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ABSTRACT

This study aims to provide an overview of the ongoing ‘Development of Common ATC Simulation Training Assessment Criteria Based on Future Pan European Single-Sky Targets (ATCOSIMA) project which primarily aims to develop common assessment criteria for simulation training courses within the ATCo basic training in order to improve students’ competencies regarding working effectively and in harmony within the integrated Pan-European air traffic system; improve metrics and scoring tools for the evaluations of students according to SESAR’s future targets and provide guidelines and recommended practices for enhanced ATCo training across the Europe. The project proposes an innovative approach to measure the performance of ATCo trainees in radar approach simulations based on integrated ATC radar and flight cockpit simulations. General methodology, real-time simulation and data collection processes and contributions of the project will be discussed.

KEY WORDS

Air Traffic Control; Radar Control Simulation Training; Human-in-the Loop Simulations; Fight Cockpit Simulations; Assessment Criteria.

1. INTRODUCTION

European Airspace accommodates one of the densest air traffic volumes in the world. The total of the flights reached over 11 million within the EUROCONTROL Network Manager (NM) Area in 2018 [1]. This traffic volume is expected to be multiplied by 1.2 to 1.8 by 2035 according to the long-term forecasts done by EUROCONTROL [2]. European Airspace, on the other hand, has been managed by numerous Air Navigation Service Providers (ANSPs) as presented in Figure 1 [3]. This fragmented structure leads to deficiencies in air traffic flow and capacity management. In order to eliminate these drawbacks and handle the ever-increasing air traffic safely, efficiently and economically, European Union (EU) launched Single European Sky (SES) initiative which aims to organize European Airspace...
according to air traffic flows rather than national boundaries [4]. While SES provides a legislative framework towards integrated airspace and air traffic management (ATM) across the Europe, it is supported by Single European Sky ATM Research (SESAR) Joint Undertaking focusing on the technological dimensions of integrated European ATM system through coordinating and conducting innovative research and development efforts [5].

Integration towards a Pan-European Air Traffic Management (ATM) requires not only adaptation of common legislative framework and technological infrastructure but also standardized air traffic controller training and assessment which support its safety, efficiency and economic targets for sustainable growth of future operations.

Air Traffic Controllers (ATCo’s) are responsible for maintaining safe, orderly and expeditious air traffic flow within the airspace under their jurisdiction according to national and international regulations. While complying with these duties, they are in charge of planning, monitoring, controlling, coordination, communication, aircraft conflict detection and resolution tasks. Due to these complex and specialized requirements, air traffic control is considered as one of the most stressful professions in the world [6].

Although the nature of their role switches dramatically from a labour-intensive one to a more technology-intensive one with increasing level of automation, they will remain as the key component of this integrated ATM system [7]. ATCo candidates should go through a combination of intensive theoretical and practical training to acquire the required competencies. ATCo training consists of three phases: initial, unit and continuation training. Initial training includes basic training and generic rating training stages to prepare ATCo candidates for next and more specific training stages at operational ATC facilities. Basic training stage in the initial phase has a special importance because it imparts fundamental knowledge through theoretical classes and develops the required skills through practical classes using synthetic training devices referred as to Air Traffic Control (ATC) simulators [8].

Despite the main elements of course, content and methods to be used in the basic training are defined within EUROCONTROL Common Core Content [9] and EU REG 2015/340 document [10] regarding licensing and certification of ATCo’s, similar to ATM, there is a diversity in training and
assessment processes of basic training across the Europe. These processes differ not only according to the specific approaches and practices adopted but also according to the study mode by each country. While some countries chose to provide basic training as a form of vocational training courses delivered by Civil Aviation Authorities (CAAs) or ANSPs, the other countries offer it as different academic degree programs in their higher education institutions [6]. All these trainings can be varied in terms of training hours, frequencies and percent shares, number of exercises, depth and breadth of theoretical and practical parts. Besides, there is no commonly agreed framework for assessment criteria especially for the practical parts of ATCo basic training. Although EU and EUROCONTROL documents state a set of general performance objectives for the training, they have two important shortcomings: neither they define any standard metrics and scoring for the assessment process nor they include SESAR’s targets regarding efficiency and economics of traffic flow.

The Air Traffic Management (ATM) systems have been increasingly shifting towards automation driven by the technological advances in communication-navigation-surveillance (CNS) systems. Although numerous researches have been conducted regarding human factors issues to investigate impacts of automation and resultant paradigm shift on air traffic controllers [11], there are not many studies in the literature on how the training and assessment of future ATCos are to be performed especially for the simulation courses in the basic training stage. Previous studies proposed some basic principles for the assessment of simulation courses such as evaluations of skills regarding air traffic separation, control judgement, implementation of methods and procedures, equipment usage, communication and coordination [12]. The evaluations of these skills, therefore, are performed based on the safety and controller work-load precepts such as number and duration of airborne conflicts, occupancy, number and duration of ground-to-air communications etc. FAA also conducted several research projects for the performance measurement of ATCo candidates based on similar metrics such as over-the-shoulder (OTS) rating scale, count of mistake and counts of actions that would be required to move aircraft from the sector at the end of the scenario [13].

Several projects addressed requirements and guidelines for the initial training of future ATCo candidates according to change in the task due to technological advancements in ATM such as ‘CAST: Consequences of future ATM systems for air traffic controller selection and training’ [14]; ‘BENT-PAC: Build and evaluate a new training path for air traffic controllers’[15]; and ‘A new evaluation system for the on-going assessment of initial training in technologically developed activities; the case of air-traffic control’ [16]. Although these projects emphasized new skills and competencies of ATCOs for the future ATM environment such as collaborative decision making, cooperative work and automation failure recovery, future competencies regarding efficiency and economics were not addressed for the integrated airspace and air traffic management. These projects were active during 1990s and the results obtained from these studies are mostly obsolete since the ATM system and ATCo tasks have changed drastically during the years.

Various studies on ATC simulation training development issues have been conducted recently to address the current and future requirements of ATM system. Updegrove and Jafre [17, 18] reviewed the current ATC training techniques and made recommendations regarding the inclusion of instructor supper technologies such as recording and playback capabilities and intelligent tutoring systems to expedite adaptation of trainees to more complex traffic scenarios. Coyne et al [19] evaluated perception of students on the use of ATC simulations to provide feedback to FAA authorized Air Traffic Collegiate Training Initiative (AC-CTI) Programs. Chhaya et al (2018) [20] proposed a scenario exploration technology platform to allow trainees and instructors to exercise wide range of simulation scenarios. Falkland and Wiggins (2019) [21] examined the role of cross-task cue utilization in the situational awareness such that perception, comprehension and prediction skills of students for initial stages of ATC simulation training. Bernhardt et al (2019) [22] studied workload and engagement metrics of ATCo students during radar approach simulations across different scenario difficulties and experience levels using EEG and pupil diameter measurements. Although these studies provided important insights in terms of human factors, ergonomics, learning technologies and curriculum
design, development ATC training assessment in parallel to the future targets regarding efficiency and economics is still an untouched issue.

This study aims to provide an overview of the ongoing ‘Development of Common ATC Simulation Training Assessment Criteria Based on Future Pan European Single-Sky Targets (ATCOSIMA) project funded by the Erasmus+ Program of the European Union within the KA2 Cooperation Innovation and the Exchange of Good Practices/KA203 Strategic Partnership for Higher Education. The project proposes an innovative approach to measure the performance of ATCo trainees in radar approach simulations based on integrated ATC radar and flight cockpit simulations.

The development of the common assessment criteria can shorten adaption times of new ATCos to operational environment, reduce times and costs of advanced ATCo training at operational ATC facilities and improve the overall quality of air traffic services for the airspace users in Europe. It can also increase the transparency and recognition of the skills, qualifications and competencies to facilitate learning, employment opportunities and labour mobility of ATCo candidates across Europe. Furthermore, the development of these criteria can improve the level of coordination and harmony between ATCo’s trained in different countries. Therefore, they become more competent to work in the integrated Pan-European air traffic system of the future. Besides, outcomes of the project will enhance their skills required by the targeted integrated European ATM such that effective communication with pilots, recognition of pilot intentions, effective use of airspace and flight efficiency. The outcomes of the project can improve overall quality of ATCo training in the higher education across Europe through the promotion of common awareness of aviation safety and efficient and economic air traffic flow management concepts of future operations. The project offers increased cross-border cooperation between higher education institutions, ANSPs and vocational training organizations involved with basic ATCo training in Europe. The outcomes can lead to possible policy revisions and improvements in the international reference documents such as EU REG 2015/340 and provide an important step to the standardization of the ATC simulation training in the transition to future Pan-European Single Sky ATM. Therefore, they will support to achieve its operational targets such that safe, efficient and economic management of an integrated airspace for sustainable growth of air transportation.

2. PROJECT DESCRIPTION AND GENERAL METHODOLOGY

The primary objective of ATCOSIMA is to develop common assessment criteria for simulation training courses within the ATCo basic training in order to improve students’ competencies regarding working effectively and in harmony within the integrated Pan-European air traffic system; improve metrics and scoring tools for the evaluations of students according to SESAR’s future targets and provide guidelines and recommended practices for enhanced ATCo training across the Europe. The project has been conducted by three higher education institutions including Faculty of Aeronautics and Astronautics at Eskisehir Technical University (ESTU), Faculty of Transport and Traffic Science at University of Zagreb (ZFOT) and Institute of Flight Guidance at Technische Universität Braunschweig (TUBS).

ATCOSIMA will be the first study which considers ATCo-Pilot interactions and reflects the performance metrics related with the needs of airspace users in order to define assessment criteria and training guidelines for radar simulation courses within the basic ATCo training. In order to reach these outcomes, the project team choses an alternative approach based on flight cockpit and integrated ATC-flight cockpit simulations. These simulations will be used to evaluate the impacts of ATCo’s instructions on pilot workload, voice communication, flight economics and efficient use of airspace. These results will support development of common quantitative assessment criteria and training guidelines for ATCo training. In order to meet this objective and its related targets, the project proposes an innovative approach to measure the performance of ATCo trainees in radar simulations based on flight cockpit and integrated ATC and flight cockpit simulations. Instructions of ATCo trainees
will be tested in terms of airspace occupancy, service times, aircraft fuel consumption, pilot workload and readability and implementability of ATCo instructions by pilot.

The general methodology of the project is presented in Figure 2. Implementation of this methodology includes two essential parts: a baseline analysis to evaluate performance of ATC trainees using current assessment criteria and training techniques and development and testing of new assessment criteria. Both parts require a close transnational collaboration between the partners providing ATCo training and conducting high-end ATM research. Each part consists of a set of planning, preparation and analysis task represented by blue blocks, real time (human-in-the-loop) simulations to be performed at ATC Radar and integrated ATC Radar and Flight cockpit Simulator setups represented by yellow blocks, and outputs represented by red blocks. Outputs include results of planning and preparation tasks and analysis of collected and post-processed data and they will be the input for the parallel and subsequent tasks.

![General Methodology Diagram](image)

**Figure 2 –General Methodology: Blue Blocks Represent Preparation and Analysis tasks, Yellow Blocks Represent Human-in-the-Loop Simulations and Red Blocks Represent Outputs.**

Planning, designing, preparation and execution of real-time simulations have mainly been carried out by ESTU and ZFOT. Both partners have been providing ATCo training at higher education level and have the necessary expertise and capabilities in ATC radar simulation training and assessment. Real-time simulations have been carried out parallel with two different trainee groups both in ESTU and ZFOT. Therefore, a common framework for ATC training and assessment can be investigated using different training approaches and cultural background. The trainees are selected among the students of air traffic control programs of ESTU and ZFOT. They are required to be familiar with ATC radar control techniques, phraseology and graphical user interface (GUI) and functions of the radar simulator. Therefore, students who took and succeeded radar control theory and simulation courses are selected as participants of ATC students. Gender equality is also ensured during the selections. The successful students in ATC radar simulations are selected to participate integrated ATC-Flight cockpit Simulations at TUBS.
Both ESTU and ZFOT have been using the MicroNav BEST ATC radar simulators. This will provide two advantages for the project. First, design, planning, execution and data extraction processes of the simulations will be done easily in such a compatible simulation environment and second, comparison of simulation results will be more accurate in the post-simulation analyses. In order to further analyse the correlation of assessment criteria and flight efficiency, integrated ATC radar and flight cockpit simulations planned to be carried out at ATC-Flight cockpit simulators of TUBS. Flight cockpit simulator is a fix-based simulator containing a full replica mock-up of an Airbus A320 cockpit. It is part of TUB’s simulation environment providing a realistic platform for research activities in terms of both airborne and ground operations. The computational units of the simulator consist of commercial off-the-shelf computers. The software modules are primarily based on commercially licensed programs and additional applications developed by research engineers of the institute. The specific architecture permits modification of individual components and is therefore particularly suitable for the execution of scientific studies. At the end of the project, the assessment criteria document and radar approach training guideline will be created as the output of the project according to the analyses obtained through the work packages. Besides, the new supplementary training guidelines will also be tested and validated in integrated ATC-Flight cockpit simulations. Since studying impacts of ATCo instructions on pilot workload is a novel approach in the field, its findings will be published in an academic journal. The simulation analyses obtained during the project will be shared on the project website. At the end of the project, radar simulation assessment criteria document and training guidance document will be published and shared with all stakeholders.

3. SIMULATIONS AND DATA COLLECTION

Vast amount of data is planned to be collected from ATC radar simulations and integrated ATC-Flight cockpit simulations for both the baseline and new criteria testing studies. In order to execute these simulations, an airspace model has been developed based on Frankfurt TMA to be used for generic exercises in ATC radar and integrated ATC-Flight cockpit simulations (Figure 3). Frankfurt TMA has generic characteristics allowing quick and easy adaptation of ATCo trainees during basic training such as a convex airspace boundary with a moderate number of entry points (fixes), low Minimum Vectoring Altitude (MRVA) allowing continuous descent approaches (CDA) and absence of prohibited and restricted areas. These characteristics also allow candidates perform sequencing of arrival and departures, implement radar vectoring techniques and develop skills for planning and execution of efficient air traffic flow within the TMAs. Frankfurt TMA can be considered as a broad airspace in which the minimum and maximum distances between its entry points are 82 NM and 146 NM, respectively. Therefore, trainees have a relatively long planning and execution time for vectoring aircraft to ILS course of the runway during their approach and landing sequences. For basic training, this relatively relaxed time window helps trainees detect aircraft conflicts and develop appropriate resolutions for them during the simulation exercises. Furthermore, this issue allows instructors convey critical pedagogical information to trainees and explain to them necessary tasks to be performed during the exercises.
In Frankfurt TMA, there are six different instrument standard arrival routes (STARs) passing through six different entry points, namely XINLA in the south, SIPRO and OLALI in the southeast, KERAX in the northeast, COLAS in the northwest and RASVO in the west (Figure 3). All arriving flights in the exercises are planned to fly along these routes composed of a chain of flight segments between fixes, geographical positions determined by reference to one or more navigational aids or by other navigational devices or techniques. Trainees are expected to direct each arriving flight from the TMA entry point to the ILS course along its route using radar vectoring techniques. Trainees should ensure that aircraft are established on ILS course before they reach to ASIMA, aircraft hand-off point from the approach control to the aerodrome control unit. ASIMA point is on ILS course and located 10 NM from FFM, the position of VOR at Frankfurt Airport. Transition altitude is selected as 5000 ft for all arriving aircraft within the TMA.

Location of Frankfurt Airport is indicated by FFM VOR point (Table 1). Frankfurt Airport has four runways in use, namely 07R/25L (runway south), 07C/25C (runway north), 07L/25R (runway northwest) and 18/36 (runway west). But in the exercises, it is assumed that 07C/25C is active only and both arrival and departures operations take place at runway 07 direction. This single-runway configuration is not only one of the most common and therefore generic features among the existing airports but also appropriate for the instruction and assessment of radar vectoring techniques to trainees in basic ATC training.

Although the TMA entry and exit points are different in the existing Frankfurt TMA, they are assumed as the same points (such that XINLA, SIRPO, OLALI, RASVO, COLAS and KERAX) in the simulated TMA model used in the exercises for convenience in training in terms of reduced complexity and increased generic-ness of the airspace. Departing flights fly 10 NM from FFM VOR point and then take a direct route planned TMA exit point. The flights are handed off to the relevant en route radar control unit (Langen North or Langen South) when they climb to FL250. All aircraft flying within the TMA should be separated at least 5 NM horizontally and 1000 ft vertically including final approach course.
The existing MRVA limits do not prevent continuous descent of arriving aircraft within the TMA, therefore they provide trainees to practice efficient and environment friendly continuous descent approach (CDA) procedures during the exercises and enhance their skills and awareness regarding flight efficiency issues in ATC operations. While the highest MRVA limit is 5000 ft near the TMA entry points, the highest MRVA limit around the ILS course is no higher than 4000 ft. As a result, aircraft can be descended from the entry points to ILS course without the necessity of any level offs or climbs during the exercises. In order to run ATC radar simulation, ten exercises were prepared for radar approach control simulation training and assessment with increasing different level of complexity and difficulty as presented in Table 1. Difficulty levels of exercises are depend on not only number of aircraft in the exercise but also a set of traffic complexity metrics such that operation mix of departure and arrivals, initial separation between successive departures, number of conflicts between arrivals and departures, and initial distances of arrivals from the ILS course. While the first exercises are designed to familiarize trainees with the TMA and potential conflict points and allow them to use basic radar vectoring techniques, the last exercises require advanced decision-making skills regarding effective and timely use of vectoring, airspeed adjustments and flight level change for conflict resolution and arrival sequencing.

A single aircraft type (i.e. Airbus A320) has been simulated in all exercises. Airbus A320, narrow-medium body twin engine jet aircraft, is on the most commonly used aircraft type with a 15.8% share in the European total traffic [23]. Aircraft performance data used in simulation are based on Base of Aircraft Data (BADA) [24] and cover airspeed, rate of climb (ROC) and rate of descend (ROD) values defined for different flight levels. For the baseline analysis, these 10 ATC radar simulation exercises were run with 19 trainees (14 from ZFOT and 5 from ESTU) under the supervision of ATC instructors. ATC radar simulation circuit and data to be collected is presented in Figure 4. The circuit consist of one ATC workstation for ATC trainee and several pseudo-pilot workstations for pseudo-pilots controlling arriving and departing aircraft within the TMA during the exercises. All stations are connected to the system administrator (sysman) computer in which all airspace and air traffic data and communication configurations are stored as inputs. During the exercises, sysman records exercise replay files and simulation logs. These data provide inputs for assessments, keeping ATCo instructions and air flight path information. Video screen captures and mouse-keyboard actions of trainees are also collected to evaluate task load and occupancy of trainees. Trainees were assessed based on the current assessment criteria adopted by ESTU and ZFOT. ATC instructors performed the assessment using video screen captures and exercise replay files.

<table>
<thead>
<tr>
<th>Exercise Number</th>
<th>Arrival</th>
<th>Departure</th>
<th>Duration (min: sec)</th>
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ATC radar simulations were done between the period of February-April 2018 at ESTU and ZFOT. According to the relevant criteria (assessment achievement, gender, age), 5 of 14 ZFOT students were selected according to go for TUBS ATC- Flight cockpit simulations. ESTU could not perform any selection because of the number of eligible trainees for the ATC simulation runs.
Trainees were administered NASA Task Load Survey (NASA TLX) assessment and task load and occupancy of the pilot through visual analysis. Simulation logs of the aircraft controlled by pseudo-pilots were collected for the estimations of flight efficiency in terms of flight time, distance flown and fuel consumed. Pilots actions were also recorded using a video camera in the cockpit in order to determine task load and occupancy of the pilot through visual analysis. Simulation logs of the aircraft controlled by pseudo-pilots were collected as well to estimate flight efficiency of other aircraft. Communication logs were acquired to analyze ATCo instructions along with simulation logs. Video screen capture files and mouse-keyboard action counts were also extracted from ATC workstations to be used for assessment and task-load/occupancy analysis of trainees. After each simulation both the pilot and trainees were administered NASA Task Load Survey (NASA-TLX) [25] in electronic form to obtain further data for their task-load analysis.

Figure 4 – ATC Radar Simulation Circuit and Data to be Collected

Integrated ATC-Cockpit Simulations were done in June 2018 at TUBS. Ten trainees participated in the simulation runs and the exercise 9 was rerun in the integrated ATC-Flight cockpit simulator circuit presented in Figure 5. In these simulation runs, 8 of the arriving and 3 of the departing aircraft were controlled by pseudo-pilots while 1 arriving aircraft was controlled by the pilot in the A320 flight cockpit simulator. ATC workstations were updated by TUBS teams in order to provide a similar GUI and system functions to trainees. Flight cockpit simulation logs including detailed flight trajectory data were collected for the estimations of flight efficiency in terms of flight time, distance flown and fuel consumed. Pilots actions were also recorded using a video camera in the cockpit in order to determine task load and occupancy of the pilot through visual analysis. Simulation logs of the aircraft controlled by pseudo-pilots were collected as well to estimate flight efficiency of other aircraft. Communication logs were acquired to analyze ATCo instructions along with simulation logs. Video screen capture files and mouse-keyboard action counts were also extracted from ATC workstations to be used for assessment and task-load/occupancy analysis of trainees. After each simulation both the pilot and trainees were administered NASA Task Load Survey (NASA-TLX) [25] in electronic form to obtain further data for their task-load analysis.
Figure 5 – Integrated ATC Radar-Flight cockpit Simulation Circuit and Data to be Collected

4. CONCLUSION

The baseline analysis tasks of ATCOSIMA have been completed and Generic Simulation Exercise Booklet including scenario details as well as simulation files and setups for ATC and integrated ATC-Flight cockpit Simulations were prepared. In addition to these intellectual outcomes, baseline assessment validation criteria were adopted and instructive ATC training guidance videos were produced in order to be used as the inputs of the next steps of the projects. A vast amount of data set was also collected for the further analysis regarding ATCo performance, flight efficiency and pilot task load and acceptance. These outcomes will not only support the development of new ATC radar simulation assessment criteria but also provide a framework and database of other studies to be done in the future. Although the project primarily targets the instructors and students of ATCo basic training programs in higher education institutions, its outcomes will provide feedback and recommendations for the revision of reference documents. Therefore, the results can be reached and used by all ANSPs, Civil Aviation Authorities and vocational ATCo training organizations in Europe.

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