation of authority, particularly in system failure situations. Nevertheless, one of the next steps in the development could be an operational situation in which all current working arrangements are re-defined.

It should be the task of ATM research organizations to look into such novel concepts without being restrained by ANSP structures or industry limitations. This would at least lead to new insights regarding the use of technology and would be an instigation for rather conservative developments started in the past, such as the introduction of EFS. Many EFS implementations we have seen were built on existing operations, roles, structures, and responsibility and authority rules and they simply replaced a paper strip with an electronic representation. Of course, the mere fact that these strips could show additional information, can be seen as a revolution, but the actual paradigm-shifting question for the airport operation is seldom asked: why do we use strips and bays as structural support aids for controlling aircraft on airports?

An elimination of such structures could direct the focus on what is needed in the real world view to better plan and execute departure sequences and to better determine the current clearance status of an aircraft. Or do we even need to know a clearance status? It could be sufficient to use attention capturing and guidance methods to advise the controller to carry out certain actions that will make sure that both the departure sequence can be realized and that aircraft do not have to wait for a required clearance to be given.

This leads us back to the topic of automation and task delegation. AR in combination with attention guidance will clearly be a helpful means to more efficiently carry out any control and monitoring tasks, simply due to the fact that a mental picture can be superimposed onto the real world view. Symbols, colors and sounds can be used to tell controllers what is happening and what needs to be done. Going a step further, automation could be used to already carry out some of the basic tasks, such as start-up, pushback, and landing clearances, via speech recognition while attention capturing and guidance is simply used to keep up controller Situational Awareness when controllers mainly have a monitoring task. Even smarter automation could receive information from the AR device sensors about the current controller workload and stress levels and could thus take over some of the tasks in an adaptive manner to reduce the workload. This opens up many new fields of study.

Another aspect, of course, is whether additional features could be integrated into the AR device view, such as video streams from cameras at gate positions that cannot be seen very well from the tower or video that zooms in on certain aspects of the operation at the gate to give an indication of the statuses for boarding and de-boarding, fueling, catering and baggage handling. For some areas, it might be useful to offer detailed views, e.g. for runways where thresholds are far away from the tower or where part of the runway cannot fully be seen (gap fillers). Eventually, a complete overview of the surveillance picture could be added as well. Or the controller could be immersed into a mixed virtual and augmented reality world and could choose views of a particular situation from each desired position or angle. The possibilities seem endless.

While we can see that some of these ideas still have a number of obstacles to overcome, both technically and operationally, and will not instantly lead to enthusiastic reactions across the aviation sector, we still have to be prepared that the technologies are coming and that we need to ask the right questions to be prepared for such a future. Last but not least we need to ensure that we have investigated the full potential of new technologies that might offer clear improvements if applied in the appropriate context. At Royal NLR, we are prepared to work with such technology and we will embrace the innovative potential it provides..

References

[1] Teutsch, Jürgen, 2021, SESAR 2020 PJ.05-W2 Sol. 97 Intermediate Technical Validation Plan (TVALP), SESAR-JU Deliverable D3.1.031, Amsterdam, NLR, EXE-001 Contribution

[2] Teutsch, Jürgen, Rolf Zon, Roy Arents, 2021, SESAR 2020 EXE-05.97.1-TRL4-TVALP-

VAR-001 Availability Note, SESAR-JU Deliverable D3.1.041, Amsterdam, NLR

[3] EUROCONTROL, 2010, European Operational Concept Validation Methodology (E-OCVM), Version 3.0, Brussels, EUROCONTROL

[4] Teutsch, Jürgen, Tanja Bos, Rolf Zon, 2021, SESAR 2020 PJ.05-W2 Sol. 97 Initial Technical Validation Report (TVALR), SESAR-JU Deliverable D3.1.050, Amsterdam, NLR, EXE-001 Contribution

Acknowledgements

The authors of this paper wish to thank all involved SESAR 2020 project partners, air traffic controllers and pseudo-pilots. Special thanks go to Ms. Ramona Santarelli from ENAV S.p.A. and Ms. Sara Bagassi from the University of Bologna for their support in coordinating and managing the related SESAR solution projects and work packages as well as Mr. Olivier Mongenie from the SESAR Joint Undertaking.

The authors further wish to express their gratitude to the NARSIM and AR development teams at the Netherlands Aerospace Centre.

The project presented in this paper has received funding from the SJU under the EU Horizon 2020 Research and Innovation Programme under Grant Agreement number 874470.

Disclaimer

Email Addresses

The authors can be contacted regarding the contents of this paper via the following e-mail addresses:

Jürgen Teutsch: Juergen.Teutsch@nlr.nl

Tanja Bos: Tanja.Bos@nlr.nl

Marcel v. Apeldoorn : Marcel.van.Apeldoorn@nlr.nl

Lansenou Camara: Lansenou.Camara@nlr.nl

Appendix I

Abbreviation List

AC&G	Attention Capturing and Guidance
AI	Artificial Intelligence
ANSP	Air Navigation Service Provider
AR	Augmented Reality
A-SMGCS	Advanced Surface Movement Guidance and Control System
ATC	Air Traffic Control

ATCO	Air Traffic Control Officer
ATM	Air Traffic Management
CARS	Controller Acceptance Rating Scale
DLR	German Aerospace Center
DTT	Digital Technologies for Tower
EFS	Electronic Flight Strip
ENAV	The Italian Company for Air Navigation Services
E-OCVM	European Operational Concept Validation Methodology
GARDS	Go-around Detection System
HMD	Head-mounted Display
HMI	Human-Machine Interface
HUD	Head-up Display
LVNL	ATC The Netherlands
NARSIM	NLR ATC Research Simulator
NLR	Netherlands Aerospace Centre
R/T	Radio Telephony
RIAS	Runway Incursion Alerting System
RWY	Runway
SA	Situational Awareness
SESAR	Single European Sky ATM Research
SHAPE	Solutions for Human Automation Partnership in European ATM
SJU	SESAR Joint Undertaking
SUS	System Usability Scale
TCD	Taxiway Conflict Detection
TCP/IP	Transmission Control Protocol/ Internet Protocol
THR	Threshold
TSD	Traffic Situation Display
VR	Virtual Reality
XML	Extensible Markup Language

2022 Integrated Communications Navigation and Surveillance (ICNS) Conference

April 5-7, 2022