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FACULTY OF TRANSPORT AND TRAFFIC SCIENCES

Dorea Antolović

DEVELOPMENT OF SCENARIOS ON THE ESCAPE ATC SIMULATOR

MASTER THESIS

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Student: **Dorea Antolović (0135241210)**
Study: Aeronautics

Title: **Development of Scenarios on the ESCAPE ATC Simulator**

Description:

Define the aim and the scope of the diploma thesis. Analyse and explain ESCAPE simulator features and configuration platform. Analyse simulator data preparation tool. Explain how to develop simulation exercises and define procedure. Develop a simulation scenario of TMA Zagreb airspace. Develop a simulation scenario of ACC Zagreb airspace. Give an overview and conclusion of the work.

Mentor: Committee Chair:

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University of Zagreb
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MASTER THESIS

DEVELOPMENT OF SCENARIOS ON THE ESCAPE ATC SIMULATOR

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Student: Dorea Antolović
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Summary

Simulators are a vital part of Air Traffic Controller Training. Croatian Air Traffic Control Training Centre (HUSK) provides Basic training for air traffic controllers at the Faculty of Traffic and Transport Sciences as a part of its undergraduate study program of Aeronautics. As a training facility, it is important to continuously develop used systems and procedures, including the Air Traffic Control (ATC) simulator. ESCAPE ATC simulator meets the conditions for being used at the University for training as well as research purposes. The research presented in this paper is based on practical work with the data preparation tool of ESCAPE to acquire knowledge and expertise as well as to develop scenarios for approach and area control exercises. Those exercises are intended to be implemented in the Basic training program provided by HUSK. The results of the research can be used in the future for improving the system and generating additional exercise scenarios, as needed.

Keywords: simulation, ATCO training, scenario development

Table of Contents

1 Introduction

Simulations are a vital part of the improvement in the area of Air Traffic Management (ATM). They offer an opportunity to safely test certain procedures, evaluate the existing airspace, test new configurations and plan or predict interactions between aircraft. Air Traffic Controller (ATCO) Training relies on simulations during a large part of the training period. After the theoretical education, students are being familiarized with the air traffic control environment and performing elementary tasks on a simulated system, followed by specialized training for their chosen discipline, whether it's tower, approach or en-route control. Croatian Air Traffic Control Training Centre (HUSK) provides Basic training for air traffic controllers at the Faculty of Traffic and Transport Sciences as a part of its undergraduate study program of Aeronautics, module air traffic control. As a training facility, it is important to continuously develop used systems and procedures, including the Air Traffic Control (ATC) simulator.

EUROCONTROL simulation capabilities and platform for experimentation (ESCAPE) is a real-time simulation platform suitable for ATCO training, as well as research and operational validation. It features a full recording of exercises for further analysis. with ESCAPE's integrated advanced data processing tools. Those analysis tools allow to quickly post-process exercise data and produce 'dashboard' reports to be used during debriefings or to rapidly analyse special events occurring during the simulation, offering greater in-sight for both students and instructors. ESCAPE Light is a lightweight version of the same software. It offers the same functionalities as its parent simulator, including a user interface representative of the most common European ATC systems. The universities can start working with it as part of their ATCO training as well as for projects and simulations as a part of research. Developing scenarios on a modular ATC simulator would imply long-term progress and the ability to meet the training organization's needs to keep in touch with the ever-evolving technology.

The goal of this research is to acquire knowledge and expertise with the data preparation tool of ESCAPE and develop exercise scenarios with an emphasis on data preparation that will allow the development of different scenarios for creating approach and area control exercises. Those exercises are intended to be implemented in the Basic training program provided by HUSK at the Faculty of Traffic and Transport Sciences as a part of its integrated Air Traffic Control study program. The results of the research can be used in the future for improving the system and generating additional exercise scenarios, as needed.

The thesis consists of 7 chapters, including Introduction. The second chapter, ESCAPE simulator features and configuration platform serves as a presentation of EUROCONTROL and its work on innovation, research and deployment in the aviation industry. Directorate European Civil-Military Aviation (DECMA) is individually presented due to the involvement of experts from DECMA/INO/VIF unit in the training on the data preparation tool of ESCAPE. Furthermore, ESCAPE and ESCAPE Light are introduced, as well as the ORACLE VM VirtualBox, the configuration platform for ESCAPE Light used during the research.

The chapter Data preparation tool is important for understanding the general principles of data preparation within ESCAPE. Individual components of IPAS, the data preparation tool, are presented, as well as how they can be used and what their purpose is. The chapter can serve as a user manual for future scenarios development using ESCAPE's data preparation tool.

In the fourth chapter, Development of simulation exercises, data provided by the Faculty to design the exercises is listed. This chapter is an extension of the previous one, explaining in greater detail the necessary actions for including the input information into the data preparation process and generating the desired result. A comparison has been made between the exercises previously used at the Faculty and the ones created in ESCAPE, both of them having the same input information.

The chapters Terminal Control Area (TMA) example of scenario development– Zagreb TMA and Area Control Center (ACC) example of scenarios development– Zagreb ACC present the way sectors were designed for terminal and upper Zagreb airspace, respectfully. Furthermore, certain steps in data preparation that are representative of only TMA or only ACC exercises are additionally explained. At the end of each chapter, the designated organization and layout for the exercises is presented

The results of the thesis are summarized in the final chapter, Conclusion.

2 ESCAPE simulator features and configuration platform

2.1 About EUROCONTROL

EUROCONTROL is a pan-European, civil-military organisation dedicated to supporting European aviation. It supports its Member States and stakeholders in an attempt to ensure safer, more efficient, more cost-effective aviation in Europe with minimal environmental impact. EUROCONTROL is committed to implementing, together with its partners, the European Union's vision for a Single European Sky that will deliver the ATM performance required for the twenty-first century and beyond. EUROCONTROL achieves its purpose by delivering technical excellence and civil-military expertise across the full spectrum of air traffic management. At the same time, it aims to come up with solutions to the key issues and challenges facing the aviation industry.

Some of EUROCONTROL's activities include service provision, concept development, research, performance improvement, Europe-wide project implementation as well as providing support to the future evolution and strategic orientations of aviation.

EUROCONTROL is an intergovernmental organisation with 41 Member and 2 Comprehensive Agreement States. Its stakeholders include air navigation service providers, civil and military airspace users, airports and aircraft/equipment manufacturers[1].

There are two governing bodies in EUROCONTROL: the Permanent Commission and the Provisional Council. The Agency is the executive body. The Agency's Director General is responsible for the management of the Agency and enjoys wide management independence in this regard. He can put proposals to the decision-making bodies of the Organisation concerning the execution of the Organisation's tasks[2]. The Organisation's stakeholder groups are also involved in guiding the Agency's efforts to ensure that the interests of all aviation stakeholders are represented[1].

2.1.1 DECMA

DECMA (Directorate European Civil-Military Aviation) is a merger of two former Directorates - Directorate ATM and Directorate Pan-European Single Sky. DECMA brings together a strong technology, State support and innovation function:

- State support units strive to ensure the development and implementation of the Single European Sky (SES) at the pan-European level, providing support to the EU and States as necessary.
- Civil-military ATM coordination division ensures appropriate civil-military and military-military ATM coordination via EUROCONTROL's unique civil-military competences.
- R&D and SESAR Contribution Management division plays a core role in SESAR 2020, where EUROCONTROL leads eight projects and contributes to many more with the goal of achieving the objectives of the SES and the performance scheme, as well as ensuring full alignment of Single European Sky ATM Research SESAR initiatives in accordance with the ATM Master Plan.
- ATM strategies division ensures the strategic development of ATM, with a particular focus on ensuring coordination at a global level with the key actors[3].

2.1.2 Innovation, research and deployment

European ATM system calls for constant and sustainable technological improvement. EUROCONTROL, as the founding member of SESAR, develops and deploys solutions to boost innovation and encourage the continuous progress of the aviation sector.

Innovation is supported in all aviation domains, with an added focus to those fields that are thought to have a major contribution to their development, such as artificial intelligence, data mining and big data. Emerging and disruptive technologies are being fully developed to face the growing needs of European air transport. EUROCONTROL is a part of ACARE (the Advisory Council for Aeronautics Research in Europe) General Assembly and collaborates in various working groups to help identify main research areas and to define, monitor and update its strategic agenda (SRA)[4].

EUROCONTROL is an active contributor to the ATM industrial research activities. Special emphasis is placed on the SESAR programme to accelerate the modernisation of the European ATM system and meet the goals of the SES. The Agency is leading, managing or coordinating European research in domains with a profound impact on capacity and safety, such as runway throughput, demand capacity balancing, user-driven prioritisation, safety nets and U-space. It contributes to all phases of a project, starting with the development of a concept and following through to demonstrations. There is a comprehensive suite of models and tools which are used for validation in all research areas:

- fast-time simulations
- ATFM modelling tools
- airport simulation platforms
- environmental modelling tools
- aircraft performance databases
- ATC and ATFCM real-time simulations

Once SESAR delivers solutions to help improve the performance of the European ATM network, they are ready to be implemented operationally. As the leader of the SESAR definition phase, EUROCONTROL is fully committed to supporting the deployment of those solutions through common projects or enablers, while focusing on those projects which will bring the greatest benefit for the network, such as performance-based navigation (PBN), system-wide information management (SWIM) datalink and airport operations [4].

2.1.3 Simulations

EUROCONTROL provides simulation and validation services and develops solutions in the field of air traffic management. Its work is instrumental in evaluating the operational performance of air traffic control systems at airports, in the communications, navigation and surveillance domain and the airspace. Having accumulated over 50 years of experience, EUROCONTROL enjoys longstanding cooperation with the wider air traffic management community. It was the first centre in the world to run end-to-end digital real-time simulations [5].

Services that EUROCONTROL offers are a part of the support provided by the Network Manager to meet the Single European Sky performance targets and contribute to the validation of future network air traffic management concepts. Those include:

- validation of air traffic management concepts through simulations [6]

- realistic air traffic control, airport and flow management systems for simulations and training [7]
- assistance and consultancy for external airspace simulations [8]
- IT developments and human-machine interfaces for ATM simulators [9].

Solutions used by EUROCONTROL for the simulation and validation task include Early demonstration and evaluation platform (EDEP), Base of aircraft data (BADA), Research network strategic monitoring tool (R-NEST), EUROCONTROL simulation capabilities and platform for experimentation (ESCAPE) and more [5].

2.2   ESCAPE

EUROCONTROL simulation capabilities and platform for experimentation (ESCAPE) is a scalable EUROCONTROL ATM real-time simulation platform supporting small- and large-scale simulations in the following areas:

- Airspace design for both en-route and TMA
- Evaluation of new operational concepts and controller tools
- Pre-operational validation (live trial)
- Controller training
- Research & Development

One of the strengths of ESCAPE is its modular design and maximum use of advanced software engineering solutions. ESCAPE is a full PC/Linux platform based on Corba middleware for dynamic communications between ESCAPE components.

ESCAPE can be used for research, operational validation or training purposes. It features a full recording of all controller and pseudo-pilot input, all trajectories flown, all R/T and telephone communications, self-assessment indicators, etc. Those recordings are available for further analysis by the validation or training experts, with ESCAPE's integrated advanced data processing tools or other internal tools.

The analysis tools which are a part of ESCAPE allow to quickly post-process exercise data and produce 'dashboard' reports to be used during debriefings or to rapidly analyse special events occurring during the simulation.

It features CPDLC functions (data link) and other tools to support the operation of Free Routes. In addition to that, EUROCONTROL's and SESAR concepts like 4DT (4D trajectory management), TBS/LORD (time-based separation, optimised runway delivery), PMS (point-merge system) and ETA/RTA/TTA (target times of arrival) are integrated into ESCAPE to ensure it remains a suitable platform for research simulations [10].

2.3   ESCAPE Light

ESCAPE is also available on a light platform. The "ESCAPE-Light" simulator is a lightweight yet still high-performance version of the ESCAPE software. This light ATC real-time simulator offers the same functionalities as its parent simulator, containing a set of generic exercises and a human-machine interface representative of the most common systems in Europe. This means that universities can start working with it as part of their basic Air Traffic Control training for aviation students, while researchers can use it as part of projects and simulations. It's an ideal solution to conduct smaller real-time simulations, be it for training, research projects or small scale airspace improvements.

The number of simulated sectors is expandable and only limited by the number of inter-connected laptops. As with the standard platform, the light version includes controller working positions and pseudo-pilots working positions.

The simulator is modular by design, so users can plug in new components and exchange data with other simulators with the help of appropriate application programming interfaces (APIs) that EUROCONTROL provides. This gives freedom to researchers to develop advanced algorithms and test them in a realistic simulated environment. To train AI-based algorithms, EUROCONTROL can also provide data from past simulations that are very dense in terms of information-rich events.

The ESCAPE modular design enables easy adjustment of the ATC tools setup according to the needs of the scenario. These tools can be selected from a wide range of existing capabilities, e.g. safety nets, datalink, high fidelity aircraft performance and powerful HMI tool kit. A significant amount of data is recorded, including controller and pilot interactions, safety alerts, a/c movements, tracks. They are available for post-exercise processing; either for statistical analysis, training or research purposes [10], [11].

For the purpose of the research, ESCAPE Light is installed and used on a single laptop. The objective is to develop scenarios for the sector North within Zagreb Flight Information Region (FIR), as well as Zagreb TMA, which are used as part of the Basic ATCO training by the Croatian Air Traffic Control Training Centre (HUSK).

2.4   Oracle VM Virtual Box

Oracle VM VirtualBox is a cross-platform virtualization application. It is installed on a computer, whether it is running Windows, Mac OS X, Linux, or Oracle Solaris operating systems (OSes). It extends the capabilities of the existing computer so that it can run multiple OSes, inside multiple virtual machines, at the same time. The only practical limits for the number of installed virtual machines are disk space and memory.

Host operating system (host OS) is the OS of the physical computer on which Oracle VM VirtualBox was installed. There are versions of Oracle VM VirtualBox for Windows, Mac OS X, Linux, and Oracle Solaris hosts. To write this graduate thesis, VirtualBox for Windows is used[12]]

Guest operating system (guest OS) is the OS that is running inside the virtual machine. In this particular case, Linux is used.

Virtual machine (VM) is the special environment that Oracle VM VirtualBox creates for the guest OS while it is running. In other words, the guest OS is being run in a virtual machine. Normally, a VM is shown as a window on the computer's desktop. Internally, Oracle VM VirtualBox treats a VM as a set of parameters that specify its behaviour. Some parameters describe hardware settings, such as the amount of memory and number of CPUs assigned. Other parameters describe the state information, such as whether the VM is running or saved. [12].

There were four ESCAPE Light virtual machines initially installed in VirtualBox - the ground machine, IPAS machine, a Pilot working position (PWP) and a Controller working position (CWP). During the traineeship with the EUROCONTROL and writing the thesis, the platform has been expanded with three more virtual machines to facilitate additional working positions. Figure 1 below shows the expanded platform.

Figure 1 Virtual Machine

3 Data preparation tool

IPAS is a data preparation tool used in ESCAPE and ESCAPE Light. It's launched by opening a terminal in "empipas01" machine and typing "ipas". It usually opens to a grey coloured Supervision window, as seen in Figure 2.
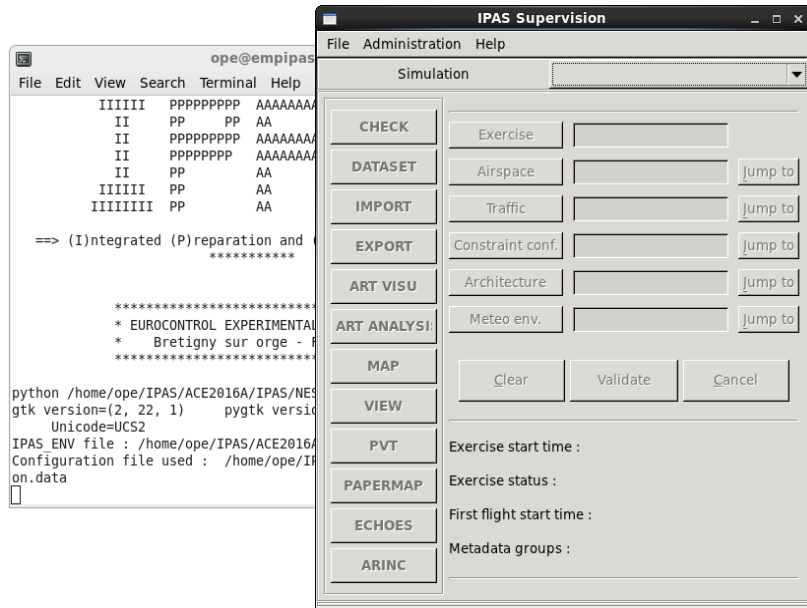

Figure 2 IPAS Supervision

Closing the Supervision window can only be correctly done by clicking on File and then Quit. Most components in IPAS work that way. If Supervision isn't closed properly, it won't open properly the next time. When that happens, a Read-only version of Super-vision in a blue window opens, with and indication in the terminal that it is the second session, out of the three allowed, like in Figure 3.
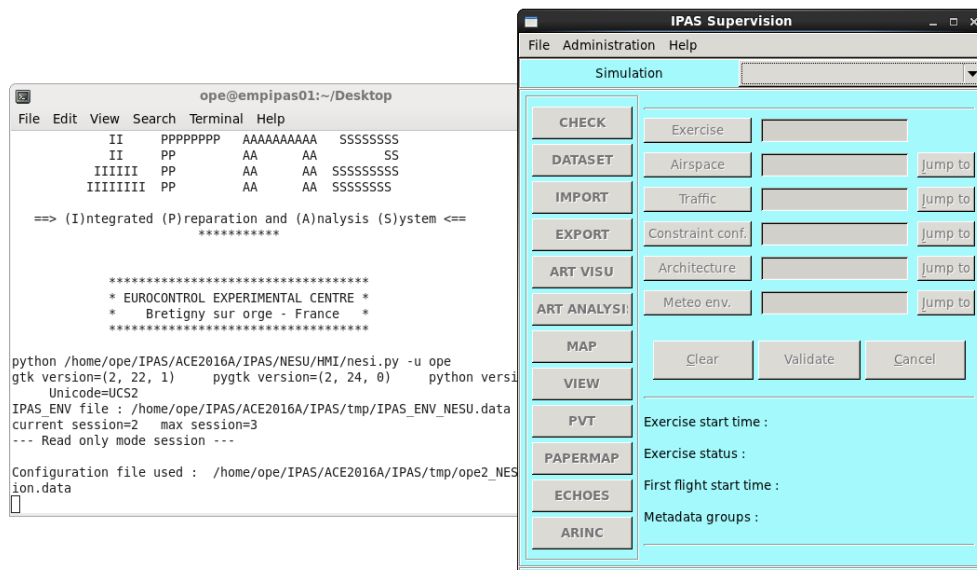

Figure 3 Read-only IPAS Supervision

In that case, an ipas_fic_user_nesu file shall be modified as seen in Figure 4. The highlighted letter "Y" shall be replaced by an "N" and the modification shall be saved. The file can be found in /home/ope/IPAS/ACE2016A/IPAS/tmp.

Figure 4 ipas_fic_user_nesu modification

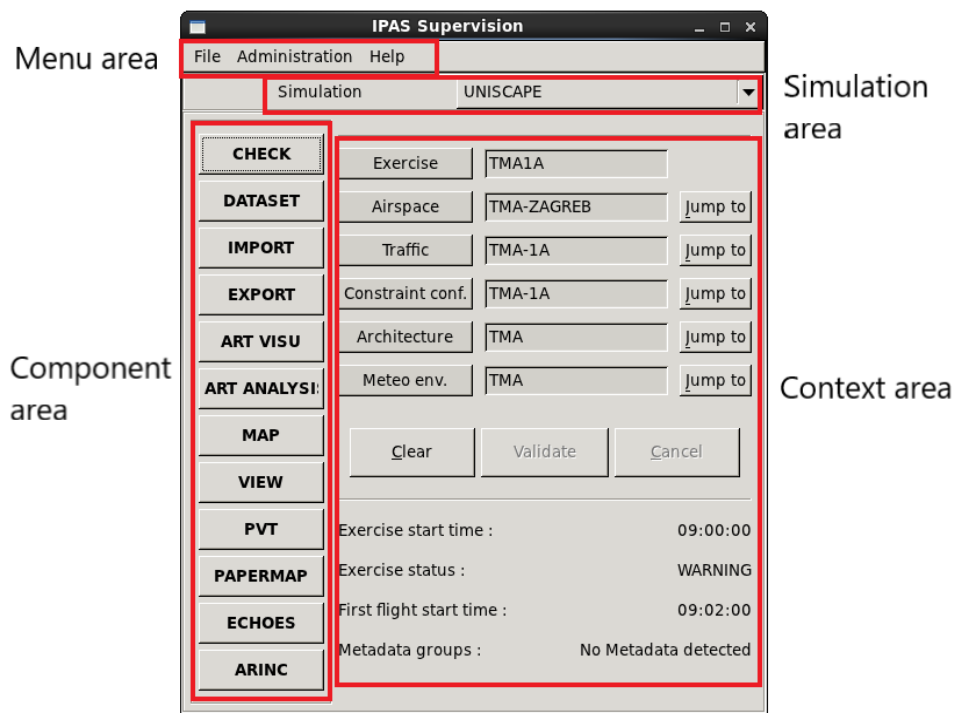## 3.1   The organization in domains

Figure 5 IPAS Supervision screen main menu

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The simulation area allows the user to select the simulation via the pulldown menu. In this case, only UNISCAPE is available. The list of available simulations is provided by the system file "ipas_fic_simul_versions".

The context area allows the user to modify the exercise. It defines the exercises and/or domains that can be worked on. The right-hand side holds "Jump to" buttons that correspond to Airspace, Traffic, Constraint configurations, Architecture and Meteo environment. Each of the tabs allows access to its parameters and a possibility to modify, duplicate, add or delete selected records, as well as refresh the list, help, and exit the screen. The commit and rollback buttons have the opposite purpose; the commit button saves all the changes made before exiting the screen, and rollback negates all the changes made if the user decides not to keep them

The component area holds a button for each component of IPAS that can be launched. The user launches them by clicking on the chosen button. Its colour turns from grey to green to indicate that it has been launched. Many components can be launched simultaneously, but there are some constraints. The main reason for that limitation is to avoid parallel modification of data. The example for that is running a check of the exercise while an import is in progress - it's impossible to generate check data while also modifying the data via import.

The menu area contains three drop menus: File, Administration and Help. The Help menu offers a User manual, a FAQ windows and About software. The Administration menu has two additional sub-menus, Maintenance and Check database integrity. There is an option within the Maintenance sub-menu to Save simulation (in dmp file) which is one of the ways to do a backup of the created exercises. The File menu proposes the following items:

- Open
    o Reference
    o Graphical data
    o Skip sector rules
    o Metadata files
    o Display status panel
    o Exercise status
    o All domains
- Parameters
    o Options
    o Windows configuration
- Quit

The reference window holds information such as Aircraft models used in the simulation, based on BADA data, as well as Real aircraft that use those models. Furthermore, there are World points that can be imported as Navigation points in the exercise. World airports are mostly used as Departure and Destination airports for the defined traffic.

The Graphical data window defines objects shown at the controller screen. It is used to create and modify maps. It's possible to upload certain points, volumes etc. into the graphical domain, as well as to create objects that are purely graphical and have no other purpose in the exercise.

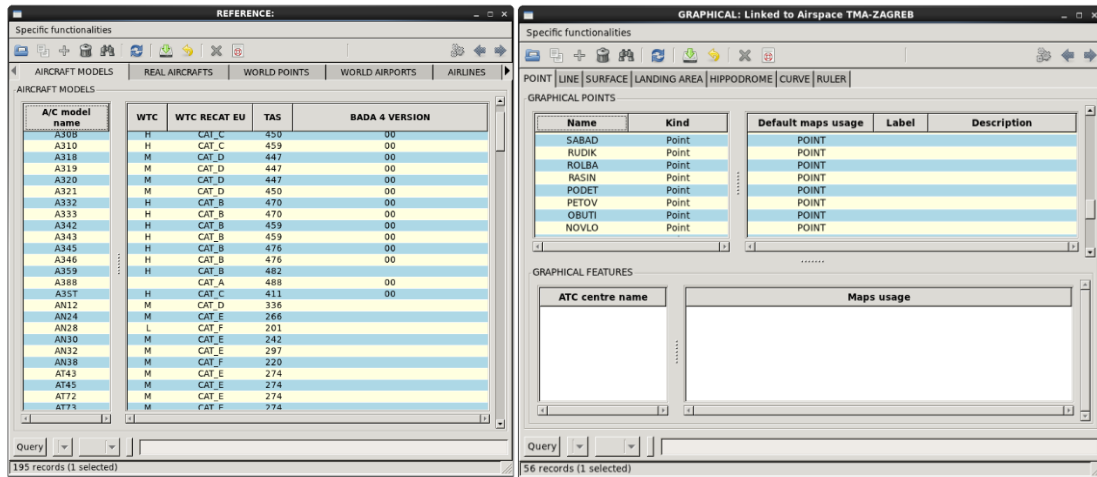Figure 6 shows the Reference window and the Graphical data, respectively.

Figure 6 Reference and graphical data

3.1.1 Airspace domain

Airspace is the main domain that links all others. It is possible to define multiple other domains within the same airspace (for example, there are 6 Traffic and 6 Constraints domains defined within ACC_A airspace) and they can each be used to create a different exercise using the same airspace. However, using a domain defined within one airspace (Airspace A) in a different airspace (Airspace B) is not possible unless a copy of the said domain has been made.

The elements of the Airspace domain are Airports, Geo points, Airways, Standard Instrument Departures (SID), Standard Instrument Arrivals (STAR), Holding stacks, Volumes, Volume conditions, ATC Centres, Sectors, Non controlled ar-eas, Projection centre point, Paths and Arrival Manager (AMAN) fix.

3.1.2 Traffic domain

The traffic domain contains two tabs: Flights and Datalink flights.

The flight tab shows all the flights defined in the exercise, along with their information such as flight path, start time, departure airport, destination airport, real a/c, a/c model etc. Aside from importing flights from a .csv file, they can be created manually using the navigators in the Flights tab.

Each flight can be modified using the modify button on the toolbar. The edit allows for a change in many parameters of the flight, as well as the path corresponding to that flight, as seen in Figure 7. The fields marked in orange are mandatory. Some of them have predefined automatic values that will be used in case they are left blank by the user
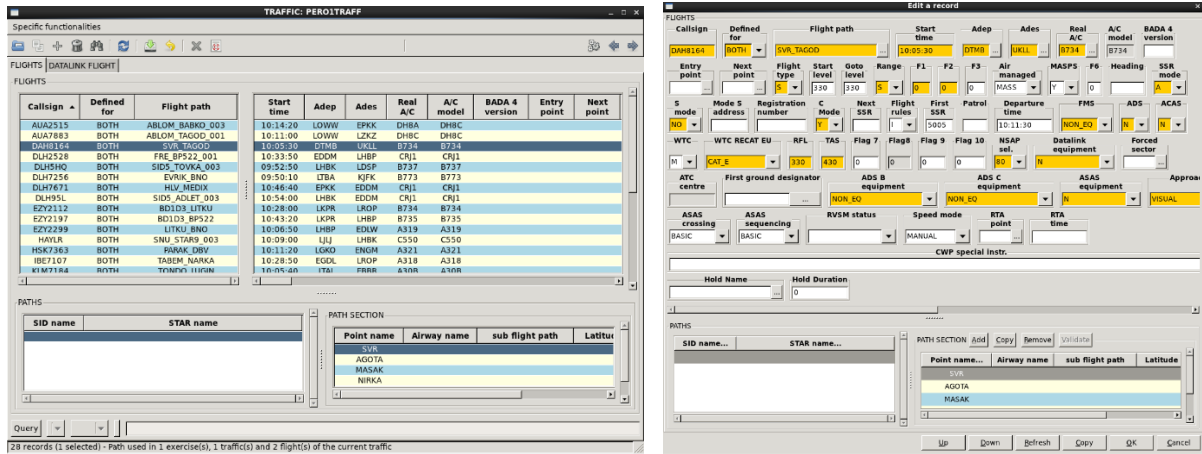
Figure 7 Traffic domain

3.1.3 Meteo domain

ESCAPE exercises support two kinds of meteorological scenarios. The meteorological conditions can be defined as either classical meteo or detailed meteo.

The classical meteorological scenario includes fixed weather conditions throughout the airspace and the duration of the exercise. Gradual change due to altitude increase is taken into account.

The detailed meteorological scenario uses multiple parameters in a 3D grid. For example, wind can be changed at a decided time in a decided volume of airspace. The weather changes can be scheduled to start at a certain time during the exercise and only include the desired volume of airspace, or span across the entire airspace, depending on the exercise requirements
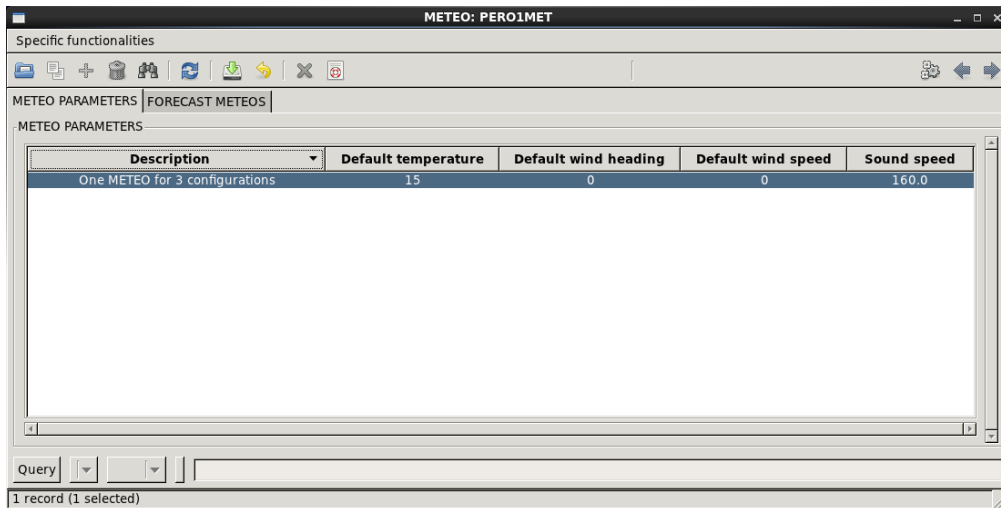

Figure 8 Meteo domain

3.1.4 Constraints domain

The constraints domain is where the vertical evolution for the computed trajectory is defined. In other words, constraints enable 3D trajectories of the flights. Two types of constraints can be defined – Requested Flight Level (RFL) and intermediate constraints. If there were no constraints defined, the flights would have flat trajectories.

The RFL constraints are typically linked to the last point of the flight's trajectory. The defined RFL constraint is the flight level the system is trying to reach. If an aircraft is instructed by the controller to climb to FL360, and its RFL constraint is at FL380, the controller will eventually get an indication that the flight is meant to continue climbing to reach its requested flight level. The reason they are linked to the very last point is that, if the flight's trajectory changes and it skips some of the points on the route, the constraint is still anchored to a point it is meant to reach. The second kind of constraints is typically used in approach, either in the STAR or SIDdesign or between en route and approach phase. They define flight levels or altitudes at certain points and are used to create a desired vertical profile of the flight.

3.1.5 Architecture domain

The architecture domain allows the user to define the working positions and certain tools for their exercise.

The first action the architecture tab is used for is to create an adequate number of controller and pilot working positions.

If the exercise requires only one executive controller and one pseudo-pilot, only one of each are defined. For each executive controller position, there shall be at least one pseudo-pilot defined. More can be planned if the exercise has too much traffic for just one pilot to manage. It's important to note that each controller and each pilot require a physical working space.

It is possible to create hybrid positions as well. They are usually used in feeder sector which is a sector where flights normally start and end. The hybrid positions' function is automatic, but the flights can also be manually managed at hybrid positions. Every change in the flight label at the hybrid position in a feeder sector will have the same result as issuing a clearance and then executing it at a pilot working position. A hybrid position's function is, therefore, a combination of the controller and pilot working positions.

Controller number can be chosen arbitrarily but must remain consistent throughout the exercise. The usual method is to start the number of executive controller positions with the digit "1". The planner position will be designated by a figure starting with "2". This exercise has no example of planner controllers. Finally, the hybrid position will start with the number "3". That way, in Figure 9 we can see only one executive position marked by number 1, and three hybrid positions, marked by "31", "32" and "33", respectively.

The example in Figure 9 is taken from an Upper airspace exercise where one executive controller is defined for Upper North sector in FIR Zagreb, and three hybrid controllers are be assigned to three feeder sectors surrounding Upper North. In that same exercise, only one pilot position is defined.

Figure 9 Controllers tab

Short Term Conflict Alert (STCA) is available within ESCAPE Light implementation. It's defined in the STCA tab in Architecture domain.

A software centre is also created in the architecture domain. It includes all the ATC centres that are planned to be used in the exercise. If the exercise uses one executive sector and several feeder sectors, it is recommended to define two separate ATC centres. The software centre should be designated by a number "1" as seen in Figure 10.
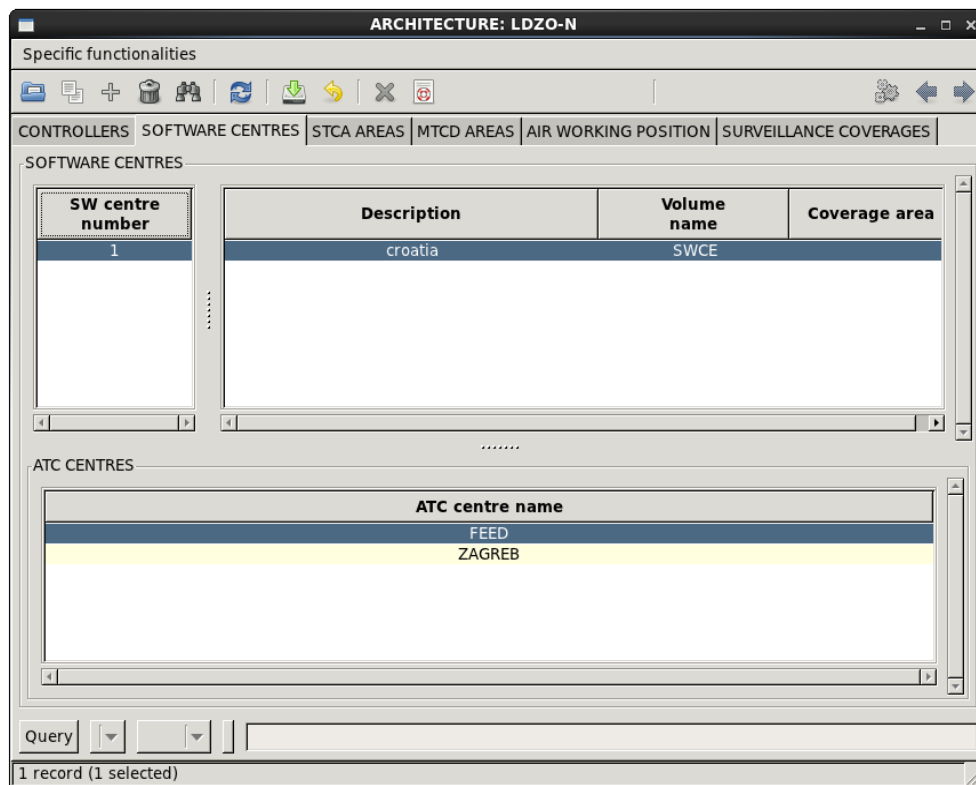
Figure 10 Software centre

3.2   Dataset

The Dataset contains all the exercises created and the domains that make up each of the exercises. The first step to creating a new exercise in IPAS is to define its domains and create the exercise itself in Dataset.

A new exercise can be created by either by copying the existing exercise or domains, or creating new domains in the Domains tab and using them to assemble a new exercise.

When creating new domains, the desired domain type should first be selected (Airspace, Traffic sample, Constraint conf., Architecture, Meteo env.), and then, when the domain type is highlighted in orange colour, it's possible to create a new domain using the Edit menu. Creating a new exercise, however, is not possible as long as an existing exercise is highlighted in orange colour. That option only allows to duplicate, modify or clear the selected exercise.
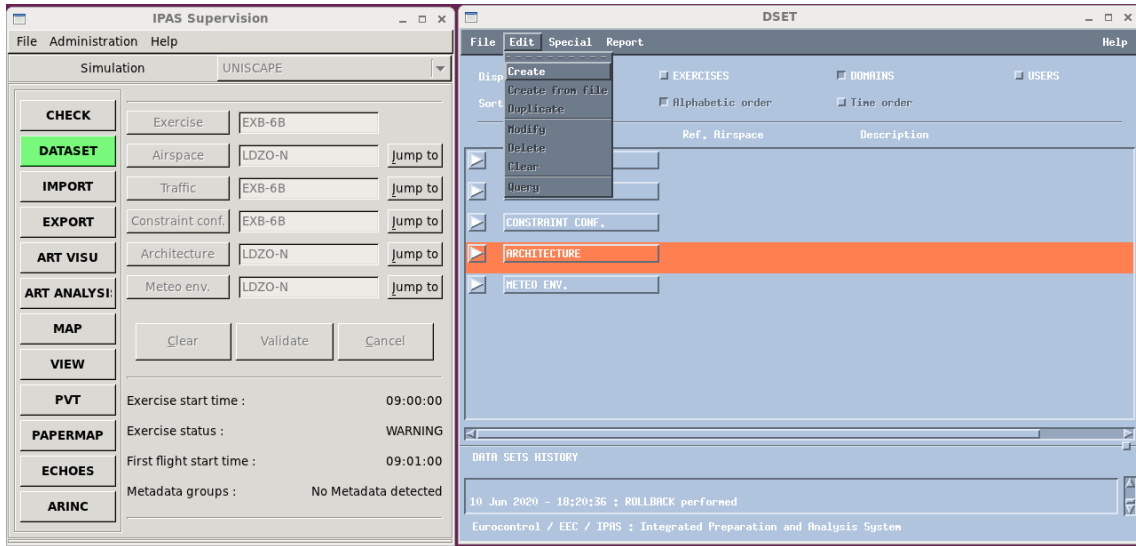
Figure 11 Creating domains

To create a new exercise, it's necessary to first deselect any chosen exercise on the list then choose Edit >Create. A window opens up that allows you to create a new exercise using the existing domains.

In case an exercise remains highlighted, the Edit drop menu will not offer an option to create a new exercise, but just to complete a certain action on the selected one. See Figure 12 for an example.
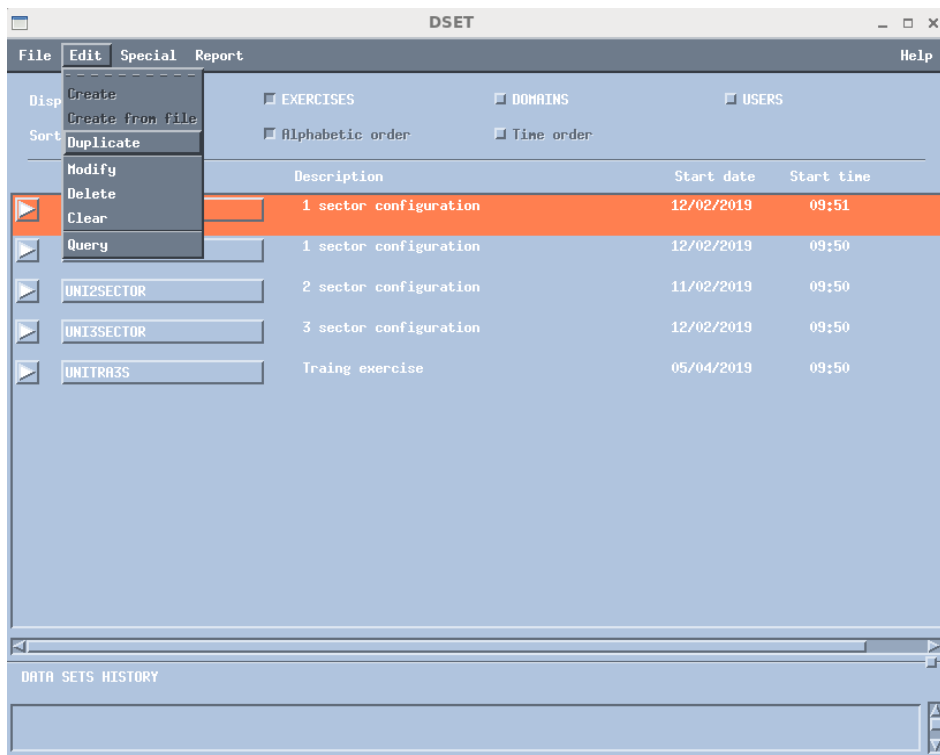

Figure 12 Edit option

3.3 IMPORT

In the process of data preparation, the data can be manually written into corresponding domains or massively imported in .csv format.

When importing the data using IPAS data preparation tool, a correct order should be respected. If one were to import sectors without importing the volumes first, the system would respond with an error message since volumes act as building blocks for sectors. In the same matter, it makes the most sense to start the import with points (outline, navigation) followed by volumes and sectors.

Each exercise needs to have at least one SID, STAR and hold procedure defined. Those can be imported at any time as long as the points that they rely on have already been imported. If there is a small number of those components needed in the exercise, it's also easy to create them manually using the Airspace domain.

When importing flights, it's important to know that they rely on paths, so paths need to be imported first. There is also an option to import flights and paths from the same file.

When importing flights, the "Create traffic sample" box is automatically checked and needs to be deselected in case the domain has already been created, as done in Figure 13. Finally, constraints need to be imported (there is also an error message if there are no constraints defined in the exercise).

Figure 13 Importing flights

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3.4   Volumes

Volumes are a way to define distinct areas inside the airspace. They can be used to construct sectors, non-controlled areas, specific meteorological occurrence areas etc.

Before a volume is given a specific function, its dimensions have to be defined in IPAS. The best way to define volumes is by using outline points. Unlike navigation points, outline points won't be displayed at the controller and pilot working position screens. They are defined in the Airspace domain, Geo points tab as type OUTL and Navaid type UNKNOWN POINT. The third dimension of the volume is defined by adding vertical limits in terms of flight levels. Creating Outline points and a list of volumes can be seen in Figure 14 below.
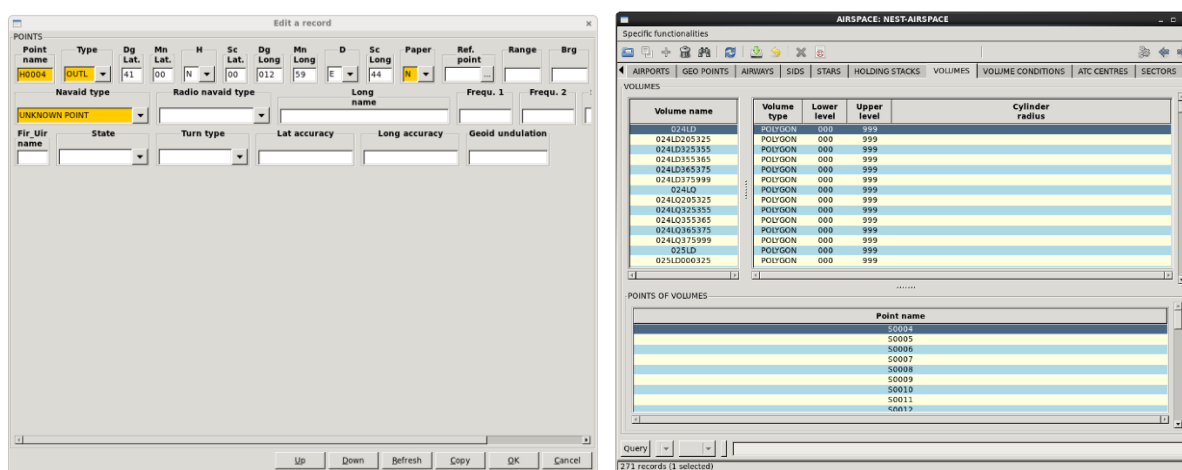

Figure 14 Volumes definition

The resulting volumes can be seen and checked in Art Visu. It is important to make sure that the volumes next to each other don't have any holes or overlaps between them. That is, they both must contain all the points that create their borderline. The hole or overlap will not be visible in the checking process at the volume level but will come up when those volumes get included in the sectors' definition.

Figure 15 is a visual representation of generic airspace that mostly corresponds to the existing borders of FIR Zagreb and the part of FIR Sarajevo within which Croatia Control Ltd provides area and terminal control based on mutual Letters of agreement.
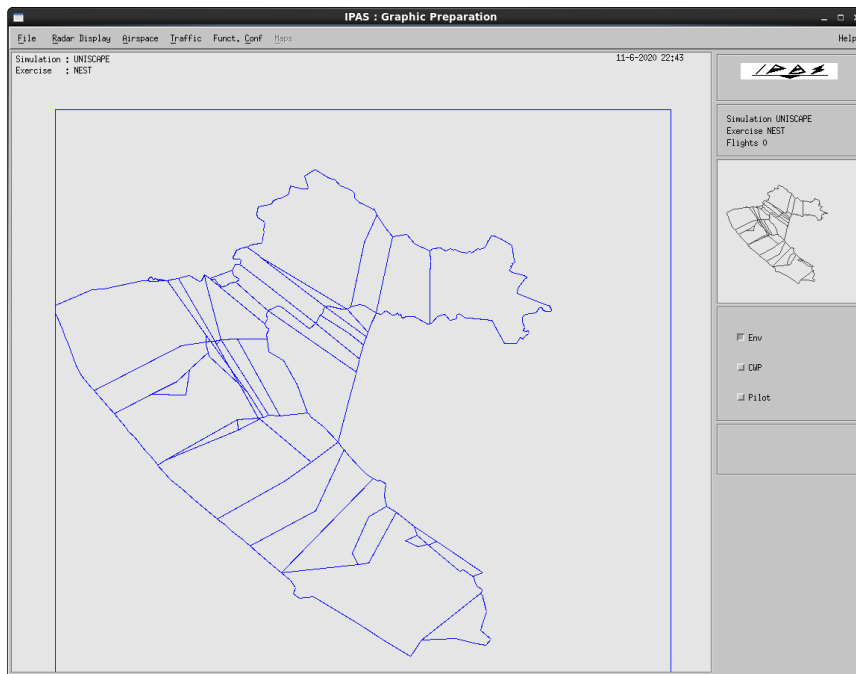
Figure 15 Volumes in Arti visu

3.5   Sectors

Sectors can be built manually or be imported. Importing them has the advantage of filling a large quantity or airspace data quickly. However, the user can not draw a mental image of the airspace they're building which more easily leads to possible airspace errors. Building them manually, the user has complete step-by-step supervision of the parameters that define their sector.

Figure 16 shows the ADRIA sector from the upper area exercises. It is a feeder sector with a hybrid controller, so its ATC centre is the one created for feeder sectors in the earlier steps while defining architecture. It is en-route control, of a civil class and the flight region is both the IFR and UIR. The user manually chooses the frequency used for that sector. The allocated controller is number 31, which means it is the first of the hybrid controllers defined for this exercise. The unit name must be the same as the sector name. Air working position field is left blank, since the controller is a hybrid unit, meaning it is both the controller and a pseudo-pilot. In the case of an executive controller, a pilot would also have to be defined.

A sector can be built from just one volume or multiple volumes. Once the sector is defined, a check is performed in Art Visu to make sure there are no holes or overlaps detected.
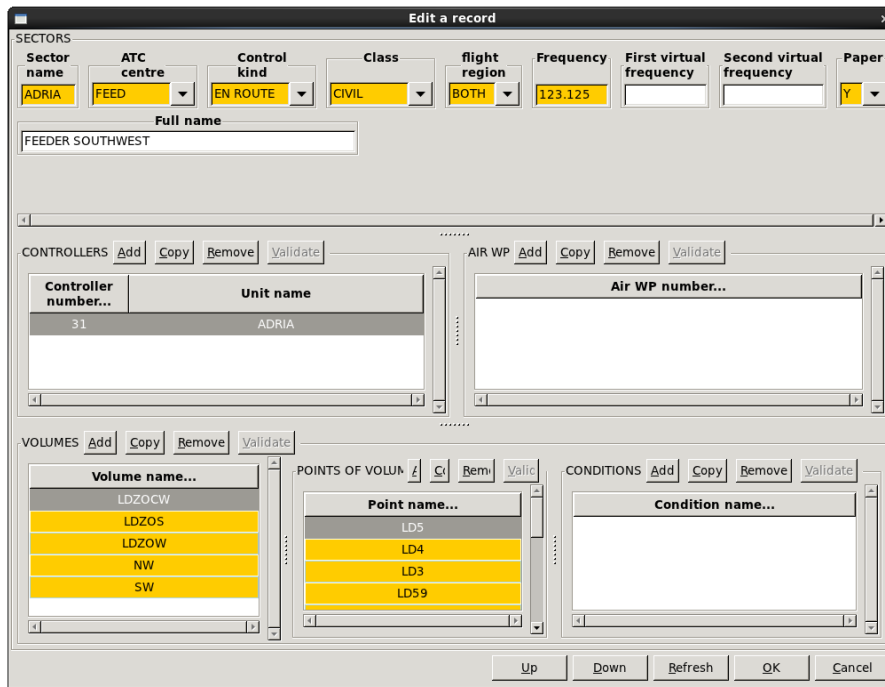
Figure 16 Parameters of the sector definition

3.6 Holes and overlaps

Holes and overlaps are a common problem in the process of defining the airspace and its sectors. Some issues the author has faced are explained below.

One of the problems that can occur is when not enough sectors are defined within the airspace. In other words, there is a big gap between the defined sectors and the limits of the airspace.

It can be seen in Figure 17 below that the points P1-P4 define a square shape which corresponds to the total airspace in the exercise. However, not the entire P1-P4 square is covered in sectors, resulting in non-common segments. The straight lines connecting the outer (P) points must be the outer limits of the defined sectors. In this example, the point of interest of the exercise is the LDZON sector in the middle of the airspace corresponding to the north-east part of Croatia. The limits of that sector don't come close to the airspace limits. Therefore, other sectors must be created to ensure a completely defined airspace and to serve as feeders for the traffic.

The presented problem is solved by defining another airspace whose west, north and south borders coincide with the airspace borders (the P1-P4 square), and the east borders share the same points as the limits of the already defined sectors. The goal is to have each part of the airspace covered, much like a puzzle game.

Another way to check the exercise for holes and overlaps is offered in the Airspace domain itself. After validating the changes, an option is available in the "Specific functionalities" drop menu for "Holes/overlaps detection". A pop-up window will offer to search for either holes or overlaps and then give the option to display different volumes included in building the sectors. The result of the check will be a 3-dimensional view of the selected volumes and the discovered hole.

Figure 17 Art Visu History window

In Figure 18, the hole is marked in green and is located between volumes LDZOW and LDZOCW. It is also visible that the hole spans through the entire vertical dimension of the airspace, from 000 to 999.

There are three points, LD3, LD4 and LD5, that are included in the definition of volume LDZOW, and are not a part of LDZOCW. This leads to a discrepancy and is displayed as a hole. To rectify the mistake, those three points must be added to volume LDZOCW in the appropriate place, so that those two adjacent volumes would share all the points that make up their border.

Figure 18 Border points discrepancy

Another example of a hole in the airspace is when a sector is planned to have two or more volumes stacked on top of each other. They could share the same points, so have the same shape in the 2-dimensional view, or have partially different shapes or different shapes altogether. If one of the volumes

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is omitted in the definition of such a sector that should have a division according to the flight levels, a "vertical" hole will appear.

In the first case, when the concerned volumes have the same shape and only take up different sections of the vertical axis, the hole that appears when one volume is not defined in the sector is purely vertical. That being said, it will be easy to correct. The volume containing the missing flight levels simply needs to be included in the sector definition. In Figure 19, the hole is between the flight levels 000 and 325. The log also states which points build the missing volume.

A case could be imagined where the missing volume doesn't have the same shape as the ones under and/or above it. In that case, both correction of the points and the flight levels will be required.
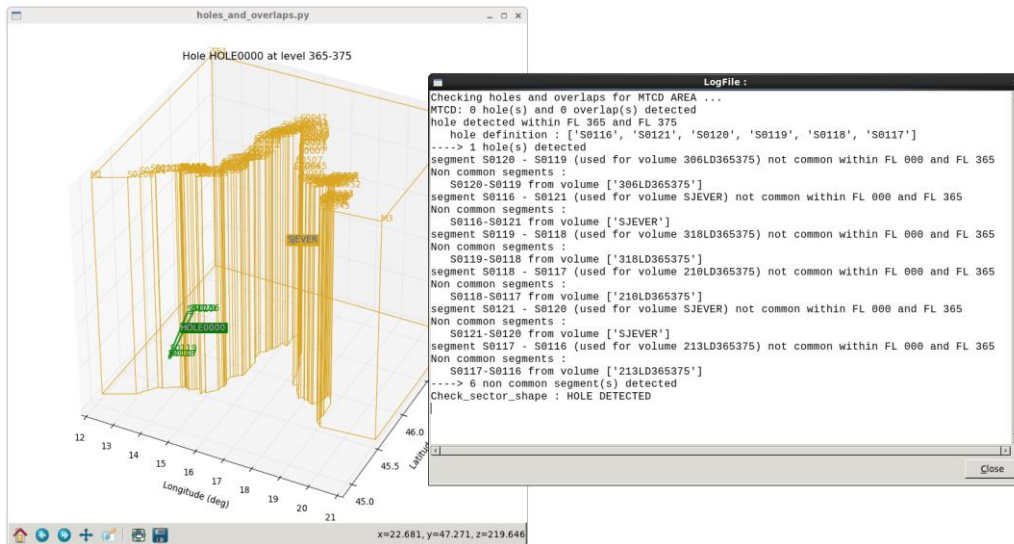
Figure 19 Vertical hole

3.7   Data generation

3.7.1 Check

After validating the modifications made in any of the domains, a check can be performed to make sure no warnings or errors that need to be corrected. The check function will also indicate if there are components of the exercise missing before delivering it.

It is possible to check just the current exercise, or another exercise or multiple exercises that have been created in IPAS.

If there are no errors detected in the exercise, that still does not mean that there are 100% no errors in the exercise, just that the Check tool hasn't been able to detect any. It's still important to manually check the parameters of any changes in the exercise. In case errors have been found, they should be corrected before delivering the exercise to avoid problems during the run.

However, a check will also be able to detect warnings. Warnings are minor mistakes that don't jeopardize the run of the exercise. A user can decide if the warning should be acted on or not, and deliver the exercise regardless.

3.7.2 Delivery

The Delivery function is a data generation process. It is carried out after a positive result from the check process. Exercise delivery is a prerequisite for instaling it on the runtime and eventually executing it. It's a way to transfer the prepared data to the executive part of ESCAPE.

Just as with the Check function, Delivery can also be performed for just one, or for multiple exercises at the same time (See Figure 20).
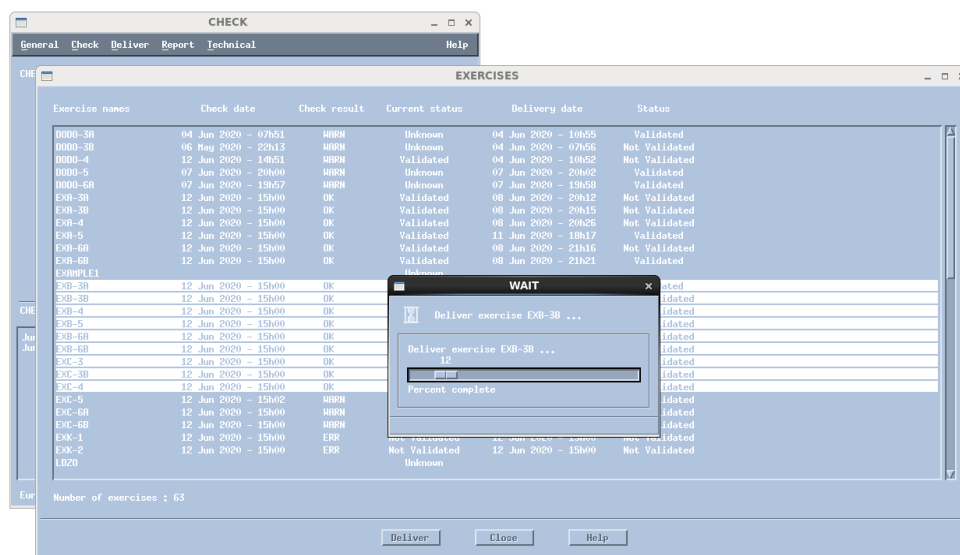

Figure 20 Multiple exercises delivery

3.7.3 Profile Validation Tool (PVT)

PVT is a tool in IPAS that allows the user to visualize traffic samples to validate their flight profiles. It can only be started after exercise delivery process. The flight profiles are computed by the system based on the flight plans defined in IPAS.

In the Interactive analysis tool, a call sign corresponding to the flight to be analysed can be selected. The chosen aircraft's trajectory is then displayed. The points and the calculated time to reach them are shown on the right-hand side. Clicking on a specific point or time shows further detail about the flight's trajectory in the window under the list. The sector sequence is also visible in the screen, as well as the time of sector entry and exit and the applicable vertical constraints.

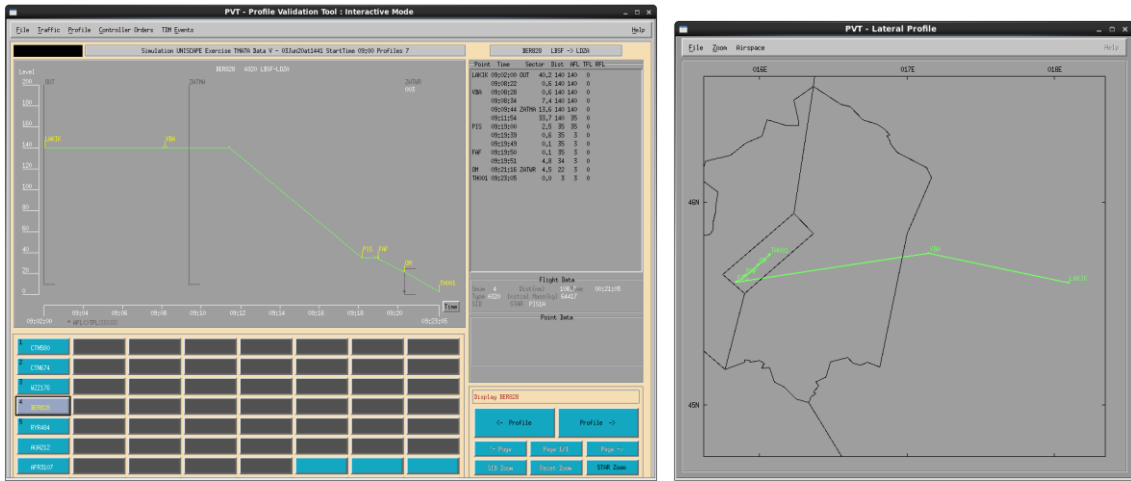As seen in Figure 21, the lateral profile of each flight can also be displayed.

Figure 21 Interactive analysis tool

Multiple other operations can be executed with PVT. Batch (Ground only) is another process of data preparation. More specifically, it generates IPAS data files. This action should be finished before installing the exercise on runtime. In the same manner, the Generate Air data also delivers data used in executing the exercise on runtime. Both of the mentioned operations also serve as an additional check of the exercise to make sure no operational errors have gone unnoticed.

3.8   Backup

There are a couple of ways to make a backup of the exercise or the whole simulation. The EXPORT option exports wanted parameters of the exercise, which is exactly the opposite of the IMPORT option. The exported files can be saved and used later. The exported files are saved in /home/ope/IPAS_data/rep_import/SIM_NAME - the same folder where files are imported from.

Another option for backing up the prepared data is generating a dmp file. It can be generated by opening the Administration drop menu at the IPAS Supervision windows before selecting a simulation.

The dmp file is saved in /home/ope/SAVED_SIMUL/SIM_NAME.
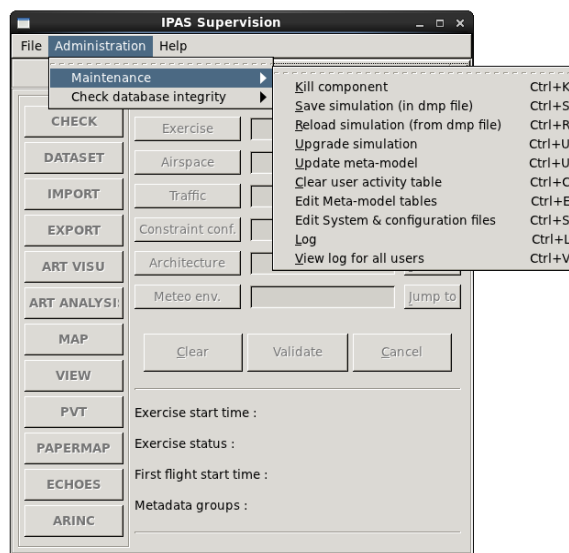

Figure 22 Saving simulations in dmp file

4   Development of simulation exercises

There are three types of air traffic controller training leading towards the issue and maintenance of an air traffic control licence and associated unit endorsements. Initial Training is the first type, followed by Unit Training and lastly Continuation Training. The objective of initial training is to prepare a candidate for training at an ATC unit. Initial training leads to the issue of a student air traffic controller licence or the issue of an additional rating and, if applicable, rating endorsement. It includes Basic and Rating Training. Basic Training is theoretical and practical training designed to impart fundamental knowledge and practical skills related to basic operational procedures[13].

The model information for this project is the exercises used for Basic ATCO training held by the Croatian Air Traffic Control Training Centre (HUSK) at the Faculty of Traffic and Transport Sciences as a part of its integrated Air Traffic Control study program. All exercises are defined and explained in the HUSK BEST Radar Simulator Training Manual [14].

4.1   Input data

The data provided by the Faculty consists of five directories:

- ACC_K: upper airspace K
- ACC_A: upper airspace A
- ACC_B: upper airspace B
- ACC_C: upper airspace C
- APP_LDZA: approach airspace

Upper airspace K is generic airspace with a simple shape and only a few points. Two exercises are intended to be completed in airspace K. There is a small number of flights per exercise with very simple planned trajectories. The objective of those two exercises is to familiarize the students with the simulator and Controller Input Orders, as well as for them to become comfortable issuing clearances and using correct phraseology while vectoring aircraft.

Upper airspace A, B, and C correspond to a modified sector North within Zagreb FIR. Those exercises are a part of the Area control simulator.

The approach exercises simulate the modified Zagreb TMA and are used for training on the Approach control simulator.

Each directory contains a list of files describing:

- The performance of the aircraft (.csv format)
- The airspace itself (.xml format)
- The traffic (.xml) [12]

The performance file contains a list of possible aircraft types and their wake turbulence categories, range of operation (engines, ceilings, maximum Mach number etc. and performances such as Rate of Climb (ROC), Rate of Descent (ROD), flight envelope etc. ESCAPE relies on BADA data for information on aircraft performance. The performance file provided by the Faculty is therefore not used in ESCAPE Light exercises.

The airspace definition files contain several parameters, such as airspace name, centre and technical and safety parameters. The proposed centre position is used as a projection centre in ESCAPE. There is also a list of fixes which correspond to NAV points in ESCAPE.

There is no information related to the sector shape. Only one sector, UPPERNORTH, is described in the provided data. Its name is changed to LDZO-N in ESCAPE since there is a limited number of characters in a sector name definition.

There is additional information provided for approach airspace:

- Airports definitions
  o Airport name, altitude, position and technical and safety parameters.
  o Landing and take-off procedures are only defined for LDZA in ESCAPE exercises, while other airports serve only as Departing/Destination aerodrome and are created as navigation points if used in trajectories
- Runway definitions
  o Magnetic Heading of a Runway (QFU), altitude and position
  o the provided position definition is used as a runway threshold in ESCAPE,
- Approaches definitions
  o QFU, glide angle, approach equipment, outer marker position
  o the provided data define approaches for Runway (RWY) 05 and RWY 23, which are not used at LDZA anymore
  o the airport, runway, SID and STAR are thus created manually in ESCAPE exercises
- Airways definitions
  o name, type, turn kind, width, allowed range of levels, direction and list of points
  o not used in the input data, thus not defined in ESCAPE Light

The traffic files contain lists of flight plans composed of the following:

- RFL
- Departure airport (ADEP)
- Destination airport (ADES)
- Aircraft type
- Search Results
- Featured snippet from the web
- Secondary surveillance radar (SSR) code and equipment
- Callsign
- Start position
  o A navigation point which can, but doesn't have to be a part of the path
  o A departing airport name
  o A range and bearing from a given point
- Start frequency
- Start time
- Start level
- Flightpath
- Network equipment[15]

The transformation of the input data to a format readable by ESCAPE is explained in detail in the Technical Annex written during the traineeship [12].

4.2   Input data vs ESCAPE Light discrepancies

4.2.1 Missing ADES/ADEP

In case a Destination or Departure airport isn't defined correctly in the file that is being imported, that specific flight will not be imported with the rest. The Import process will generate an error message in the end, indicating that the whole file hasn't been imported (See Figure 23).
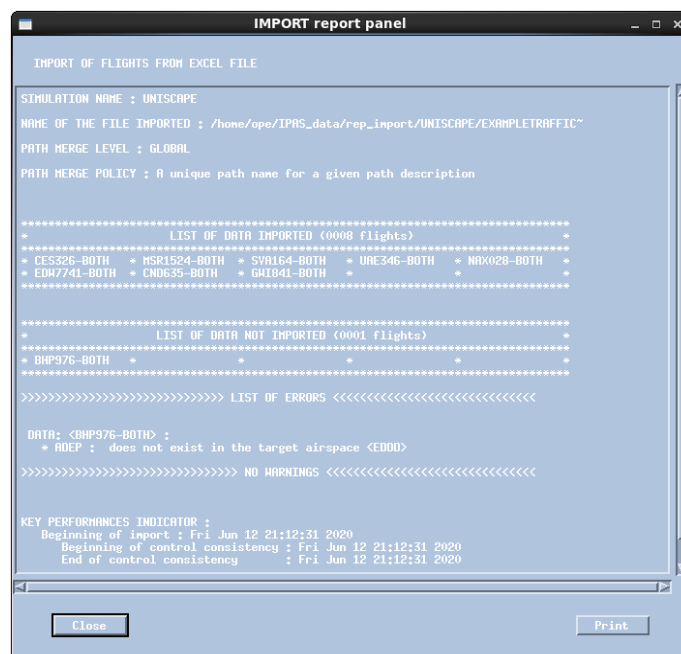

Figure 23 ADEP missing

This situations normally might indicate that the airport doesn't exist in the World airports database in the Reference menu, in which case it should be defined. On the other hand, the ICAO airport code may have been written in the wrong way, and the file refers to a non-existent airport.

In the case of a non-existent airport, the csv file that contains the flights' data should be modified. An easy way to do that is to find the folder where all the data is being imported from (/ope/IPAS_data/rep_import/SIM_NAME) and modify the traffic file by correcting the airport ICAO code, as shown in Figure 24.

In the example, EDDD code which is non-existing and has caused the error is being replaced by EDDM.

The exercises that had a problem with either the destination or a departure airport are exercise 6B in Airspace_B, exercise 6A in Airspace_A and exercise 4 in Airspace_C. The airport codes used in those exercises were LWSH, EGGL, HIGN and LTRT. Since those codes don't match either airport in the ICAO database, the conclusion was that there was possibly a typing error in those airport codes. To solve the problem, the codes were replaced by the most similar code that matches an actual airport.
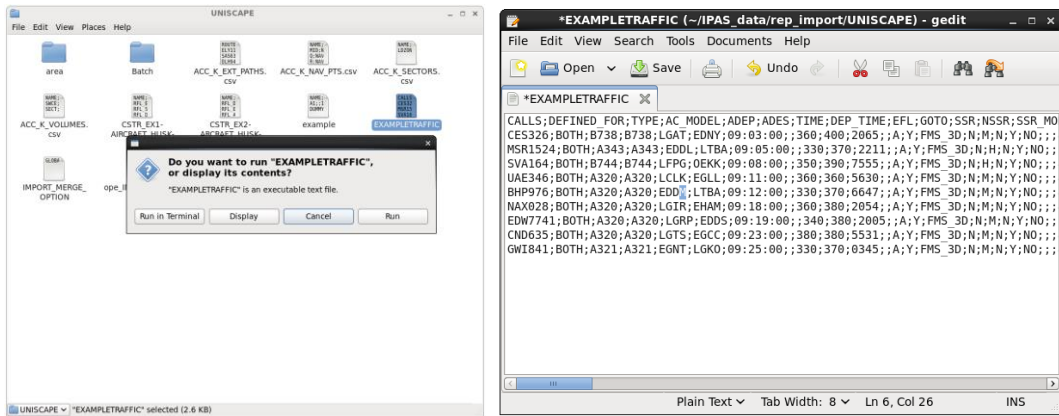
Figure 24 Missing airports issue

4.2.2 Points outside SWCE area

SWCE area is the total defined airspace in the exercise. If a point is defined outside the limits set by the four SWCE points, the check procedure will indicate an error, like in Figure 25. If certain navigation or outline points are being imported in a blank airspace domain, this situation will occur if the SWCE coordinates aren't modified to include all the points.
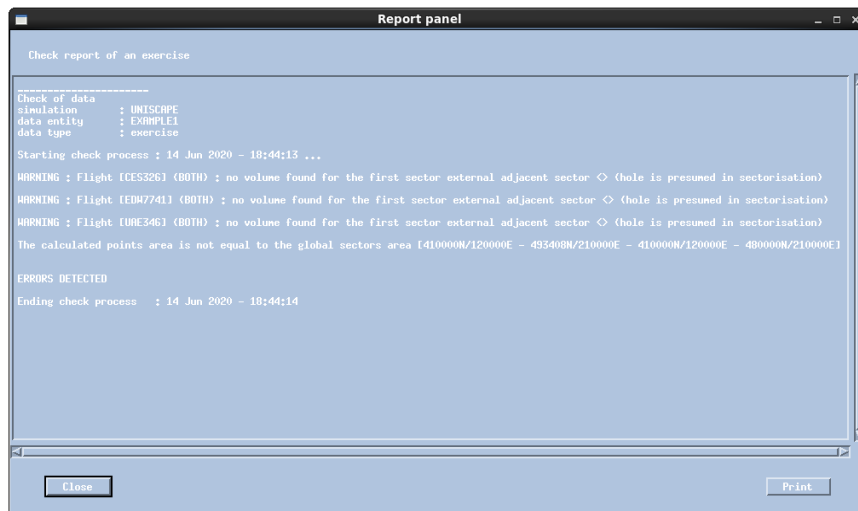

Figure 25 Check results in case of points outside SWCE area

The same result can be seen in Art Visu when all the points are displayed – one or more will be drawn outside the airspace limits (See Figure 26).

In case the point in question is a part of one or more flight paths, the Check procedure shall indicate further warnings.

In all cases of errors generated due to one or more points being defined outside the established volume, the solution is to either increase the airspace definition to include the point(s) in question or to alter the point(s) coordinates if possible.
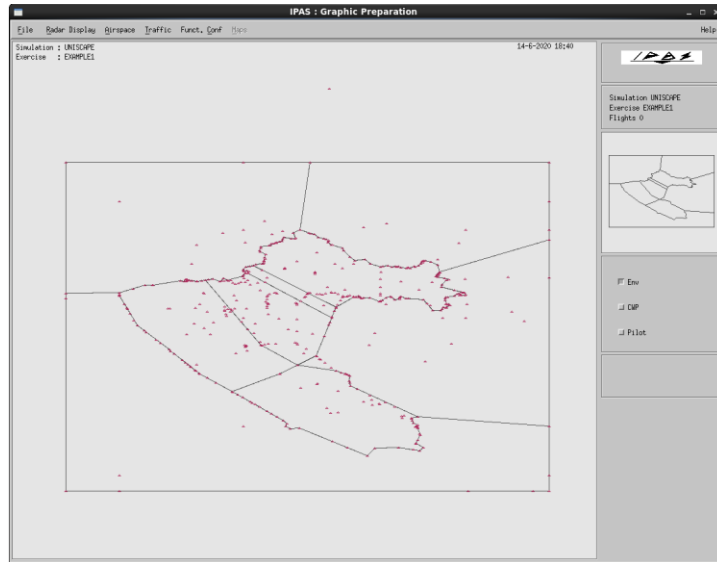
Figure 26 Points outside SWCE area in Art Visu view

4.2.3 Sector reentry

This problem was found in all the Upper airspace exercises that used the trajectories that either started at D9 point which was followed by GUBOK or SIVLA or ended at D9 after passing GUBOK or SIVLA. The specific shape of the Croatian borders conditions the reentry problem when a direct route is attempted. Figure 27 pictures the lateral and vertical flight profile, respectively. It can be seen that the MGX354 flight leaves the LDZON sector at GUBOK point, only to briefly re-enter shortly after.
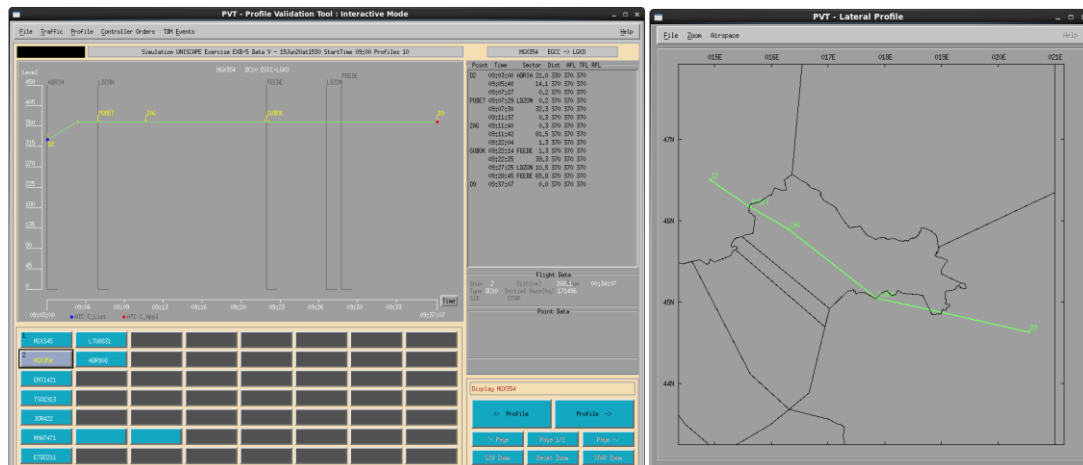
Figure 27 Re-entry in LDZON sector

The solution that was chosen for this problem was to create another point which such flights would be redirected to avoid re-entry problem. In a real-life situation, a flight plan that has a re-entry situation would likely not be accepted, so that is also avoided in this simulation. The created point is named D13. It is created south of the Croatian airspace segment where re-entry happens. The trajectories are then modified to include D13, thus physically avoiding re-entering the Croatian airspace.
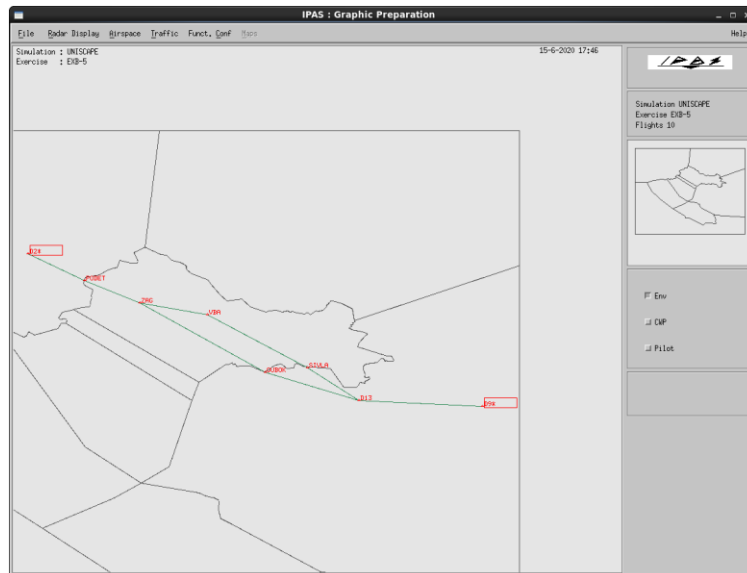
Figure 28 Trajectory modification

There is another option within the ESCAPE system to skip sectors. It doesn't alter the flight's trajectory but just includes a rule that, under given conditions, a certain flight will skip a sector where re-entry normally occurs. This option is available in File >Open >Skip Sector Rules. The user can define the sector that should be skipped, the sector before and after it and various additional conditions for the rule. The skip sector option can be seen in Figure 29.
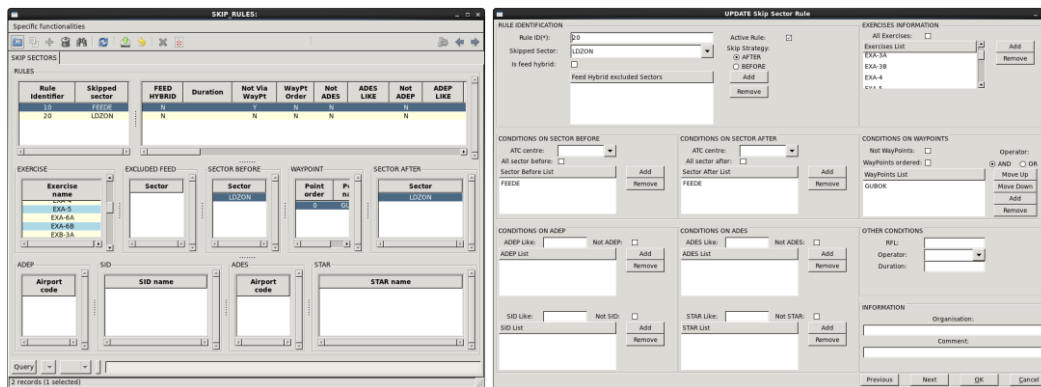

Figure 29 Skip sector rules option

When the rule is applied, the lateral flight profile is unchanged - the plane still follows its original trajectory. The only difference is that now, once it exits the LDZON sector at GUBOK point, it doesn't return to it again. It falls under the jurisdiction of the FEEDE sector. This would manifest on the runtime as the aircraft contacting the neighbouring (FEEDE) sector's frequency and becoming a non-concerned flight, even if it does fly over a part of the Croatian airspace again. Since it doesn't represent a realistic situation, in this case, this solution wasn't applied during the data preparation for this traineeship but could be a useful option in other cases. Figure 30 shows how the LDZON sector re-entry problem would be solved by introducing skip sector rules.
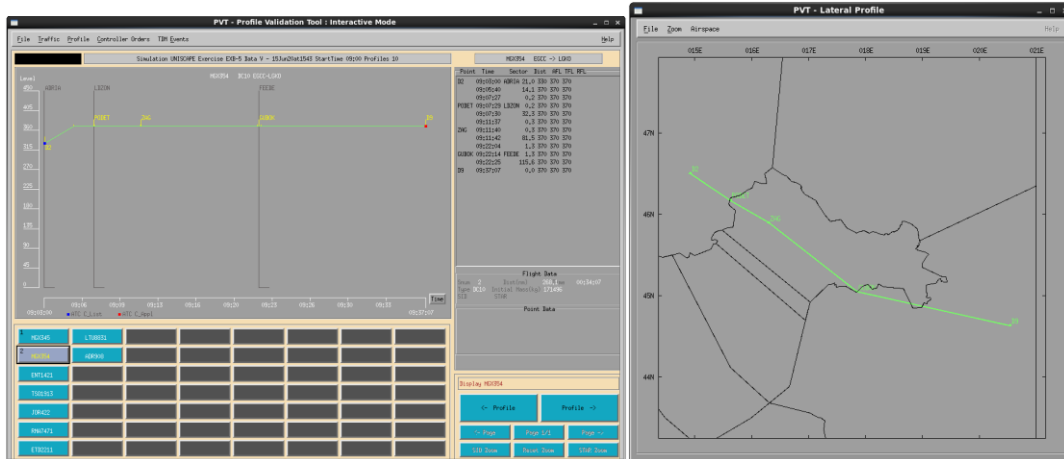
Figure 30 Skip sector rules option

The list of trajectories that have been altered by adding point D13 can be found in Annex 1 at the end of the document.

4.2.4 BADA4 missing/aircraft code not found in BADA

Upper airspace A, exercise 4 came with two of the flights using the aircraft type Airbus A380. The callsigns of those flights were PRI459 and THY1542.

Airbus A380 does exist in BADA, but under a different synonym. The exact type for which BADA defines performance parameters is Airbus A380-841, hence the synonym A388. The list on the left-hand side in Figure 31 is the original synonym list for BADA version 3.13. The error was caused by the fact that the aircraft type for the two mentioned flights was defined as A380, not A388. The way to fix the error is to add a line which defines flight parameters under the synonym A380. For this simulation, it has been decided that the performance data for the wanted aircraft type, A380, shall be the same as the one described in the existing database under A388. A copy of the Synonym file has been made not to make a permanent change in the original file. After that, the line containing A388 definition has been copied and the synonym has been changed to A380.
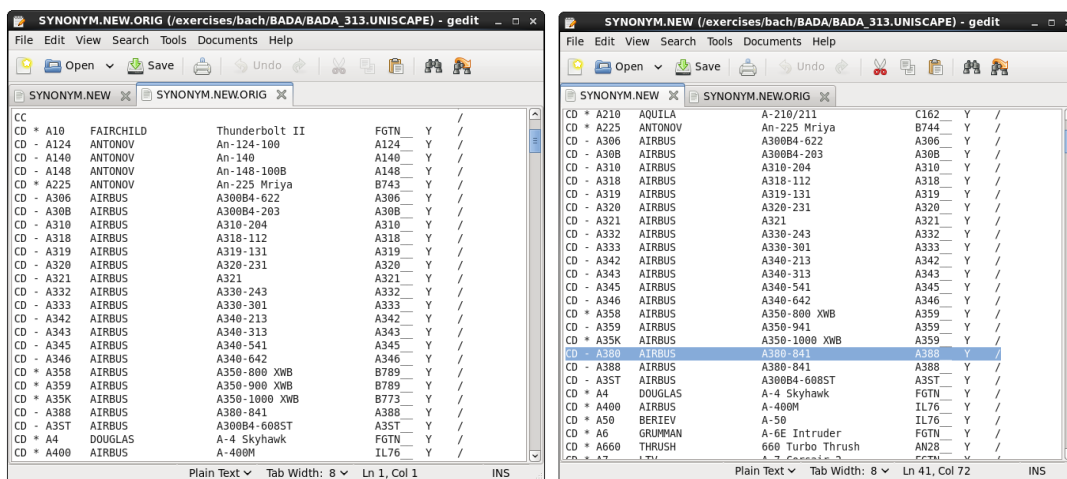

Figure 31 BADA synonym file modification

For the change to be applied in the exercises, it is necessary to import the new synonym file. There is an option within the IMPORT tool to import BADA data. Afterwards, the flights with the aircraft type Airbus A380 can normally be imported and used in the simulations.
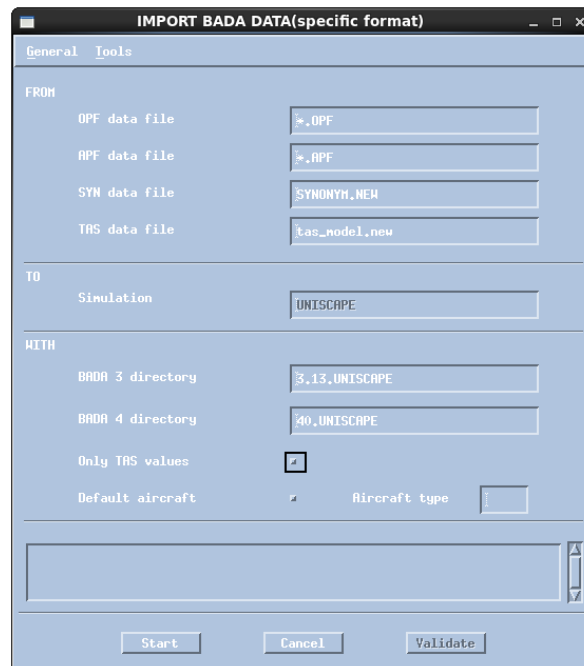

Figure 32 Importing BADA data

4.2.5 Flight profile (starting FL greater than RFL)

This kind of flight plan doesn't cause any problems in the run of the exercise. It doesn't even show in the Check procedure. It can only be read in the flight plan or seen in the PVT at the vertical trajectory analysis, as shown in Figure 33. The reason it's mentioned in the report is just that it's an odd occurrence since aircraft usually climb until reaching their cruise level, they don't descend to it.

RFL and Exit Flight Level (XFL) may have different definitions in the BEST simulator and ESCAPE Light, which could be what caused this uncommon situation.
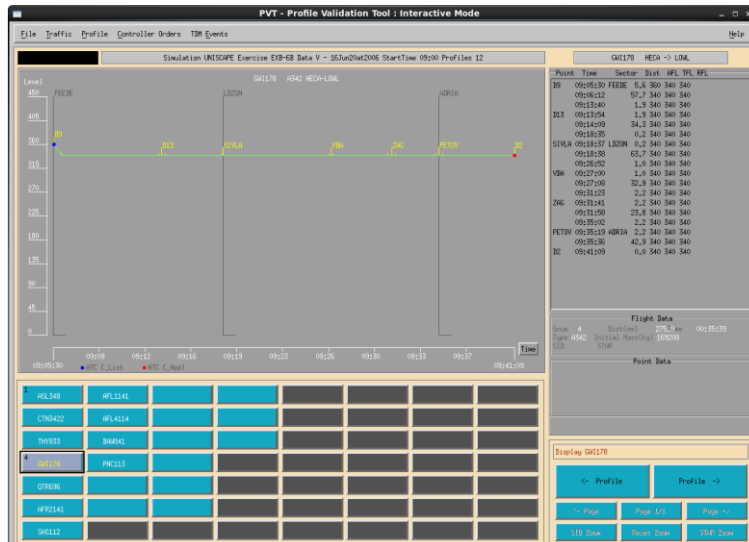
Figure 33 A flight with the starting FL greater than the RFL

The starting flight level value was changed to one at or below the requested flight level for each flight where it occurred. The list of modified flights sorted per exercise can be found in Annex 2 at the end of the document.

4.2.6 Repetitive SSR code

A case of the repetitive SSR code was spotted in the input data in Airspace_A, exercise 6B in flights AUA844 and VLG841. The SSR code in AUA844 has been manually changed to a unique value. For example, see Figure 34 below.
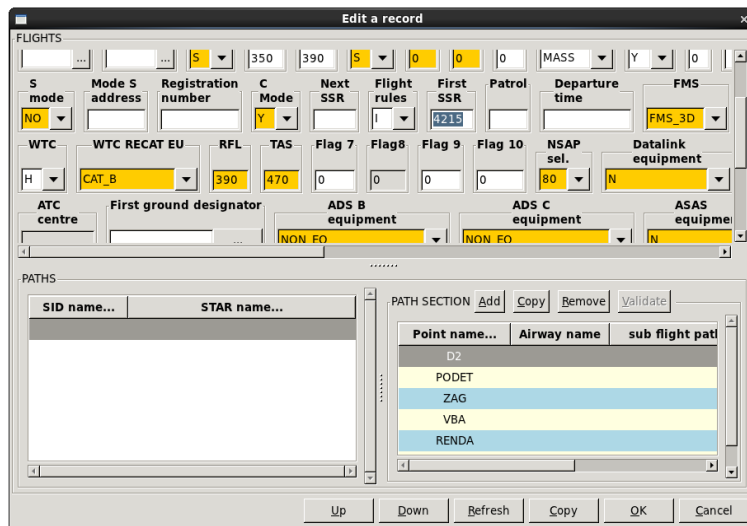
Figure 34 SSR mode modification

4.3 Cloning machines

For the upper and terminal Croatian airspace exercises prepared in ESCAPE, several working positions have been defined. Each of them matches a dedicated sector in the airspace. To be able to execute the exercise, a physical working position must be available for each of the defined sectors.

In the installation of ESCAPE Light using Oracle VM VirtualBox Manager, the working positions are virtual, but still, need to be defined in the appropriate number to carry out the exercise requirements.

The main constraint in data preparation considering the number of sectors used is the number of available virtual machines. Each of them exhausts a certain share of the available RAM of the computer the Virtual Box is installed on, so the number of possible virtual machines is limited. The computer used in this project has a 16GB working memory.

ESCAPE Light came with 4 virtual machines: ground machine, IPAS machine, one controller working position and one pilot working position. It has been expanded with 3 more virtual machines meant to host the hybrid controllers. Further expansion is not possible because starting an exercise requires all of the positions active, which takes up 96% of the available memory. Figure 35 shows a part of the cloning process (left) and the working memory used for running the simulation with 7 virtual machines.
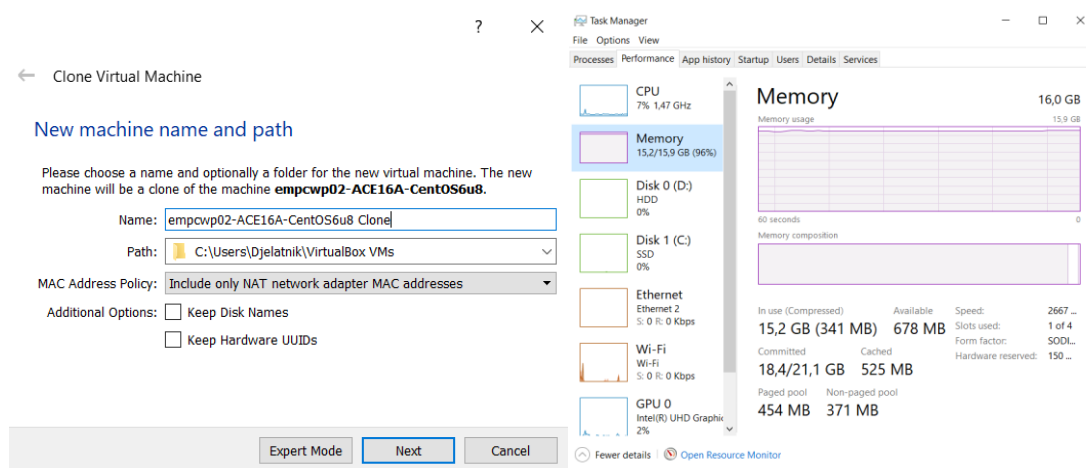

Figure 35 Cloning process and constraints

The cloning process is described in detail in the Technical note written during the traineeship. [13]

4.4 Working positions

All of the created exercises are intended for training purposes and require a single executive controller. In this case, the controller shall be a student in training. It isn't planned for the instructor to have a separate working position.

The executive sector is provided with a pseudo-pilot position to carry out the controller orders.

Hybrid positions correspond to feeder sectors. They are automatic, meaning they don't necessarily require a physical person to navigate the flights. The flight plan will automatically be followed. The hybrid positions initiate transfer 2 minutes prior to entering the executive sector. The flight can then

be assumed by the controller and falls under the jurisdiction of the executive sector and the pseudo-pilot position.

If a person does wish to and has the conditions to navigate the flights via the hybrid position, the changes in the flight plan and the aircraft state will be performed simply by changing the data in the label. There is no seed for a separate pilot interface.

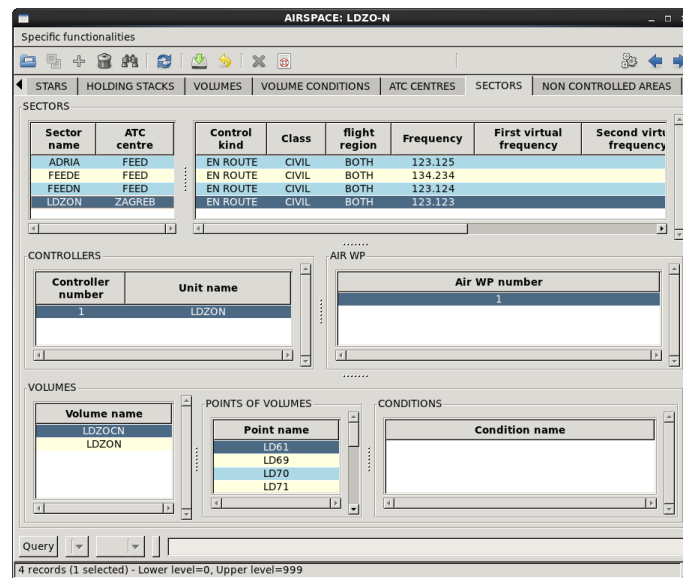In these exercises, only two people are meant to take part in the exercises - the controller and the pilot. The hybrid positions remain automatic.

Figure 36 Sectors and corresponding working positions

4.5 Maps creation

The CWP contains a set of maps which are highly configurable and can be adapted in many ways. The items that can be displayed on the map are ATC elements, graphical objects and combined objects (graphical objects relying on ATC elements). ATC elements are navigation points, airports, SIDs, STARs, sectors, non-controlled areas, runways etc. Graphical objects that can be created and displayed are points, lines, surfaces, curves and rulers.

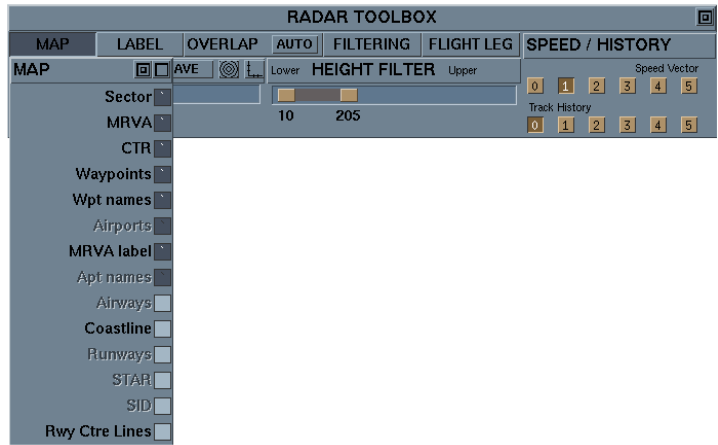The display of the map elements can be organized in a menu accessible to the controller, shown in Figure 37.

Figure 37 Radar toolbox Maps menu

4.5.1 Graphical data

The graphical data for upper airspace exercises are taken directly from sector definitions, making them combined objects - related graphical data is created from sectors to define map surfaces. Relevant navigation points are also displayed on the controller screen.

In the terminal airspace, more elements are displayed on the controller map. Navigational points and sectors rely on ATC definitions, the same as in upper airspace. There are two more types of elements defined as surfaces in terminal airspace, Minimum Radar Vectoring Altitude (MRVA) and Control Zone (CTR). The graphical surfaces used in the terminal airspace are shown in Figure 38.

Figure 38 TMA graphical surfaces

The "Default maps usage" column corresponds to the map elements accessible to the controller in Figure 37. Those additional elements have been given their unique definitions so they can be displayed or hidden unrelated to other maps elements.

MRVA volumes correspond to the non-controlled areas where Area Proximity Warning (APW) is used. CTR is the Zagreb airport controlled area. Its volume has previously been defined and is used as an ATC element as a part of sectors definition.

The CTR definition in the maps configuration file corresponds to the Zagreb CTR (the square shape around LDZA airport) and Lučko CTR (the adjacent semi-circle shape corresponding to LDZL airport). The points for CTR Zagreb have been imported to graphical data from the airspace domain where they have been used to define the CTR Zagreb volume. CTR Lučko has been drawn in the graphical domain using a line and a curve. It's only meant to be displayed on the map for orientation and accuracy purposes but isn't a part of any sector definitions.
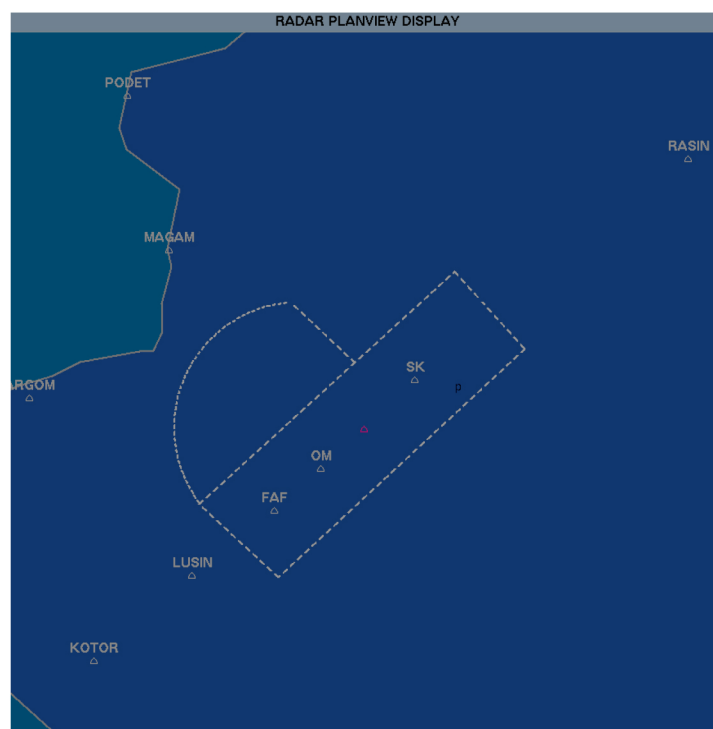

Figure 39 CTR Zagreb and CTR Lučko

The runway in use in the terminal airspace exercises is RWY 04. However, both of the runways are displayed as graphical maps elements on the CWP screen. More precisely, they are drawn using rulers.

4.5.2 Map Configuration file

Maps are configured in detail in the MapConfiguration_UNISCAPE_V1.0 Excel spread-sheet. Each element and its characteristics are specified in the Excel file.

Starting with Menu definitions, it is possible to define the Menu buttons visible to the controller in the radar toolbox (Figure 37), as well as to create sub-menus, assign the map's elements to certain sectors or roles and to define if the element will be activated by default.

Maps usage column defines keywords indicating which IPAS elements will be associated with the menu buttons. It must match the maps usage keyword used in the Graphical data menu in IPAS.

Further columns in the spreadsheet define line properties, area properties, point properties and ruler properties, such as visibility, symbols, colour, thickness etc. The last column, Priority, determines whether an object will mask or be masked by others in case of an overlap on the display.

The Excel spreadsheet includes the option to define colours to be used for every element of the map. They are RGB codes that can be assigned to those elements. When deciding on the colour scheme of the map, it is important to take note of the colour configuration of the screen on the computer that's used, since it can influence the perception of the chosen colours. The same RGB codes might appear different on two separate screens.

To apply the changes made to the Excel file, an ECHOES configuration file must be generated. It is then imported to IPAS as to visually assess the map's layout. Once the user is satisfied with the map display, the same configuration file is imported and saved to the ground machine at /exercises/bach/prepesc/Simulations/UNISCAPE/appli/CWP/config/CSV_FILES. The first time the exercise is run after a change has been made on the ground machine it must be Light deployed for the change to be applied in the exercise.

Figure 40 Maps configuration file

4.5.3 ECHOES

ECHOES is a powerful tool in IPAS which allows a preview of the CWP maps display. It uses the MapConfiguration_UNISCAPE_V1.0 Excel spreadsheet that needs to be imported to /exercises/bach/UNISCAPE/escape/ECHOES_LIGHT_CFG on the IPAS machine.

The benefit of using ECHOES to preview the maps display is that each change made in the graphical data in IPAS can be immediately seen on the display, so it's simple to fine-tune the graphical elements. Also, if a new version of the configuration file is uploaded to the IPAS machine, that change can be applied to ECHOES without restarting it.

4.6   Exercise installation on Runtime

To install the exercise on runtime, the AcePlatform_runesc2016A is used (See Figure 41). The tool is launched by opening a terminal in the ground machine and typing run_escape and logging in as ESCAPE user "uni".

Once the installation screen opens, the user is presented with a list of options. They can be chosen by typing in their ordinal number. Once a choice has been made, a new screen opens and the next set of options appears. The steps to follow in the process of exercise installation:

1 - ESCAPE Delivery/Installation menu

1 - Configuration Parameters menu

2 - Exercise menu

1 - Create (and Prepare)

After the last step, a list of available exercises is opened. The name of the chosen exercise should be written and confirmed in order to complete the installation.

Figure 41 Available exercises in run_esccape
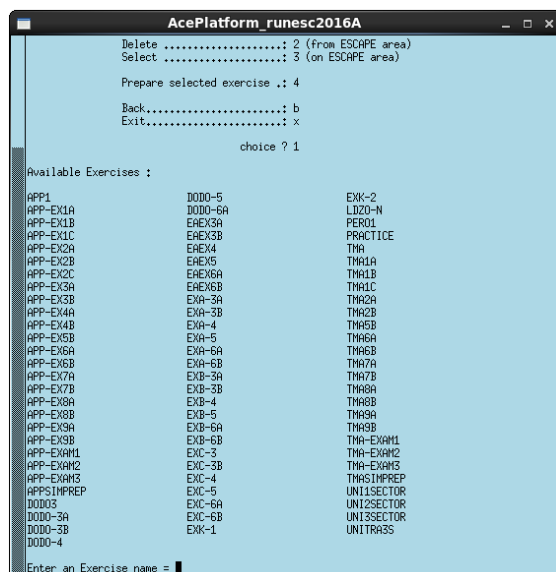
After the exercise has been successfully installed on runtime, a run has to be created to start the simulation. The launch_spv command is written in a terminal, followed by the ESCAPE user "uni". A run has to be created for each of the exercises that are installed on runtime if they are planned to be started and used. Figure 42 shows a window where a run can be created or edited.
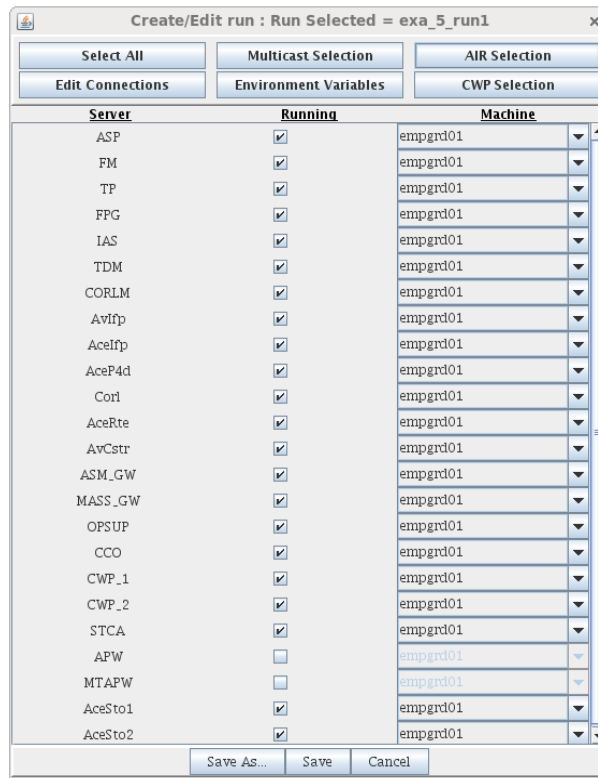
Figure 42 Create/Edit run

One of the differences in creating a run for upper and terminal airspace is in the Air and CWP positions. The difference comes from the organization and layout definitions explained in Subsections 6.2 and 5.4. In case of creating a run for a terminal airspace exercise, there will only be three CWP available. Screens for CWP and AIR selection for an upper airspace exercise can be seen in Figure 43.
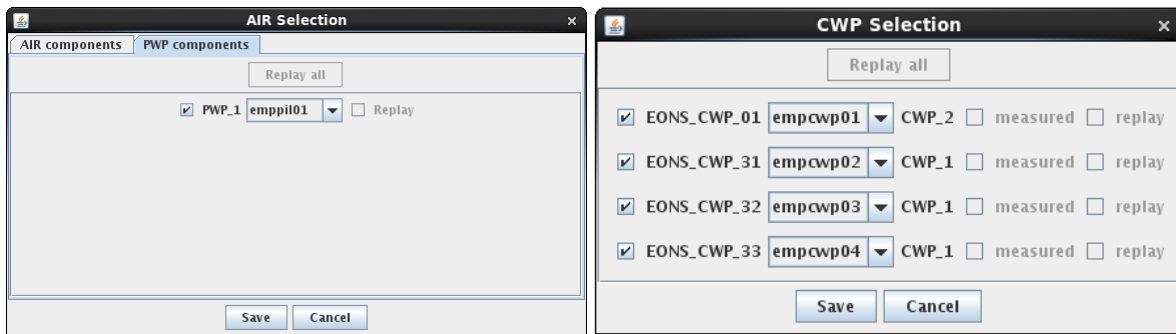
Figure 43 AIR and CWP selection

ESCAPE Light comes with a minimum list of components and services available. They can be seen as selected in Figure 42. The only two unselected components are APW and Medium Term Area Proximity Warning (MTAPW). They are not part of the standard ESCAPE Light package and have been unlocked subsequently [12]. Those components are used in the terminal airspace exercises as additional safety components.

The only safety component available in the standard configuration and used in the upper airspace exercises is STCA. However, STCA can also be unselected for a particular run. However, terminal airspace exercises can make use of APW as well which has been unlocked for that purpose [12]. It's an

additional safety element and can be used depending on the exercise requirements. It is possible to have more separate runs for the same exercise with different tools activated.

Multiple runs can be created for each exercise, with different components and tools available in each run. Another example of that is the option to choose between two different ECHOES configurations. An additional ECHOES configuration called "NOMONA" which doesn't include the monitoring aids was created to help the learning process. This leaves the option for the same exercise to have two runs - one with the monitoring aids and one without, the latter one being more suitable for ATCO training[12].
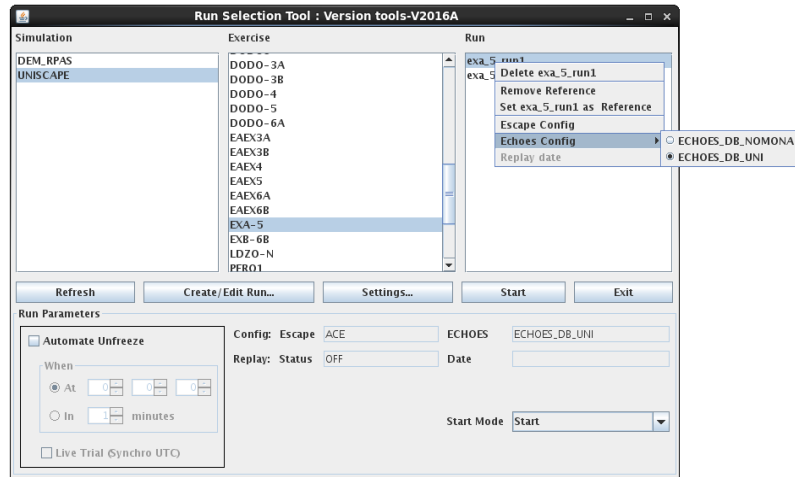
Figure 44 Echoes configuration

The final step in creating a run is to link it to the correctly defined organization (Figure 45). The correct organization needs to be used in the process of creating a run to achieve a coherent exercise execution. The positions used with their respective names are first defined in IPAS during data preparation and must be consistent throughout organization and layout definition. ORGLDZON is used for upper airspace exercises, and ORGAPP_TMA is used for terminal airspace exercises.

Figure 45 Run System Settings

4.7   Further development possibilities

During the research, several new ideas appeared as an upgrade of the original objectives. Initially, only a transfer of the existing exercises provided by the Faculty to the ESCAPE Light platform was imagined. It became apparent, however, that those existing exercises can be improved by utilizing some of the available tools and options.

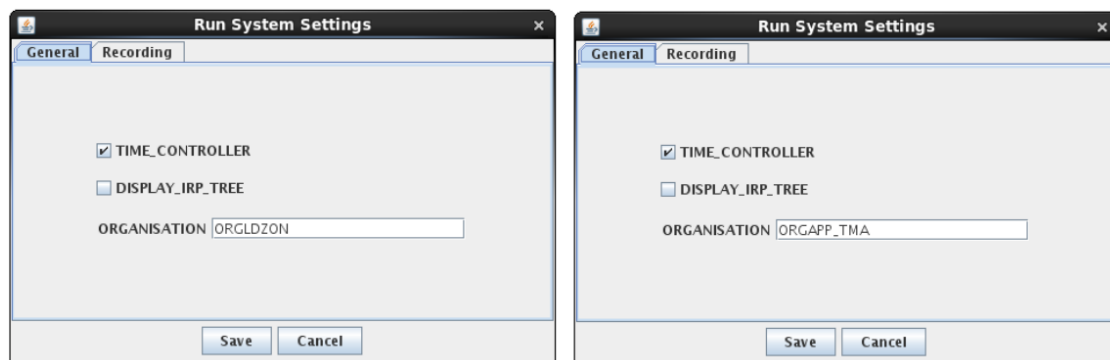With that in mind, feeder sectors were defined to simulate the entry and exit transfer procedures and serve as starting and ending points for the flights. They made the exercises more dynamic and realistic, with the possibility to have coordination between adjacent sectors. Another addition to the scenarios was introducing APW to the terminal airspace exercises. It could allow the ATCO student to make full use of the defined MRVA in their airspace, potentially making the exercises more demanding but aiding the learning process. Alternatively, the tool can be shut down, leaving only the visual indication of the MRVA's. Similarly, the monitoring aids that are a part of the default package with ESCAPE Light can also be disabled for the student to develop their situational awareness and skills first.

It can be imagined for the simulation to be further improved by expanding the platform to multiple computers, which would allow for more working positions, or by implementing other tools to help the controllers. Due to technical constraints of working on a single laptop, and the time constraint, some of those ideas remain development possibilities for anyone willing to continue the project.

4.7.1 CPDLC

Controller Pilot Data Link Communications (CPDLC) is a means of communication between controller and pilot, using data link for ATC communications[16]. It can transmit non-urgent strategic messages to an aircraft as an alternative to voice communications. The message is displayed on a flight deck visual display.

The controllers are provided with the capability to issue ATC clearances (level assignments, lateral deviations/vectoring, speed assignments, etc), radiofrequency assignments, and various requests for information.

The pilots are provided with the capability to respond to messages, to request/receive clearances and information, and to report information. A "free text" capability is also provided to exchange information not conforming to defined formats[17].

Datalink is available for implementation with ESCAPE Light. The reason it wasn't used in the course of the traineeship is that it likely wouldn't be a part of the Basic ATCO training that the exercises are created for. Due to the time constraint of the project, other tools have been given priority.

4.7.2 Free Route Airspace

Free route airspace (FRA) is a specified volume of airspace in which users can freely plan a route between defined entry and exit points. FRA is a way of overcoming the aviation sector's efficiency, capacity and environmental problems by helping reduce fuel consumption and emissions while improving flight efficiency. At the same time, it paves the way for further enhanced airspace design and ATM operational concept[18].

FRA has been successfully introduced in Croatia as a part of SECSI FRA (South East Common Sky Initiative). SECSI FRA is a merge between SAXFRA (Slovenian Austrian Cross-border Free Route Airspace) and SEAFRA (South-East Axis Free Route Airspace). It represents an important step towards achieving Free Route airspace across Europe[19].

With such advances in ATM in Europe, it would be beneficial to develop simulation exercises that follow the progress. It would require to expand the existing airspace definition, create entry and exit points and introduce coordination procedures at some of the borders where the vertical span of FRA differs.

4.7.3 Multiple sectors exercise

Croatian airspace is, at the most basic level, divided into 4 main sectors: North, Central, West, and South. Combining them or further dividing each of them either horizontally or vertically allows to fragment the airspace and make it more manageable in times of high traffic demand.

The input data provided Upper airspace exercises created for the North sector only. During the traineeship, the other sectors mentioned above were also created, as well as a model exercise for each of them. With this approach, each of those sectors took the role of the executive sector, while the others became a part of the feeder sectors.

The next step could be to expand the system to enough computers to be able to facilitate an adequate number of working positions to run an exercise with two executive sectors. That way, two student controllers could work on the exercise together, each in charge of their sector with two corresponding pseudo-pilot positions.

4.7.4 Instructor/Planner working position

After the monitoring aids were made optional by adding another ECHOES configuration, it was noted that it might be interesting to have two identical controller positions in a single exercise - with one of them utilizing monitoring aids, and the other running without them. This approach is the first step to having an instructor working position which would serve only as an observation point of the work done by the student.

A different step forward would be to create exercises with a planner position. It isn't necessary at the Basic training level but would be an attractive addition to some more advanced exercises.

The main prerequisite for such working positions is having a physical machine where they could be run, which is why it couldn't have been developed during the traineeship. It is, however, an interesting improvement idea for the created exercises and some that could be created after.

5 TMA example of scenario development – Zagreb TMA

5.1 Sectors

The terminal airspace exercises are based on a modified Zagreb TMA. They are constructed from the exercises used in the Faculty of Transport and Traffic engineering as a part of the Air Traffic Control study program in approach to control simulator training. The only airport used in the exercises is LDZA - Zagreb airport.

There are 3 sectors defined in the terminal airspace - 1 executive and 2 feeder sectors. The executive sector is called ZATMA. Its lower limit is 1000 feet and upper FL 205 in the whole sector except for above the CTR Zagreb area, where the lower limit is 2500 feet. One of the feeder sectors is called ZATWR and corresponds to the volumes under ZATMA. ZATWR is created to take advantage of the NAVSTART feature available at the hybrid position. It allows the flights to be manually started at a chosen time, which corresponds to the take-off clearance. On the other hand, arriving aircraft can be transferred to ZATWR after being established on approach, which closely resembles the real-life situation. The Art Visu view of the ZATMA sector is shown in Figure 46.

The other feeder sector called OUT corresponds to the remaining volumes in the defined airspace, which is the whole SWCE airspace aside from ZATMA and ZATWR. Its vertical limits are from 000 to 999 everywhere but above ZATMA, where it first starts at FL 205.
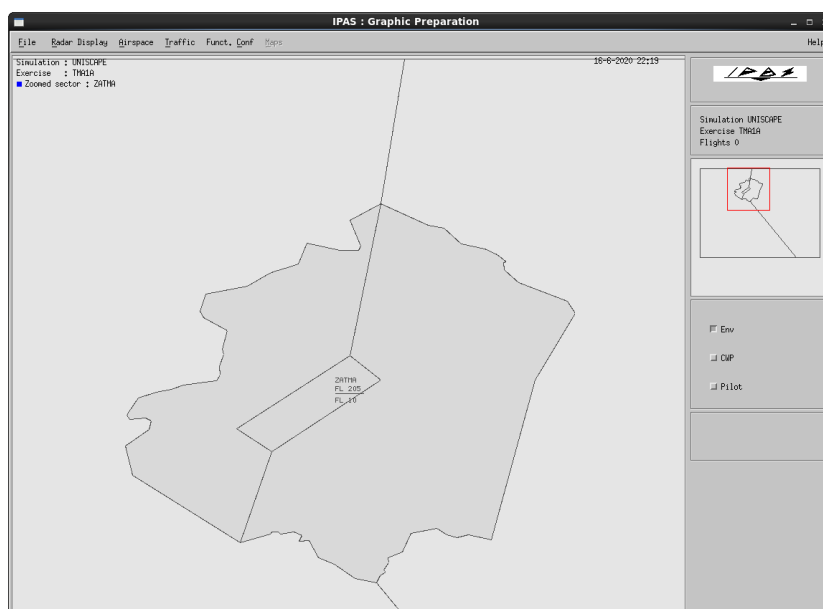

Figure 46 Simulated TMA Zagreb sector

The terminal airspace exercises useless sectors than upper airspace exercises do. The reason for that is that all of the flights land or take-off at LDZA, so there won't be any re-entry issues related to the lateral sectorization.

The coordinates for the ZATMA sector were taken from the eAIS package for Croatia shown in the Figure below[20]. They are the same as the ones defining the actual TMA Zagreb airspace. For the parts of the TMA border that are meant to follow the FIR border, the existing upper airspace border sections have been used. For the upper airspace, see Subsection 6.1.

Name Lateral limits Vertical limits Class of airspace	Unit providing service	Call sign Languages Area and conditions of use Hours of service	Frequency / Purpose	Remarks
1	2	3	4	5
ZAGREB TMA 460715N 0171052E - 455046N 0170045E - 451111N 0164948E - along the FIR BDRY Zagreb/Sarajevo - 451031N 0154640E - 452710N 0151943E - along the FIR BDRY Zagreb/Ljubljana - along the FIR BDRY Zagreb/Budapest - to the point of origin 460715N 0171052E. Class of airspace: C • Upper limit: FL 205 • Lower limit: 1000 FT AGL 460715N 0171052E - along the FIR BDRY Zagreb/Budapest - 455553N 0172323E - 450912N 0170950E - along the FIR BDRY Zagreb/Sarajevo - 451111N 0164948E- 455046N 0170045E- to the point of origin 460715N 0171052E. Class of airspace: C • Upper limit: FL 205 • Lower limit: FL115 Class of airspace: D • Upper limit: FL 115 • Lower limit: 1000 FT AGL 452710N 0151943E - 451031N 0154640E - along the FIR BDRY Zagreb/Sarajevo - 450414N 0154529E - 452527N 0151100E - along the FIR BDRY Zagreb/Ljubljana - to the point of origin 452710N 0151943E Class of airspace: D • Upper limit: 7500 FT MSL • Lower limit: 1000 FT AGL *Note: Also see "Delegated Provision of ATS", ENR 2.2.*	ZAGREB APP ZAGREB FIC	ZAGREB RADAR EN, HR H24 H24 H24 H24 ZAGREB INFORMATION EN, HR H24	 120.7 MHZ/PRI FREQ 118.5 MHZ 121.5 MHZ/EMERG VHF FREQ 243.0 MHZ/EMERG UHF FREQ 135.05 MHZ/PRI FREQ	Nil

Figure 47 Lateral and vertical limits of Zagreb TMA[20]

5.2   Changing RWY designator/heading

The declared runways for LDZA airport in the input data are RWY 05 and RWY 23. However, the runways in use at LDZA are now RWY 04 and RWY 22, making the input data obsolete. The RWY designators and headings have for that reason been changed for terminal exercises data preparation. The edited RWYs can be seen in Figure 48.

Figure 48 RWY designators and headings for LDZA

5.3 MRVA

Minimum Radar Vectoring Altitude is the lowest altitude, expressed in feet Above Mean Sea Level (AMSL), to which a radar controller may issue aircraft altitude clearances during vectoring/direct routing except if otherwise authorized for radar approaches, departures and missed approaches [21].

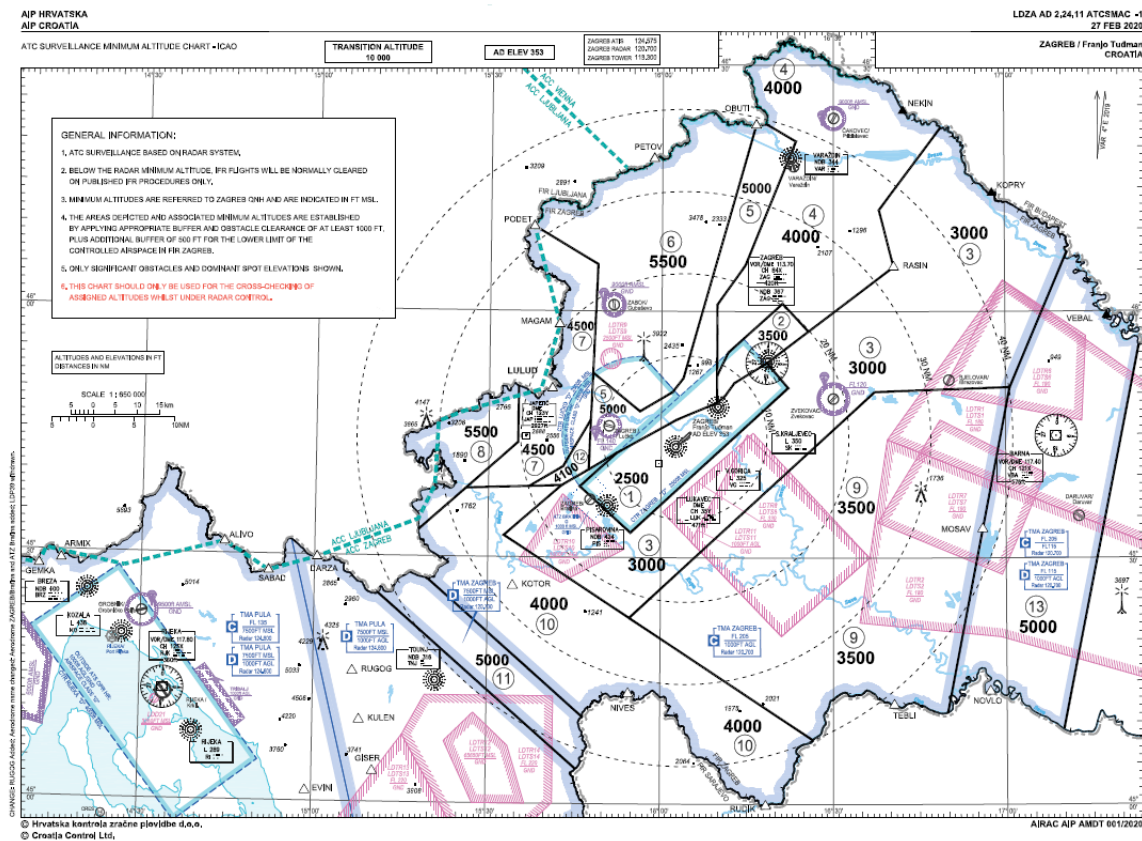Minimum Radar Vectoring Altitudes for TMA Zagreb are defined in the AIP for Croatia shown in Figure 49.

Figure 49 AIP Croatia map of MRVA

In the terminal airspace exercises, MRVA's are defined as non-controlled areas. More specifically, their type is MSAW (Minimum Safe Altitude Warning).

The Maps Configuration file has been edited to include MRVA's and their labels as a Map Menu Button. The controller has the option to display or hide the MRVA borders and the labels indicating the altitude in feet on their screen. A radar plan view display with MRVA's visible is shown in Figure 50.
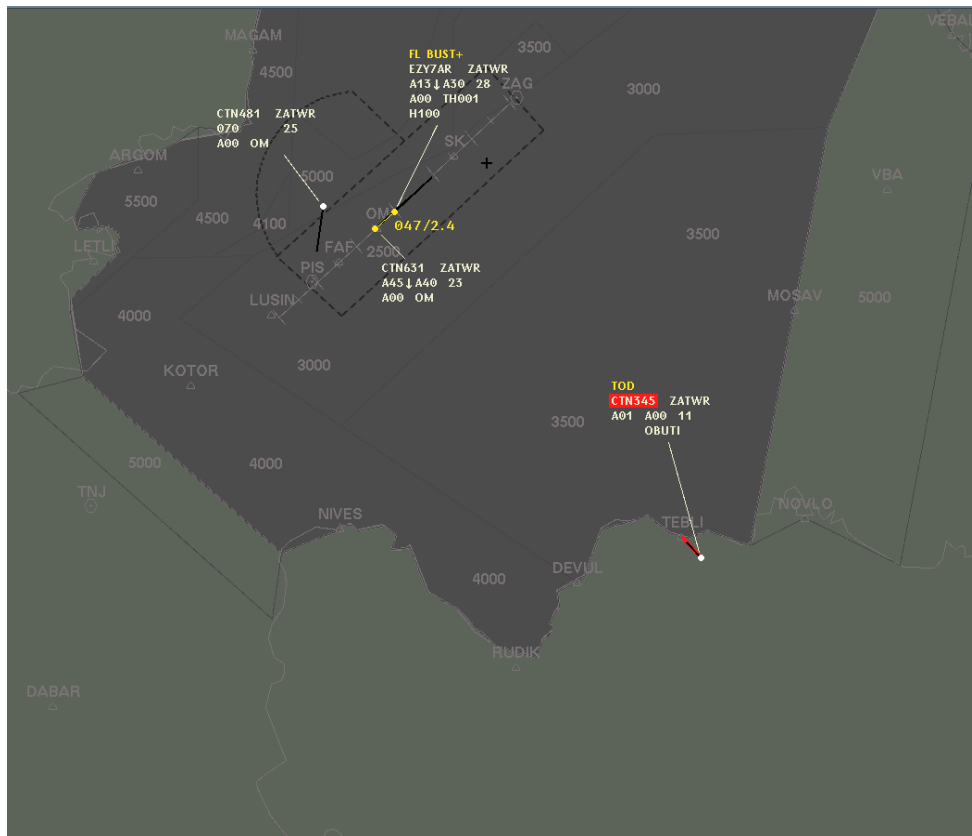

Figure 50 Controller screen in ECHOES

Area Proximity Warning (APW) is a ground-based safety net which uses surveillance data and flight path prediction to warn the controller when an aircraft is or is predicted to be flying into a volume of notified airspace, such as controlled airspace, danger areas, prohibited areas and restricted areas [22].

APW is not a part of the original ESCAPE Light package and has been included in terminal airspace during the research. It isn't selected by default, so it shall be activated while creating a run to make sure the tool is included. In case it isn't activated, that particular run won't have the option of using APW. However, the controller will have the visual representation of MRVA's in both cases.

In the terminal airspace exercises, APW is used to warn controllers of non-compliance with MRVA. Since MRVA's are defined as MSAW non-controlled areas in IPAS, APW is activated for those sectors.

The warning will activate when a flight initiates descent to an altitude lower than the minimum safe vectoring altitude declared for that area. If the MRVA is 4500 feet, and the aircraft is cleared to descend and initiates decent to 4500 feet precisely or an altitude above, the APW will not activate. If the aircraft initiates descent to a lower altitude, the APW activates. The APW will also activate if the aircraft flies into an MRVA sector at an altitude lower than the lowest allowed one.

It has been decided that the two MRVA sectors that are the closest to the airport and are 2500, 3000 and 3500 feet will not be included in the APW definition to avoid warnings for landing flights and flights that are taking off (See Figure 51)
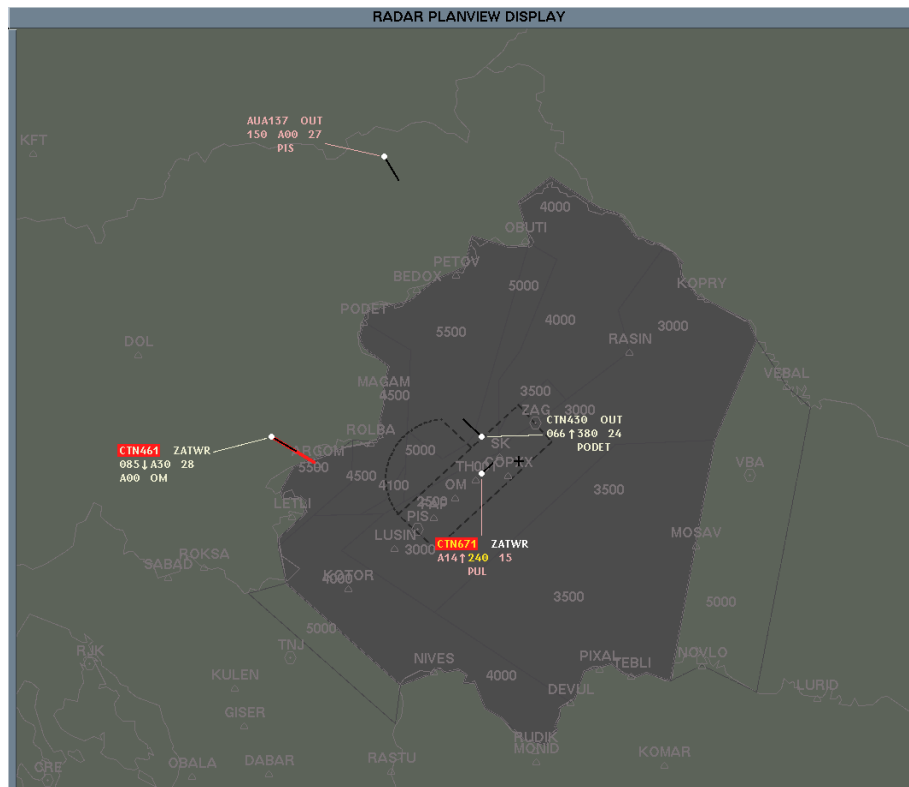

Figure 51 APW in ZATMA

5.4   Organization and layout

The layout and organization complement the elements of the exercise they are used in. More precisely, the layout definition includes all the sectors used in the exercises, along with the numbers for working positions used, their names, their type (feed or TC), the defined ATC centre name, the control kind etc. The terminal airspace layout is called LAYOUT_ORGAPP_TMA. Its structure can be seen in Figure 52. The layout file for the terminal airspace exercises is also defined in the ground machine at /exercises/prepesc/Simulations/UNISCAPE /appli/CWP/config/SIMU/CSV_PROD_FILES.
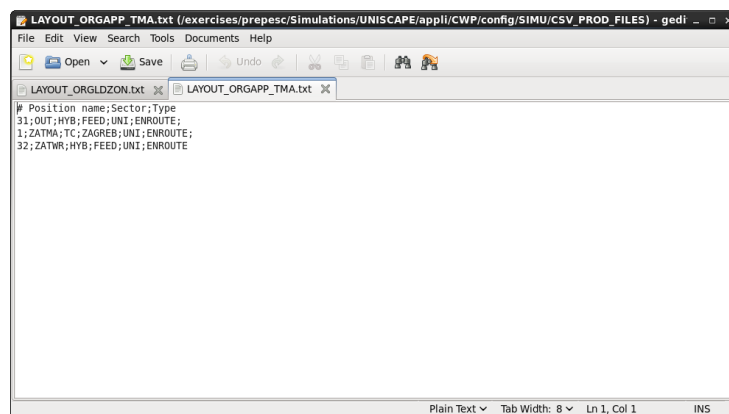

Figure 52 Layout for terminal airspace

The organization structure for terminal airspace is stored in /bach/exercises/prepesc /Simulations/UNISCAPE/appli/CWP/config/SIMU. It is called ORGAPP_TMA and has the following structure:

- ORGAPP_TMA - UNI
  - ENROUTE
    - HYBRID
      - POSITION_31
      - POSITION_32
    - TC
      - POSITION_1

6 ACC example of scenarios development – Zagreb ACC

6.1 Sectors

The upper airspace exercises were originally made for generic airspace closely resembling the Upper North sector in Zagreb FIR and are used in the Faculty of Transport and Traffic engineering as a part of the Air Traffic Control study program. More specifically, they are used for the training on the area control simulator.

When transformed and imported into ESCAPE, the exercises lacked the sector definitions.

Each exercise only had one sector which corresponded to the entire airspace.

In the process of data preparation with IPAS, multiple sectors have been defined (Figure 53). The executive sector corresponds to the Upper North just as in the original exercises. In ESCAPE, it's called LDZON. There are three more sectors defined in the Upper airspace in ESCAPE, which serve as feeders for traffic. All flight paths start and end in those sectors. FEEDE roughly corresponds to the Serbian and Bosnia and Herzegovina airspace. FEEDN covers the Hungarian airspace. ADRIA is the biggest sector in the defined airspace. It spans across Slovenia, part of Italy, Montenegro, Lower North and the other Croatian sectors - Central, West, South.

The majority of flight paths through the Croatian airspace dictate the boundaries of the created feed sectors. The idea behind designing them is to make sure no flight re-enters the same feeder sector, thus making one feeder sector on the north, one on the east and one on the west to accommodate all the flights using the LDZON sector.
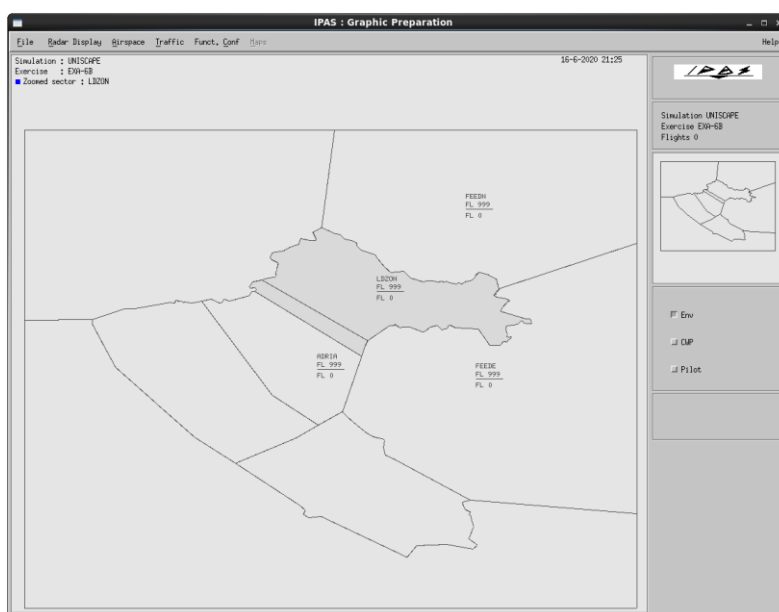

Figure 53 Upper airspace sectors

The coordinates for the sector points were taken from NEST 1.7 using Aeronautical Information Regulation And Control (AIRAC) cycle 2003. The executive sector, LDZON, can be seen in NEST in Figure 54. The first approach was to manually write the coordinates in IPAS and then create volumes and sectors. The second approach was exporting the coordinates from NEST and then transforming the data into an IPAS compatible format and finally massively importing the points and volume definitions.

The second approach generated a much larger number of points and volumes compared to manually typing them in. The accuracy was also greater. However, it was decided to use the sectors that were initially manually defined because the process of defining con-troller maps is much simpler with a smaller number of defined sector points. Furthermore, the sectors defined that way are accurate enough to be used in the simulation.
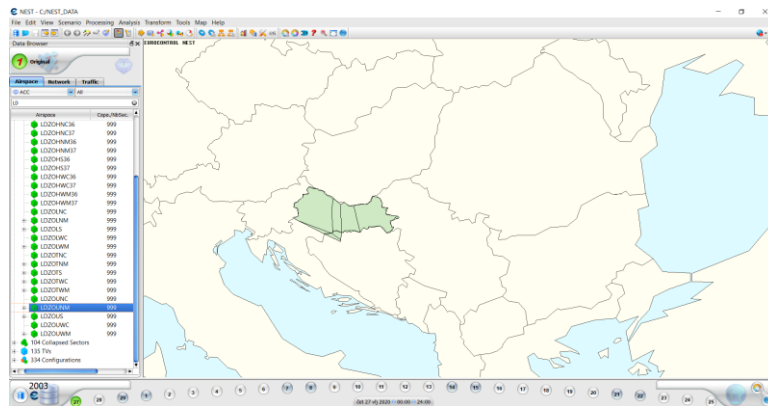

Figure 54 NEST

6.2 Organization and layout

The layout of the upper airspace exercises shall be a unique file because it needs to correspond to the elements of the exercise it is used in The layout file is defined in the ground machine at /exercises/prepesc/Simulations/UNISCAPE/appli/CWP/config/SIMU /CSV_PROD_FILES. In the upper airspace, there are 4 sectors in total, three feeders and one executive. Figure 55 shows the layout for the upper airspace exercises.
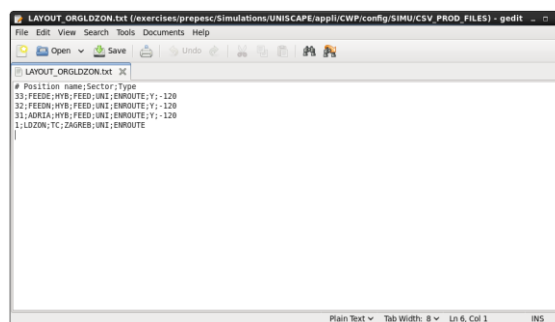

Figure 55 Layout for upper airspace exercises

The organization is also unique to each set of exercises. It is also defined in the ground ma-chine at /exercises/bach/prepesc/Simulations/UNISCAPE/appli/CWP/config/SIMU. For upper airspace, the organization is called ORGLDZON and has the following structure:

- ORGAPP_TMA - UNI
  - ENROUTE
    - HYBRID
    - POSITION_31
    - POSITION_32
    - POSITION_33
  - TC
    - POSITION_1

51

7   Additional sectors in the Croatian airspace

As mentioned before, the Upper and Terminal airspace exercises were made mostly using the input data provided by the Faculty to duplicate the existing training program inESCAPE Light. The next logical step in developing skills on the data preparation tool was to create new airspace without any pre-existing input.

Croatian area control is typically spread across several distinct sectors which are further split up horizontally and/or vertically depending on the current traffic demand. The basic division consists of sectors North, Central, West and South. The Upper airspace exercises developed following the Faculty's input closely resemble the North sector in the Zagreb FIR. The exercises created in this step will be named LDZO-W, LDZO-C andLDZO-S, corresponding to each of the sectors aside from North, for which several exercises were already created.

The data extracted from NEST was not only helpful to distinguish North's borders, but also the shape of the remaining en-route sectors. The first step in building the new exercises was to design an airspace for each of them. Using the coordinates from NEST, Croatian airspace has been parted to create several distinct volumes. Figure 56 shows volumes LDZON, LDZOCN, LDZOCW, LDZOW and LDZOS inside the Croatian borders, and volumes NW, NE, E and SW surrounding them and filing the entire SWCE volume. The LDZOCN volume is can be a part of either North or Central, depending on the used configuration
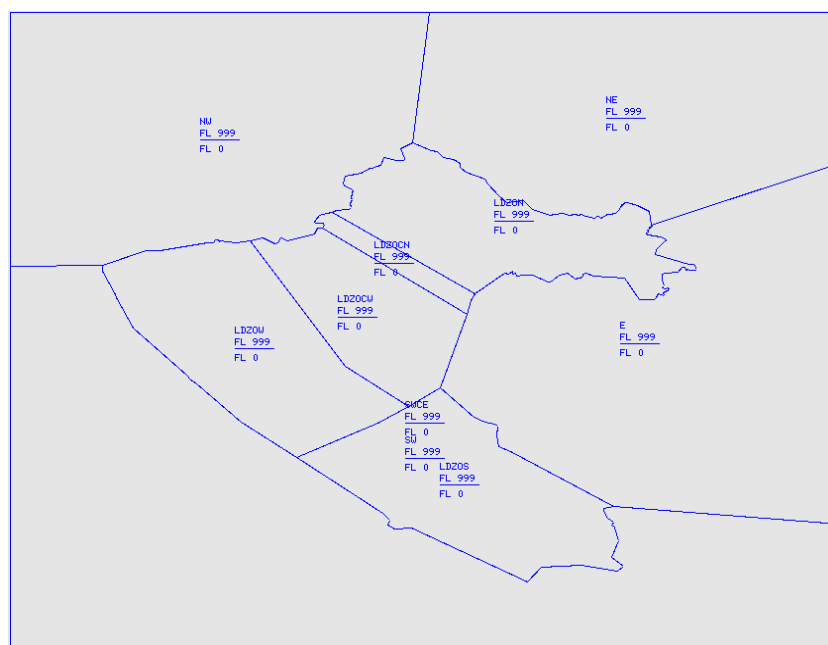

Figure 56 Simulated Zagreb FIR sectors

Three separate exercises were created, each with a separate airspace domain, one for every remaining Croatian sector. The table below shows how the executive and feeder sectors were designed in each case. The names of the sectors are written in black, and the names of the volumes that define them in blue.

Table 1 Volumes and sectors in LDZO-W, LDZO-C and LDZO-S

Exercise name	Executive sector		Feeder sector 1		Feeder sector 2		Feeder sector 3	
LDZO-W	LDZOW		FEEDE	E LDZOCN LDZOCW LDZON NE	FEEDN	NW	FEEDS	LDZOS SW
LDZO-S	LDZOS		FEEDE	E LDZON NE	FEEDN	LDZOCN LDZOCW LDZOCW NW	FEEDS	SW
LDZO-C	LDZOC	LDZOCN LDZOCW	FEEDE	E	FEEDN	LDZON NE NW	FEEDS	LDZOS LDZOW SW

After the airspace domains have been created, traffic and constraints were also designed. The average number of flights in the exercises is 10, following the example of Upper area exercises corresponding to North. The flights' trajectories and start times have been set up in a way that each of the exercises will have at least one conflict for the ATCO student to solve. The constraints enable flights' 3D trajectories throughout the exercise.

Setting up the architecture for each of the sectors follows the same logic described in chapter 3.1.5. Every exercise will have a single executive position with a pseudo pilot and three feeder positions delegated to hybrid controllers. The meteorological domain follows the classical scenario in all the newly created exercises.

Installing the exercises on runtime requires creating new organizations and layouts for each of them since the sectors have different roles in every case. The layouts can be found in the ground machine at /exercises/prepesc/Simulations/UNISCAPE/appli/CWP/config/SIMU /CSV_PROD_FILES. The layouts can be seen in the Figure below. The organizations follow the example shown in Subsection 6.2, with the distinction of having a different name. That way, the organization used in LDZO-W is ORG_WEST, LDZO-Suses ORG_SOUTH and LDZO-C uses ORG_CENTRAL
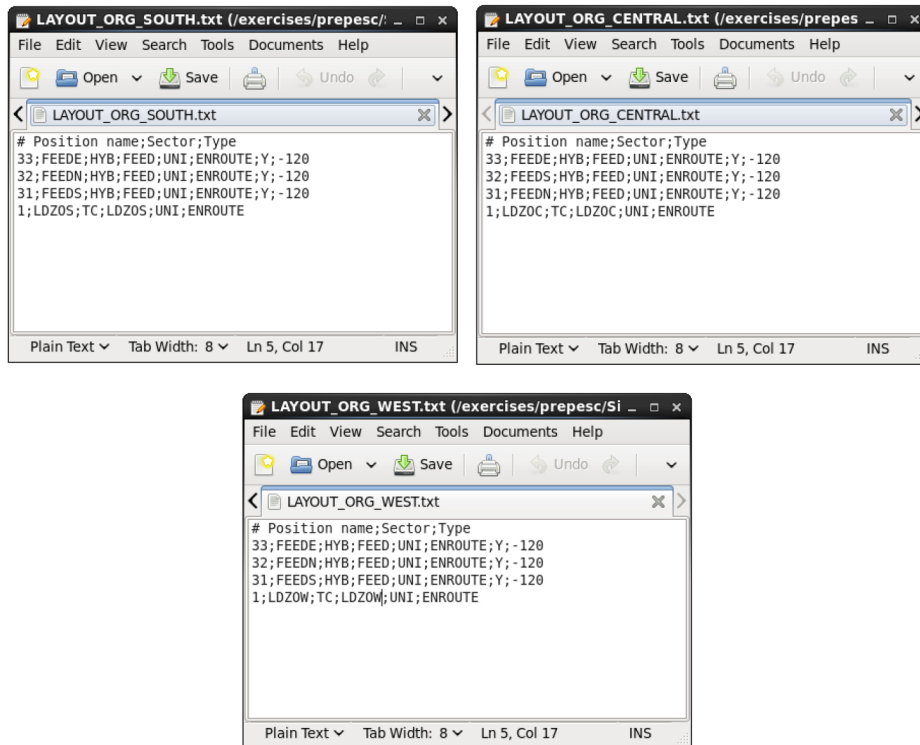
Figure 57 Layouts in the additional sectors

After the layout and organization have been created, the exercises have been installed on runtime and launched. When setting up the runs, it was important to make sure the different organizations and remain consistent. Figure 58 shows a run of the LDZO-W exercise
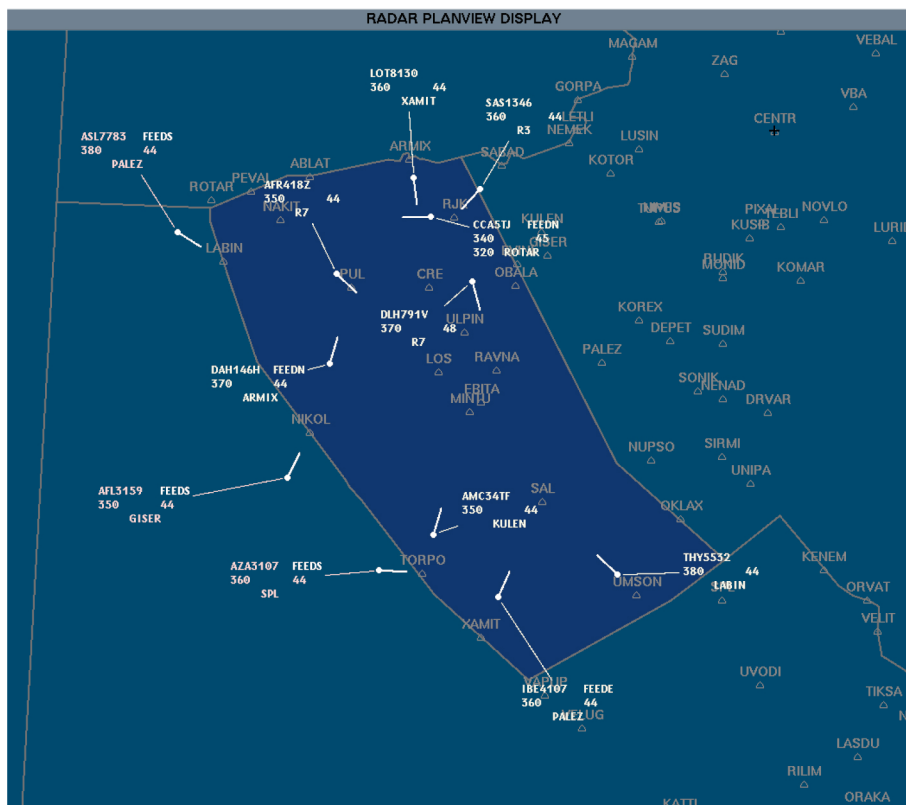

Figure 58 LDZO-W run

8 Conclusion

Simulator training is a vital part of the Basic ATCO training held by HUSK at the Faculty of Traffic and Transport Sciences. It enables students to gain practical knowledge of air traffic control and put the learned theory to use. It is important for HUSK, as a certified training organization, to continually improve its systems and keep pace with the advancements in technology, to provide the best training experience possible. Using the ESCAPE ATC simulator at the Faculty provides a long-lasting practical solution for training and various projects.

ESCAPE ATC simulator is developed by a renowned company known for supporting the progress of aviation in Europe, cooperating with numerous ANSPs, national aviation authorities, members of the science community, researchers and companies. The features of ESCAPE, such as its modular design, expandable platform, flexible use and the possibility of simple post-processing make it the ideal ATC simulator to be used in training as well as in research and validation.

Using ESCAPE's data preparation tool during this research has been proven to be a user-friendly, simple, expeditious and effective method of developing scenarios for exercises that can be used in training as well as in various projects students could take part in. This thesis confirms the possibility of ESCAPE to be used at the Faculty as a part of the Basic ATCO training, as well as a platform for conducting research and projects. It has been shown that data preparation is an understandable process and can be accomplished at the Master student level of knowledge. Aside from the option to import existing data and generate known airspace, the simulator offers the possibility to design one's generic airspace and the following exercise scenario, meaning it has the potential to be used for various projects and future researches.

The result of this research, aside from the thesis, is the generated exercises correspond-ing to the upper and terminal Zagreb airspace that can be readily used for training purposes. There is sufficient information in the paper to conduct further research and improve the existing exercises, with some ideas for future development already mentioned. Furthermore, completely new exercises related to a different airspace or serving a different purpose can be imagined.

References

[1] EUROCONTROL, "About us." https://www.eurocontrol.int/about-us (accessed Aug. 18, 2020).

[2] AUTHOR, "Executive body." https://www.eurocontrol.int/info/executive-body (accessed Aug. 18, 2020).

[3] EUROCONTROL, "Philippe Merlo." https://www.eurocontrol.int/bio/philippe-merlo (accessed Aug. 18, 2020).

[4] EUROCONTROL, "Innovation, research and deployment | EUROCONTROL." https://www.eurocontrol.int/innovation-research-deployment (accessed Aug. 18, 2020).

[5] EUROCONTROL, "Simulations and validation | EUROCONTROL." https://www.eurocontrol.int/simulations (accessed Aug. 18, 2020).

[6] EUROCONTROL, "Validation of air traffic management concepts through simulations." https://www.eurocontrol.int/service/validation-air-traffic-management-concepts-through-simulations (accessed Aug. 18, 2020).

[7] EUROCONTROL, "Realistic air traffic control, airport and flow management systems for simulations and training." https://www.eurocontrol.int/service/realistic-air-traffic-control-airport-and-flow-management-systems-simulations-and-training (accessed Aug. 18, 2020).

[8] EUROCONTROL, "Assistance and consultancy for external airspace simulations." https://www.eurocontrol.int/service/assistance-and-consultancy-external-airspace-simulations (accessed Aug. 18, 2020).

[9] EUROCONTROL, "IT developments and human-machine interfaces for air traffic management simulators." https://www.eurocontrol.int/service/it-developments-and-human-machine-interfaces-air-traffic-management-simulators (accessed Aug. 18, 2020).

[10] EUROCONTROL, "EUROCONTROL simulation capabilities and platform for experimentation (ESCAPE) | EUROCONTROL." https://www.eurocontrol.int/simulator/escape (accessed Aug. 18, 2020).

[11] EUROCONTROL, "New version of ESCAPE ATC simulator will facilitate academic research worldwide." https://www.eurocontrol.int/news/new-version-escape-atc-simulator-will-facilitate-academic-research-worldwide (accessed Aug. 18, 2020).

[12] Philippe Bouchadon, "ESCAPE REAL TIME SIMULATOR, From BEST simulator to ESCAPE simulator (ZAGREB)." EUROCONTROL, internal document.

[13] EUROCONTROL, "EUROCONTROL Specifications for the ATCO Common Core Content Initial Training." .

[14] HUSK, Faculty of Transport and Traffic Sciences, "HUSK BEST RADAR SIMULATOR TRAINING MANUAL, Rev: 01.04.206." internal document.

[15] ORACLE, "Virtualbox user manual." https://www.virtualbox.org/manual/ch01.html (accessed Aug. 18, 2020).

[16] ICAO, *Procedures for air navigation and air traffic management pans-atm doc 4444.* Place of publication not identified: ICAO, 2016.

[17] "Controller Pilot Data Link Communications (CPDLC) - SKYbrary Aviation Safety." https://www.skybrary.aero/index.php/Controller_Pilot_Data_Link_Communications_(CPDLC) (accessed Aug. 18, 2020).

[18] EUROCONTROL, "Free route airspace (FRA) | EUROCONTROL." https://www.eurocontrol.int/concept/free-route-airspace (accessed Aug. 18, 2020).

[19] EUROCONTROL, "South East Common Sky Initiative Free Route Airspace (SECSI FRA) successfully implemented | EUROCONTROL." https://www.eurocontrol.int/news/south-east-common-sky-initiative-free-route-airspace-secsi-fra-successfully-implemented (accessed Aug. 18, 2020).

[20] CroControl, "AIP CROATIA | ENR 2, AIR TRAFFIC SERVICES AIRSPACE," *Republic of Croatia Aeronautical Information Publication*. https://www.crocontrol.hr/UserDocsImages/AIS%20produkti/eAIP/2020-08-13-AIRAC/pdf/LD_ENR_2_1_en.pdf#E.ENR1006230716114 (accessed Aug. 18, 2020).

[21] "Minimum Vectoring Altitude (MVA) - SKYbrary Aviation Safety."
https://www.skybrary.aero/index.php/Minimum_Vectoring_Altitude_(MVA) (accessed Aug. 18, 2020).

[22] "Area Proximity Warning - SKYbrary Aviation Safety."
https://www.skybrary.aero/index.php/Area_Proximity_Warning (accessed Aug. 18, 2020).

List of Figures

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List of abbreviations

ACARE	Advisory Council for Aeronautics Research in Europe
ACC	Area Control Centre
ADEP	Aerodrome of Departure
ADES	Aerodrome of Destination
AIRAC	Aeronautical Information Regulation And Control
AMAN	Arrival Manager
AMSL	Above Mean Sea Level
APW	Area Proximity Warning
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
BADA	Base of Aircraft Data
CPDLC	Controller Pilot Data Link Communications
CPU	Central Processinf Unit
CTR	Control Zone
CWP	Controller Working Position
DECMA	Directorate European Civil-Military Aviation
EDEP	Early Demonstration and Evaluation Platform
ESCAPE	EUROCONTROL simulation capabilities and platform for experimentation
FIR	Flight Information Region
FRA	Free Route Airspace
HUSK	Croatian Air Traffic Control Training Centre
MRVA	Minimum Radar Vectoring Altitude
MSAW	Minimum Safe Altitude Warning
MTAPW	Medium Term Area Proximity Warning
OS	Operating System
PVT	Profile Validation Tool
PWP	Pilot Working Position
QFU	Magnetic Heading of a Runway
RFL	Requested Flight Level
R-NEST	Research network strategic monitoring tool
ROC	Rate of Climb
ROD	Rate of Descent
RWY	Runway
SAXFRA	Slovenian Austrian Cross-border Free Route Airspace
SEAFRA	South-East Axis Free Route Airspace
SECSI FRA	South East Common Sky Initiative
SES	Single European Sky
SESAR	Single European Sky Air Traffic Management Research
SID	Standard Instrument Departure Route
SRA	Strategic agenda
SSR	Secondary Surveillance Radar
STAR	Standard Arrival Route
STCA	Short Term Conflict Alert
TMA	Terminal Control Area
VM	Virtual Machine
XFL	Exit Flight Level

Annex 1

The list of trajectories that have been altered by adding point D13:

MRS1960_D9 _D2	BAW131_D9 _D2
PGT191_D9 _D2	OHY565_D2 _D9
EDW686_D2 _D9	TCW284_D1 _D9
CFG588_D2 _D9	BIE4456_D2 _D9
AEE414_D2 _D9	CAI386_D9 _D3
EDW7741_D9 _D2	ROJ175_D9 _D2
GWI841_D2 _D9	NWS221_D3 _D9
RMA7471_D9 _D2	CES326_D9 _D2
QTR696_D9 _D2	SVA164_D3 _D9
PNC113_D3 _D9	UAE346_D9 _D4
CES3930_D2 _D9	CFG767_D9 _D
VLG141_D3 _D9	2BAW633_D2 _D9
MRS1960_D9 _D2	OHY686_D2 _D9
TOM9699_D9 _D2	MGX135_D2 _D9
EXH471_D9 _D2	MGX345_D2 _D9
RYR588_D2 _D9	LTU3131_D9 _D2
CFG414_D2 _D9	LGL3434_D9 _D2
BAL868_D9 _D2	TVS662_D2 _D9
OAL860_D9 _D2	CFG581_D2 _D9
LBT141_D3 _D9	CYP1414_D9 _D3
DLH9699_D9 _D2	AUA8411_D2 _D9
FHY355_D9 _D2	GWI178_D9 _D2
EZS169_D9 _D2	MGX354_D2 _D9

Annex 2

The list of modified flights sorted per exercise:

Airspace_B, exercise 6B

GWI178

NLY171

AFL1141

ASL348

PNC113

Airspace_B, exercise 6A

BAW131

CTN221

EZS169

THY355

LTU596

SAS777

Airspace_B, exercise 5

EZY5565

LTU8831

Airspace_B, exercise 3A

GWI444

Airspace_A, exercise 6A

BAL868

Airspace_A, exercise 6B

DLH9699

LBT141

Airspace_C, exercise 4

HAY491

MGX345

Airspace_C, exercise 3

CAI326

CES1492

FIN452

MSR1960

NAX558

QTR553

TFL426

TRA936

Annex 3

A list of created exercise and organizations and ECHOES Database used

List of created exercises		
Exercise name	Organization	ECHOES DB
Upper airspace		
EXA-3A	ORGLDZON	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
EXA-3B	ORGLDZON	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
EXA-4	ORGLDZON	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
EXA-5	ORGLDZON	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
EXA-6A	ORGLDZON	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
EXA-6B	ORGLDZON	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
EXB-3A	ORGLDZON	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
EXB-3B	ORGLDZON	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
EXB-4	ORGLDZON	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
EXB-5	ORGLDZON	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
EXB-6A	ORGLDZON	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
EXB-6B	ORGLDZON	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
EXC-3	ORGLDZON	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
EXC-3B	ORGLDZON	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
EXC-4	ORGLDZON	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
EXC-5	ORGLDZON	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
EXC-6A	ORGLDZON	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
EXC-6B	ORGLDZON	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
EXK-1	KRIZ	ECHOES_DB_NOMONA
EXK-2	KRIZ	ECHOES_DB_NOMONA
Terminal airspace		
TMA1A	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA

TMA1B	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA1C	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA1C	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA2A	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA2B	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA2C	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA3A	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA3B	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA4A	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA4B	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA5B	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA6A	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA6B	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA7A	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA7B	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA8A	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA8B	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA9A	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA9B	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA-EXAM1	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMA-EXAM2	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
RMA-EXAM3	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
TMASIMPREP	ORGAPP_TMA	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
Sector West		
LDZO-W	ORG_WEST	ECHOES_DB_UNI
		ECHOES_DB_NOMONA

Sector Central		
LDZO-C	ORG_CENTRAL	ECHOES_DB_UNI
		ECHOES_DB_NOMONA
Sector South		
LDZO-S	ORG_SOUTH	ECHOES_DB_UNI
		ECHOES_DB_NOMONA

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