D3.1 – Human factors design principles for an en-route digital assistant

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Abstract

This deliverable provides the use case definition of a digital assistant designed to support en-route air traffic controllers (ATCOs) with AI-driven functionalities to improve situational awareness and reduce workload by assisting with routine tasks. The document examines the introduction of higher levels of automation in en-route air traffic control operations from a human-centric perspective. The goal is to ensure that technology is adapted to enable safe cooperation between air traffic controllers and automation technology while prioritizing user requirements and human factors research. The potential benefits of increased automation in en-route operations are outlined, including increased capacity and support for ATCOs dealing with increasingly complex traffic. On the other hand, the

potential drawbacks of automation such as skill degradation are acknowledged and emphasized to be considered in both the development stage and the subsequent validation and evaluation process of the tool. This analysis has been conducted using the Human-Factors design principles framework currently being developed by the SafeTeam consortium, which at the time of this deliverable consists of three main phases: system model and mapping model, and implementation. The first phase aims to develop an understanding of the system components and their interactions, as well as the necessary contextual factors. The second phase seeks to generate a task allocation that optimises the performance of the human-automated system, preventing potential risks. The third phase consists of applying the results of the previous phases and designing efficient, effective and satisfactory solutions, avoiding potential problems arising from automation.

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Introduction

In this deliverable, the introduction of higher levels of automation in the en-route air traffic control operations is analysed from a human-centric approach. The user requirements, together with human factors research on the subject are placed at the core of the technology, that should be adapted to enable the safe cooperation between air traffic controllers and automation technology.

In the en-route environment, much higher levels of automation could be applied in certain traffic situations. Such increased automation would enable further capacity for ACCs and UACs. Furthermore, with the amount of air traffic expected to increase significantly in the future alongside new means of air transport, the complexity of air traffic will also increase. To ensure that the human ATCOs can keep focus with increasing complexity, the introduction of highly reliable automation for the handling of simpler scenarios and tasks will be indispensable. However, a seamless human-automation collaboration will require more advanced and intuitive HMI solutions than what we have today.

There is a dire need for automation in en-route ATC, though such solutions often don't materialise because of the lack of intuitive HMI solutions. ATCOs only trust automation that is reliable and straightforward, which poses specific challenges to the research and development of new tools. On the other hand, the rather rigid roles in en-route control provide us with a suitable environment for the analysis of human performance implications of automation and its HMI representation. Furthermore, considering the amount of en-route control centres in the world (more than 250 ACCs tasked to more than 150 countries), the conclusions from the en-route scenario would benefit a large audience, with substantial gains in terms of ATCO throughput.

New crew and team configurations based on two ATCOs will probably remain in charge of a sector (albeit larger sectors) owing to the third team member: automation. The planner (CC) will probably maintain an overview of the entire sector with the help of highly automated planning tools, while the executive (EC) and the automated agent will focus on the more ad-hoc traffic situations.

Potential external hazards such as the loss of certain (sub)systems (e.g. CPDLC) due to failures or cyber-attacks can render automation unreliable, coercing ATCOs to revert to an old modus operandi. Moreover, the concurrent occurrence of airborne emergencies can lead to an abrupt increase in ATCO workload unless automation can also provide support during such situations.

1 En-route digital assistant: Use case definition

1.1 The system

Air Traffic Control (ATC) is still a very manual task. Current technology requires air traffic controllers to monitor manually the airspace traffic, however do not provide any level of automation. This fact makes the system hard to scale, leading to capacity limits, airline delays and increases in fuel consumption and emissions. Current technology, including cloud-computing capabilities and Machine Learning technology is capable to support air traffic controllers in certain tasks like detecting potential conflicts among 2 aircraft or providing recommendations on **optimal separation** to increase capacity and minimize emissions. Introducing automation and AI technology into the operational room requires to fulfil with strict safety requirements that entail dedicated human factors research.

The first digital assistant to be analysed under the SafeTeam project is Victor5, an Artificial Intelligence digital assistant that improves airspace management efficiency. Victor5 is designed to assist Air Traffic Control (ATCO) and airspace managers in making informed decisions based on real-time and reliable recommendations, on how to organise the traffic in a given airspace sector. Victor5 is a digital assistant that is expected to boost Air Traffic Controller (ATCO) performance provided the necessary human factors requirements are met. It facilitates efficient airspace control and assists air traffic controllers in issuing instructions to aircraft to achieve highest levels of capacity, performance and safety. Ultimately, Victor5 might be used to improve airspace management and reduce airline delays, consequently reducing costs, fuel consumption and emissions whilst allowing more airspace capacity for new users, like drones and electric air vehicles. To fulfil this roadmap, a user-centric approach needs to be adopted, introducing the necessary requirements on the technology to meet their needs and ensure highest levels of usability and facilitate its adoption. Victor5 has been built over a secure data platform and conceived with several features to support different users' profiles.

Regardless the technology that supports the functionality, a digital assistant for air traffic control needs to meet certain basic requirements:

- Safety of use, adapted to the target level of autonomy, human supervision and verification.
- Validation of the technology, engaging the final user (ATCOs) at the different design and development stages to enable a gradual improvement.
- Adaptability to the existing technology and ATC procedures in order to achieve seamless integration in the operational room.
- Scalability to adapt to current and future traffic demands and sector configurations.
- Easiness for the regulator's approval and/or certification to be used in an operational environment.

The current section describes the system at the beginning of the project. The scope of this deliverable is to capture users' requirements, in terms of UX and expected use, and design principles in order to incorporate them into the system at a later project stage and validate those improvements to achieve a human-centric approach to automation in aviation.

1.1.1 Introduction of a disruptive AI feature in the ops room

The Victor5 solution

Running in a cloud-based secure data architecture, DataBeacon has developed proprietary algorithms to create a first version of a digital air traffic controller twin, Victor5. Building the solution by understanding the problem, has allowed DataBeacon to create the building blocks that allow deployment of assistant tools to the operations room. These building blocks are powered by proprietary algorithms that have been tested and validated.

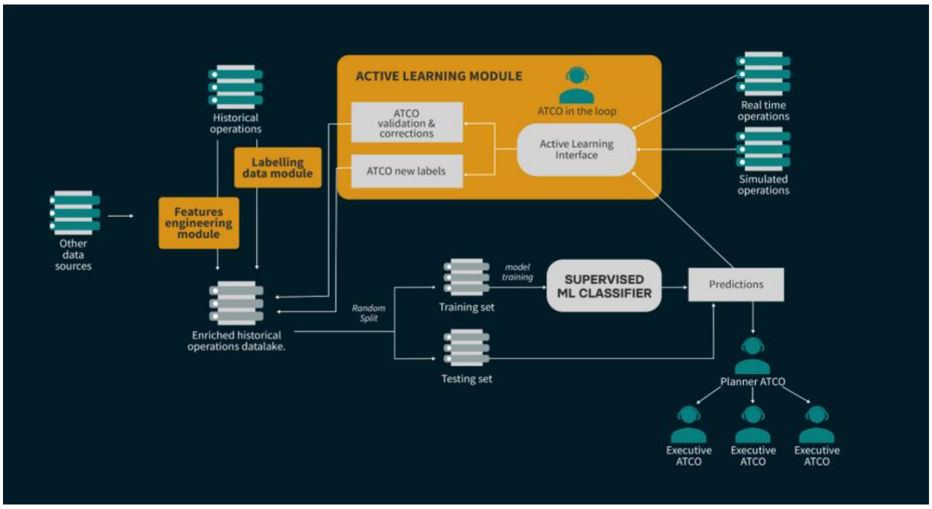


Figure 1 Victor5 pipeline

Victor5 currently offers the ATCO the following functionalities:

- **ADS-B based real time surveillance data**, including mode S, for Europe and the United States presented in an interface very similar to an ATC console, including speed vectors.
- **Interactive visualization:** Flight Levels can be filtered as well as zoom level adapted to the user needs. The interface is easily customizable to adapt to user's preferences.

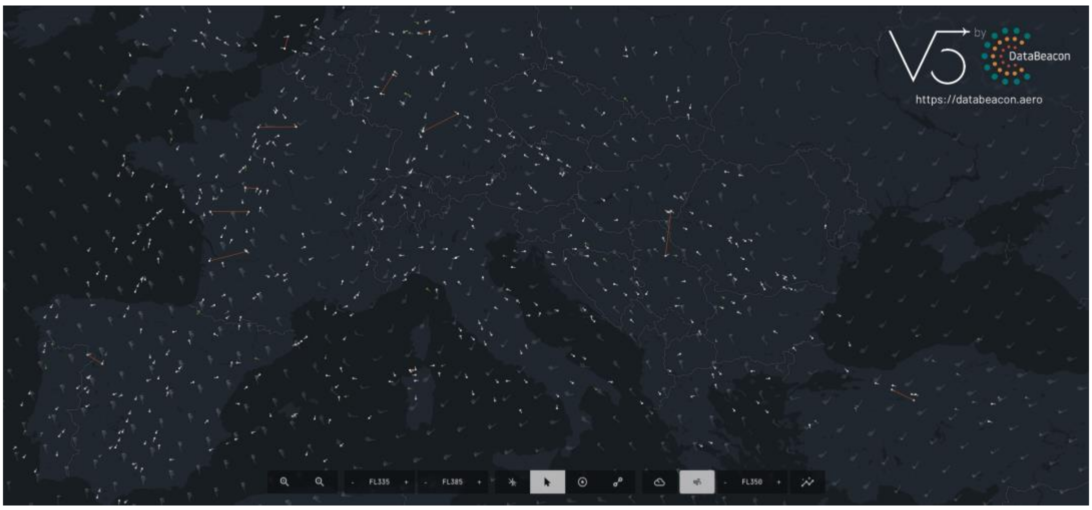


Figure 2 Victor5 HMI for surveillance data

- **PCDs: Potential Conflict Detection.** The distance among pairs of aircraft is continuously monitored by Victor5. Each pair of aircraft whose distance will be below 9NM along their trajectories is joint by an orange segment and a label is applied. The label indicates the current distance among the two traffics, the minimum distance that will be reached, and the time to the minimum distance or to lose standard separation, what happens first. Also, the aircraft crossing first is highlighted in orange. Applying H3 geospatial indexing, Victor5 optimizes the complexity of these computations for conflict detection and streamlines detection of entries in air sectors. If required, Victor5's conflict detection can easily be adapted to be used as MTCD (Medium Term Conflict Detection) or STCA (Short Term Conflict Alert).

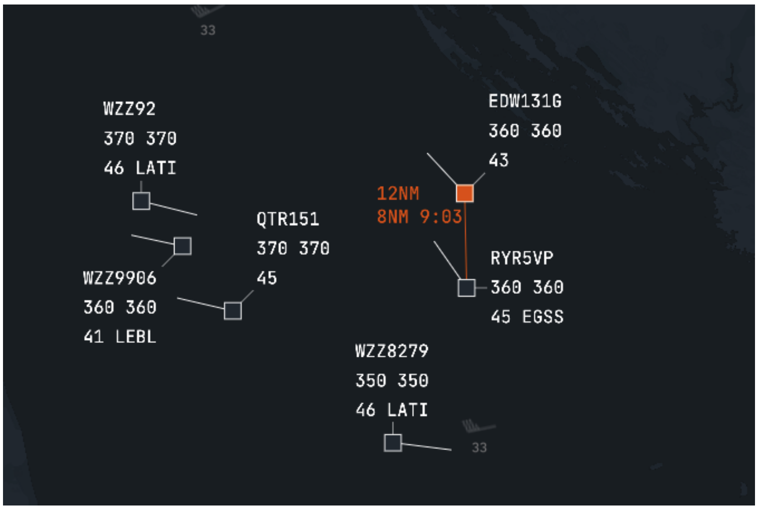


Figure 3 Victor5 PCDs representation

- **NCTs**: Non-Conflicting traffics. Traffics that are predicted to cross a certain sector without interfering with other traffics are marked in green. This conflict-free condition may change along the flight and the colour is marked accordingly.

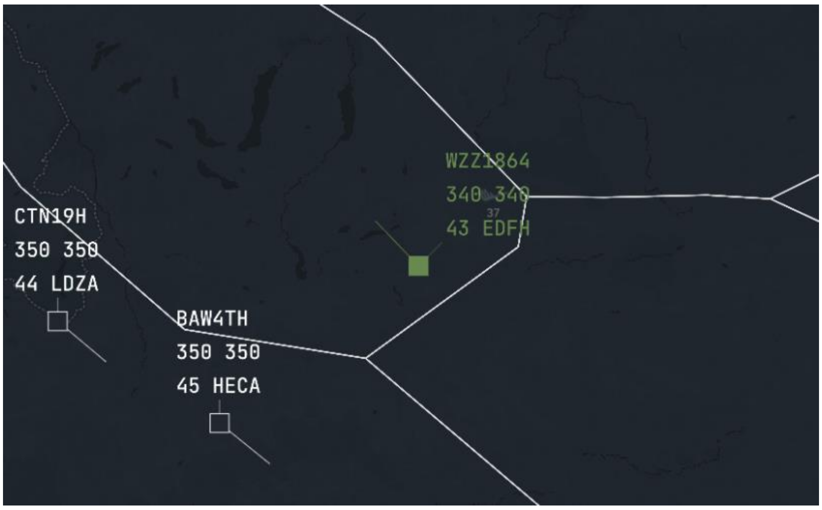


Figure 4 Victor5 NCTs representation

- **Wind map**: A wind map by flight level is integrated in Victor5. Wind intensity and direction is captured from the ADS-B mode-S obtained from aircraft crossing the airspace at that level and complemented by predictive models. Air traffic can be hidden by the user for this purpose.

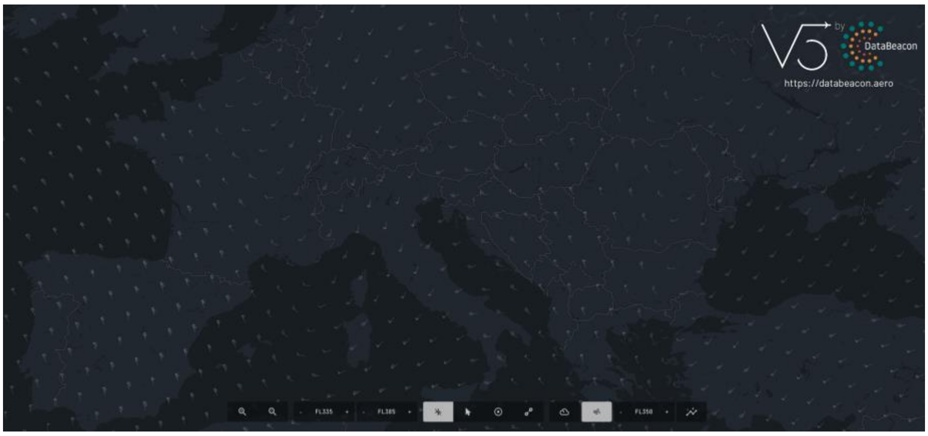


Figure 5 Victor5 Wind map representation

- **5 NM ring:** A 5 NM halo can be applied manually to any traffic to force monitoring the safety distance for that traffic.

Figure 6 Victor5 5NM halo representation

- **Forced PCD**: As in current ATC consoles, an ATCO can manually select two traffics and link them by an orange dashed-segment to continuously monitor its distance.

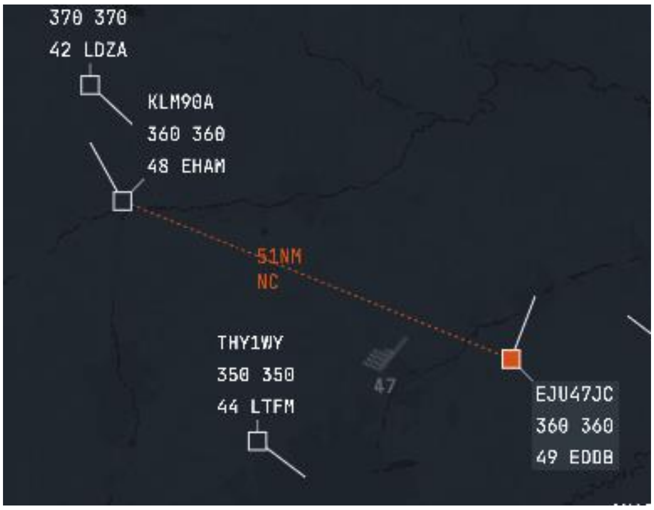


Figure 7 Victor5 forced PCD representation

- **Weather or third-party layers**: Victor5 is prepared to include additional useful information from third parties, such as weather storms.

1.1.2 The architecture

Victor5 is an application built over the DataBeacon BeSt cloud lambda architecture. BeaconStack, or BeSt, is the cloud computing infrastructure, capable of ingesting data (both historical and real time), labelling the data, running the machine learning models and finally, delivering the data and results of the models to the local layers. BeSt uses solid proven open-source tools, selecting the best performing technologies in every category. The technology stack has been chosen to address the hard challenges that an application like this requires, including:

- Providing a **consistent** view across clients despite asynchronous ingestion and parallel transformation*
- Incomplete or corrupt data and high availability that requires advanced platform **observability**, and
- **Problem complexity** that requires distributed computation cluster and custom, heavily optimized, segmented geospatial algorithms, for which there is no complete off-the-shelf solution in the market.

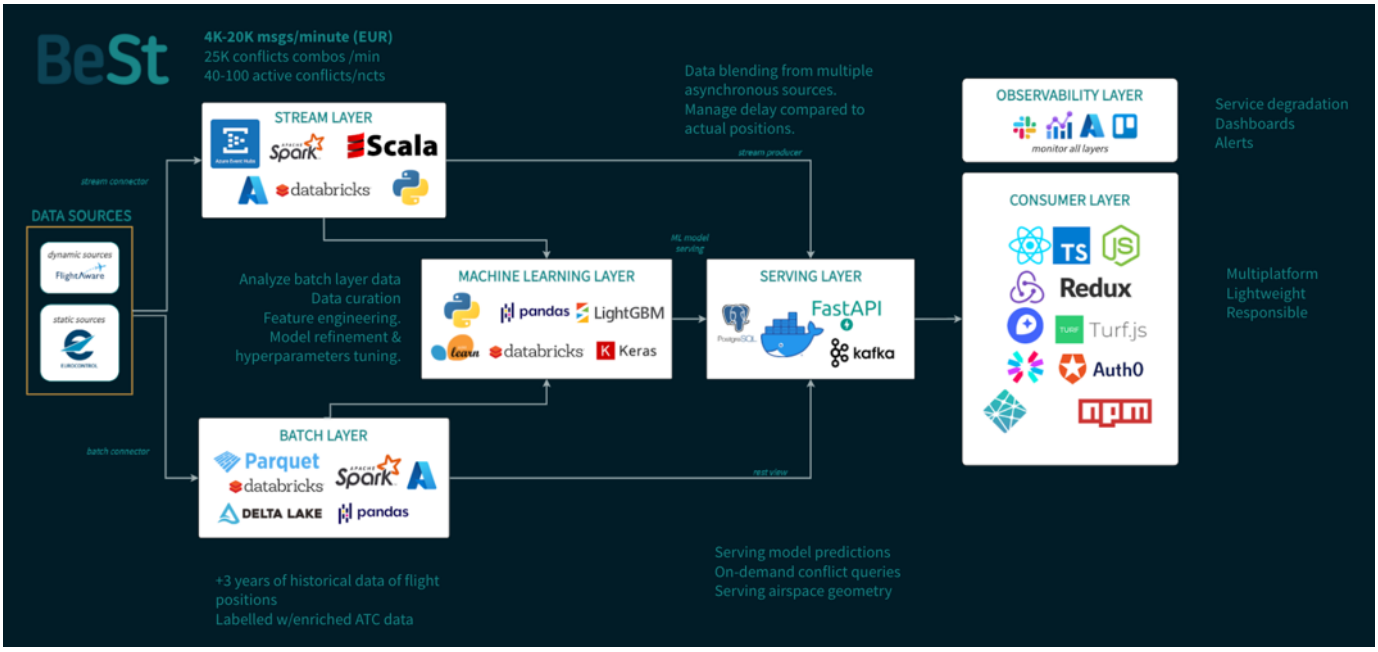


Figure 8 BeSt Architecture

1.2 The users

Different ATC profiles operate in an operational room, each of them with clearly identified roles, tasks and responsibilities. In this section, an overview of the main profiles is presented in order to provide a description of how an operational room performs. Understanding the users' profile is key to a correct definition of the use case and, particularly, to precisely define the interaction between the system, Victor5, and the user. The collaboration of the users will be requested to define the use case in order to achieve a smooth integration of the Victor5 digital assistant into the OpsRoom.

1.2.1 Air Traffic Control positions

The most common position setup in the operational room consists of two air traffic controllers per position, the executive and the planner. Both are responsible for the same sector, but they perform different and interconnected tasks:

- The **executive controller** is in charge of tactical tasks and the communication with aircraft, for instance, passing instructions and clearances for the correct use of the airspace, including traffic separation provision.
- The **planner ATCO**'s main responsibility is to coordinate with the neighbouring sectors and units, to anticipate potential conflicts and to cross-check the executive ATCO's actions.

In addition to the executive and planner controllers, an operational room typically includes a **supervisor** position. The supervisors are responsible of managing the ATC operating room (or part of it, depending on the complexity of the room). They are the ATCOs responsible for the resources allocation, including the adequate distribution of the other controllers in the sectors with a balanced workload, the opening or closing of sectors and the identification of non-nominal conditions in the common operation.

On top of the above, ATC needs **managers**, with or without ATC licenses, who are able to look ahead in the future to improve procedures, to accommodate new equipment, to plan the request of personnel for the next years, or to investigate hazardous events to increase the safety of the operation. These ATC managers need excellent data to be able to fully understand the scenarios during different periods of time.

1.2.2 Victor5 potential uses

Victor5 functionalities have been originally designed targeting different applications for different users. The diverse usages of the Victor5 platform have considered not only the currently assigned tasks for each of the ATC profiles but also the challenges for the adoption of increasing levels of automation in a safety-critical environment like an operation room is. The first use cases for Victor5 to be introduced in the OpsRoom should ensure a gradual and collaborative incorporation of this new technology, demonstrating a fruitful ATCO-Victor5 cooperation.

The use cases described below present those foreseen during the development of Victor5. In the next section, the users will be asked to validate and rank these use cases and to suggest other potential applications not initially foreseen. The conclusions will be presented in the Conclusions section.

- **Victor5 for planner air traffic controllers**

Considering the criticality of the executive controller function and the applicable regulatory framework for legacy systems, training and procedures, Victor5 focus on the multi-sector planner position (MSP). Victor5 gives the planner additional information complementing the traditional ATC console (e.g. an automatic MTCD (Mid Term Conflict Detection) or potential conflict resolutions to be ultimately approved by a human controller). These functionalities are offered to the planner before the interaction happens (so not a tactical or urgent task is needed) so the information can be understood and transmitted to the adjacent controller or the sector's executive controller directly. Also, Victor5 provides information about Non-Conflicting Traffic (NCTs), which can be pinpointed to the executive controller if it is considered relevant. Victor5 is considered for the Multi Sector Planner (MSP) position, offering a mid-term conflict functionality away from the ATC console. In order to do this, the NSCAS (Non-Safety Critical ATM Screen) allows an entry point. This is a good opportunity for Victor5 to introduce a disruptive AI feature in the ops room that is compatible with the existing procedures and equipment.

The MSP technology will be gradually improved to achieve further capacity gains and costs reductions, but those business opportunities can only be explored by first introducing AI technology into the operational room. Victor5 may help to move from a mono-sector planner configuration to a multi-sector planner one, improving the operational efficiency, providing higher scalability and mitigating the current problems associated to the lack of ATC capacity. During this phase, Victor5 performance will be allow for usage in an operational environment but under human supervision, as the system will learn from deviations detected by the planner ATCO.

Once the MSP position has been accepted and run in the operation room for a period of time, the logical evolution will be the auto-planner. Some ANSPs (e.g., LFV) have agreed that this is their ultimate goal. Suppressing the human supervisory role on the planning function will require a mature technology proven over a number of years in the operational room.

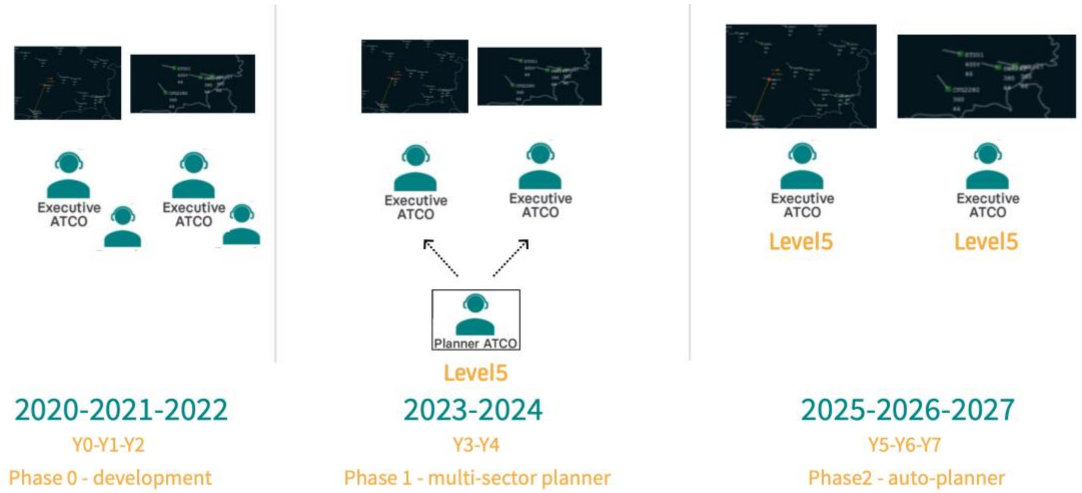


Figure 9 Victor5 roadmap

The MSP will serve from 2 to 4 upper sectors with the mission of advancing possible conflicts and recommending the best solutions, when necessary, assisted in both functions by Victor5.

In order for Victor5-MSP to properly support the MSP, the conflict detection algorithms will have to anticipate potential conflicts at a predefined time or distance before they actually occur. Different time-windows (or distance-windows) will be necessary depending on the concrete MSP position.

The MSP position will include the same control system that the executive controllers are using. Additionally, the MSP will use the Victor5-MSP screen (possibly as part of the NSCAS) and the standard communication set with the adjacent units and involved sectors. The solutions provided by Victor5-MSP will be validated by the human MSP in the Victor5 screen. After that, the MSP will propose the solution to the executive ATCO or inform him if the solution has already been executed by coordination (depending on local procedures, the MSP can overwrite the electronic label of the control system).

- **Victor5 for supervisors**

Victor5 may also be customised to serve the **supervisors** as a mean to increase their situational awareness of the future incoming traffic. With a quick glance, the supervisor can see that, for instance, one specific sector will be specially challenging the next period of time as Victor5 displays several conflict alerts. Victor5 also integrates a weather layer showing storms, their positions, altitudes and strengths, to anticipate possible traffic deviations.

The detection by Victor5 of potential conflicts and non-conflicting traffic, fed with a wind and weather layer and sectorization information, provides a much precise information about the actual workload than the metrics and tools currently available (mostly based on entry counts). By adding predictive capabilities, this information can be presented to the supervisor to have a reliable forecast of the demand and traffic complexity in the next blocks of time (e.g., in the next 20 minutes, 20-40min or 40-60min). Developing personalized dashboards for the supervisor would enable a better allocation of the resources available and better sectorization.

- **Victor5 for ATC managers**

Victor5 provides real time traffic information and functionalities, however, post-analytical tools can be offered that are specially interesting for managers as they will be able to easily replay traffic scenarios and track:

- The evolution of the ACC efficiency by comparing FPL distance with actual distance flown in different periods of time.
- The suitability of new traffic configurations in terms of capacity balance (what-if scenarios).
- The overall ACC performance by the aggregate analysis of the separation instructions given, avoiding being too close or too far from the minimum legal separation (5NM in en-route).
- The fuel efficiency of the ACFT in different periods of time. Based on the exact trajectories, flight levels and aircraft type, Victor5 can easily create models to aggregate fuel consumption data.

2 Users' requirements

2.1 Requirements capture methodology. User test Victor5 v1.0.0

This section describes the testing of Victor5 digital assistant by ATC users for air traffic operations.

For 21 days, participants were able to use the Victor5 platform, **10 ATCOs** and **3 Supervisors**. After receiving an informative and descriptive e-mail, participants interacted with the functionalities offered by the Victor5 individually.

The results obtained indicate that Victor5 v1.0.0 presents a design with a very good usability and an excellent user experience, enjoying great acceptance by ATC professionals.

Evaluation period: 19th January to 8th February 2023

Report compliant with ISO/IEC 25062, common industry format for Usability Test Reports (DIS, ISO).

2.1.1 Background and context

2.1.1.1 Analysis background

Victor5 is not an Air Traffic Control system but an additional support system to the current ATC consoles. It displays real-time data of air traffic in Europe and USA. Victor5 is designed to be used in a variety of scenarios within the ATC environment. For example:

- By the ATC supervisors to anticipate workload.
- For planner ATCOs to support coordination with adjacent ACC units.
- For executive ATCOS, as a support tool, providing an accurate MTCD with real wind data.
- For everyone in the ATC OpsRoom, as a transition-to-contingency resource in case of major radar/console failures and other adverse events.
- For ATC managers as a smart post-analysis tool.

The diverse usages of the Victor5 platform have considered not only the currently assigned tasks for each of the ATC profiles but also the challenges for the adoption of increasing levels of automation in a safety-critical environment like an operating room is. The first use cases for Victor5 to be introduced in the OpsRoom should ensure a gradual and collaborative incorporation of this new technology, demonstrating a fruitful ATCO-Victor5 cooperation.

2.1.1.2 User analysis and use environment

Victor5 is intended for ATC profiles. Different ATC profiles operate in an OpsRoom, each of them with clearly identified roles, tasks and responsibilities. Understanding the users' profile is key to a correct definition of the use case and, particularly, to precisely define the interaction between the system, Victor5, and the user.

The most common position setup in the operating room consists of two air traffic controllers per position, the executive and the planner. Both are responsible for the same sector, but they perform different and interconnected tasks:

- The **executive controller** is in charge of tactical tasks and the communication with aircraft, for instance, passing instructions and clearances for the correct use of the airspace, including traffic separation provision.
- The **planner ATCO**'s main responsibility is to coordinate with the neighbouring sectors and units, to anticipate potential conflicts and to cross-check the executive ATCO's actions.

In addition to the executive and planner controllers, an OpsRoom typically includes a **supervisor** position. The supervisors are responsible of managing the ATC operating room (or part of it, depending on the complexity of the room). They are the ATCOs responsible for the resources allocation, including the adequate distribution of the other controllers in the sectors with a balanced workload, the opening or closing of sectors and the identification of non-nominal conditions in the common operation.

On top of the above, ATC needs **managers**, with or without ATC licenses, who are able to look ahead in the future to improve procedures, to accommodate new equipment, to plan the request of personnel for the next years, or to investigate hazardous events to increase the safety of the operation. These ATC managers need excellent data to be able to fully understand the scenarios during different periods of time.

Victor5 functionalities have been originally designed targeting different applications for different users.

2.1.1.2.1 User characteristics

The personnel who offer services in the context of Air Traffic Control are highly qualified professionals with the following skills and competencies:

- Mental agility to process information and ability to provide effective responses in a short space of time.
- Orientation in space.
- Abstract reasoning.
- Concentrated and divided attention.
- Stress self-control.
- Ability to coordinate in operational situations.
- Ability to analyse and make decisions in a short space of time.
- Ability to work as a team.
- Maturity and emotional stability and resistance to fatigue.

2.1.1.2.2 Features of the devices used

Each user was free to use the Victor5 HMI on their preferred tablet, laptop or desktop device.

2.1.1.3 Limitations

No notable limitations in the report.

As general objectives, we propose:

- Make a usability report with real users in a non-real controlled environment to obtain preliminary data on the perceived ease of use of Victor5.
- Know the opinion of real users about the design characteristics of Victor5.
- Know the opinion of real users about the acceptability of the Victor5 solution as an option for their work environments.

2.1.2 Methodology

The methodology has been designed by DataBeacon's Human Factors and User Experience Team. This methodology has been carried out based on professional criteria in the field of Human Factors Engineering and good practice guidance.

Questions are intentionally clustered in four groups to facilitate further analysis and extract usability metrics. Particularly:

- **Respondent profiling**: aimed at understanding the level of experience of the responders and the ATC roles they have performed.
- **System Usability**: aimed at quantifying the Victor5 usability metric.
- **Interface**: to evaluate the design aspects of the interface.
- **Digital Assistants**: analysing the potential uses of digital assistants in ATC and its suitability for the different applications.

2.1.3 Participants

13 users have participated in a non-real context but with real life traffic. The participants in the test have been recruited by DataBeacon with the collaboration of IFATCA (International Federation of Air Traffic Controllers' Associations). All the participants are active Air Traffic Controllers from all over of the World. Of the 12 valid participants, 10 usually play the role of Air Traffic Controller and 2 of Supervisor. Its general characteristics are listed in the following table:

2.1.3.1 About the participants

Table 1 Participants general characteristics

Users	Age	Current main role	Experience in ATC operations
User 1	51-55	ATCO	>16 years
User 2	51-55	ATCO	>16 years
User 3	51-55	Supervisor	>16 years
User 4	51-55	ATCO	>16 years
User 5	51-55	ATCO	>16 years
User 6	46-50	ATCO	>16 years
User 7	51-55	Supervisor	>16 years
User 8	56-60	ATCO	>16 years
User 9	41-45	ATCO	>16 years
User 10	36-40	ATCO	11-15 years
User 11	46-50	ATCO	>16 years
User 12	26-35	ATCO	11-15 years

2.1.3.1.1 Age

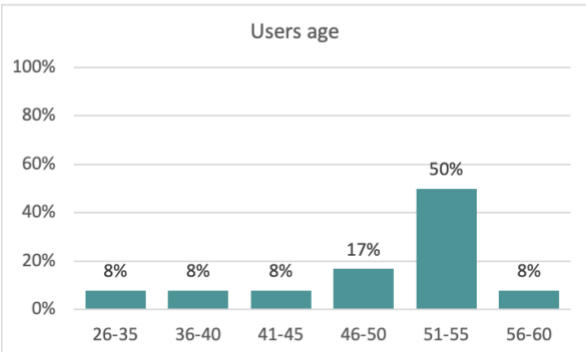


Figure 10 "User age" statistics

The age of participating users ranges from 26-35 to 56-60 years old, the most frequent range being 51-55 years old.

2.1.3.1.2 Role

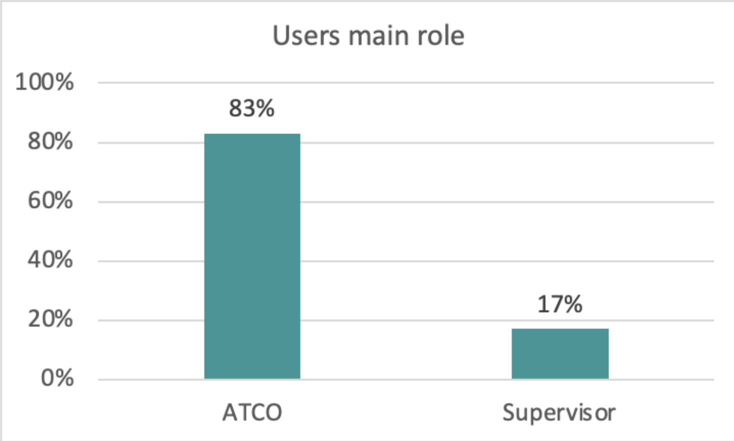


Figure 11 . "Users main role" statistics

83% of participating users have a main role as ATCO and 17% have a regular role as supervisors.

2.1.3.1.3 Experience

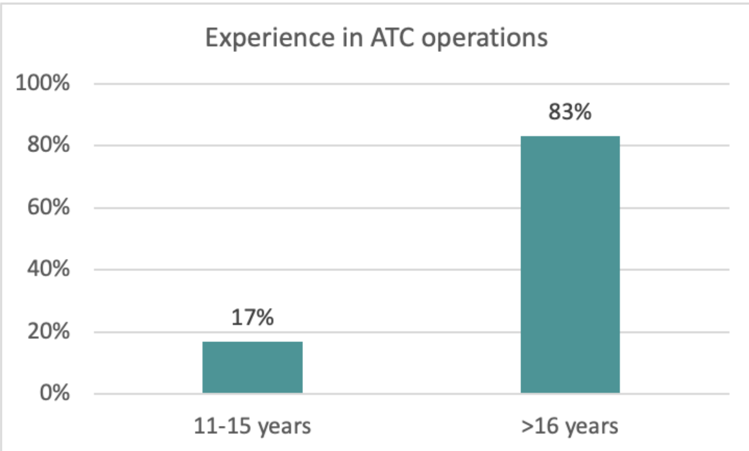


Figure 12 "Experience in ATC operations" statistics

83% of participating users have more than 16 years of experience while the remaining 17% have between 11 and 15 years of experience.

2.1.4 Trials execution

DataBeacon acted as the organiser of the recruitment of users for the test. An explanatory email was designed to describe both the purpose of the test and the access to the Victor5 HMI. This email with a brief Victor5 manual and the details of the test was sent to a database of active air traffic controllers in coordination with IFATCA. Participation in the tests has been voluntary. The collection of the data has been carried out through a questionnaire prepared for the occasion and which has been layout using Google Forms.

2.1.4.1 Environment

There was no restriction on the environment during the trial. It was the collaborating users themselves who chose the place and the time to carry out the evaluations.

2.1.4.2 Tasks to perform

In the instructions sent by DataBeacon, after an explanation of the objective and the description of Victor5, users were asked to "play" with the platform and then answer some questions related to the digital assistant.

2.1.4.3 Device

Each collaborating user employed their own device.

2.1.4.4 Procedure

The procedure carried out in this test with users was:

1. Construction of questionnaire and instructions.
2. Sending email based on data of potential users.
3. Completion by the collaborating user.
4. Reception and analysis of the data provided by users.
5. Preparation of a report of results and conclusions.

2.2 Questionnaire results. Users' requirements for an en-route DA

The results obtained for this report have been based on quantitative metrics where the perception of use by users was collected. These metrics have been obtained through the completion of the different questionnaires provided to users (see Appendix) along the questions blocks defined on the methodology (section 2.1).

2.2.1 Metrics

2.2.1.1 System Usability Scale (SUS)

SUS is one of the few standardized validation tools in the world of usability (Brooke 1986). In this case we have included it in the evaluation procedure after the completion of the tasks proposed to the user and for each app. The SUS tool, used to measure the usability of interactive systems, has a standardized cutting criterion where the usability of the evaluated system is scored. This scale considers a score of 68 as the indispensable minimum that a system must have, evaluating with an Anglo-Saxon academic scale the "quality" of the usability of the system.

According to the responses provided by users, the digital assistant Victor5 has obtained a score of 75 points out of 100. This result qualifies as a B at the SUS scale.

We can see it in the following figure:

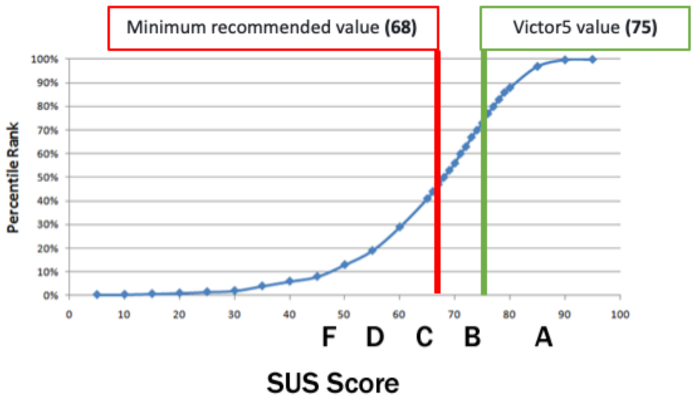


Figure 13 Victor5 SUS Score assessment

2.2.1.2 About HMI elements

The HMI elements questionnaire, or the questionnaire about Victor5's interface, is made to collect the opinion of users about the different elements that make up the interface, as well as its features. This questionnaire collects the user's opinion using a Likert scale where 1 is totally disagrees and 5 is totally agree.

This are the results:

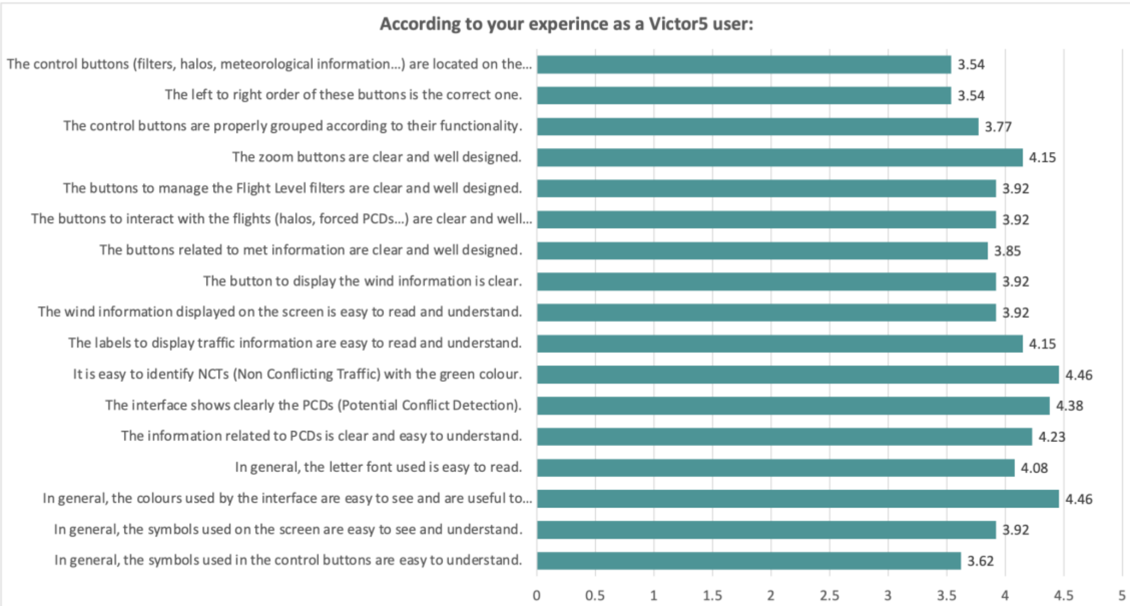


Figure 14 Results questionnaire "According to your experience as Victor5 user"

2.2.1.3 About digital assistants' efficiency

The About-digital-assistants'-efficiency questionnaire aims at collecting the opinion of users on specific functionalities of the digital assistant, as well as the perceived likelihood of being used in ATC.

The questionnaire is divided into two parts. The first part is linked to the suitability or usefulness os Victor5 for the different ATCO positions. The second part evaluates the respondent's opinion on each of the functionalities offered. It uses a Likert scale where 1 is totally disagrees and 5 is totally agree.

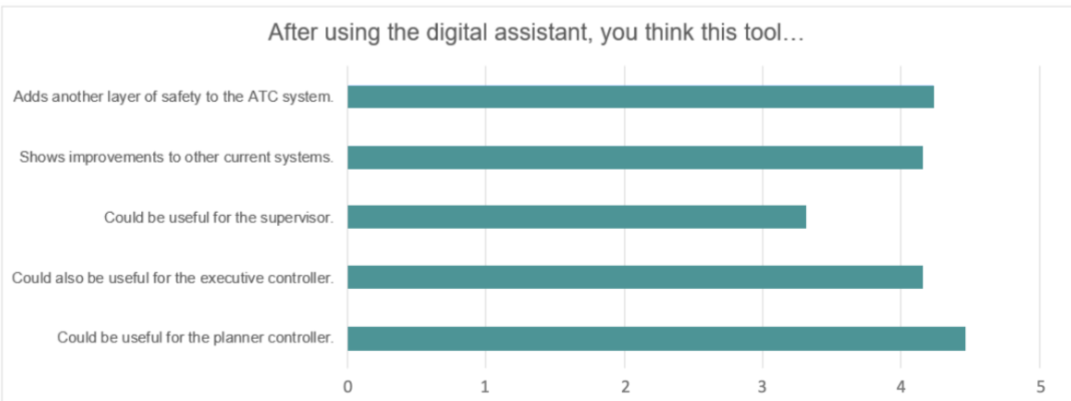


Figure 15 Results questionnaire "After using the digital assistant, you think this tool..."

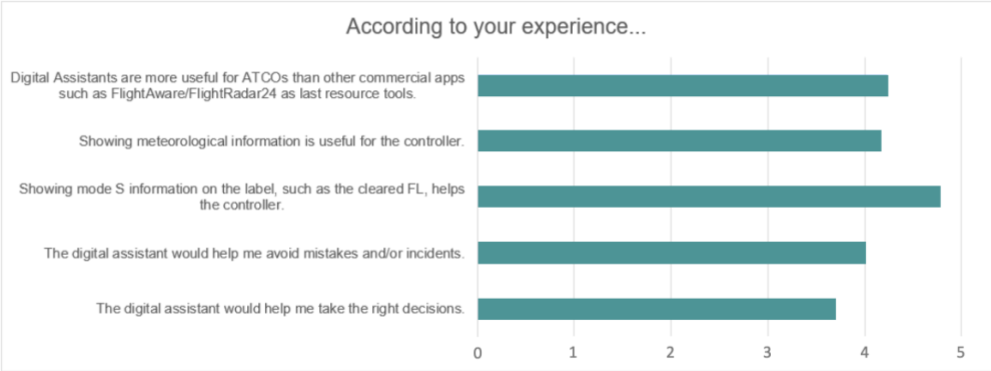


Figure 16 Results questionnaire "According to your experience..."

2.2.1.4 Net Promoter Score (NPS)

The Net Promoter Score (NPS) is an indicator to measure customer loyalty to a trademark (Reichheld 2003). It is based on a single question: "How likely are you to recommend the product or service to a family member or friend?" To answer this, they are asked to qualify on a scale from 0 to 10, where 0 is "Very unlikely" and 10 is "I would definitely recommend it."

The Net Promoter Score for Victor5 v1.0.0 is collected on the following graphs:

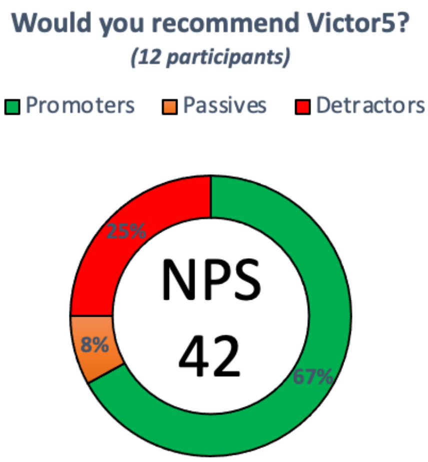


Figure 17 "Net Promoter Score (NPS)" results

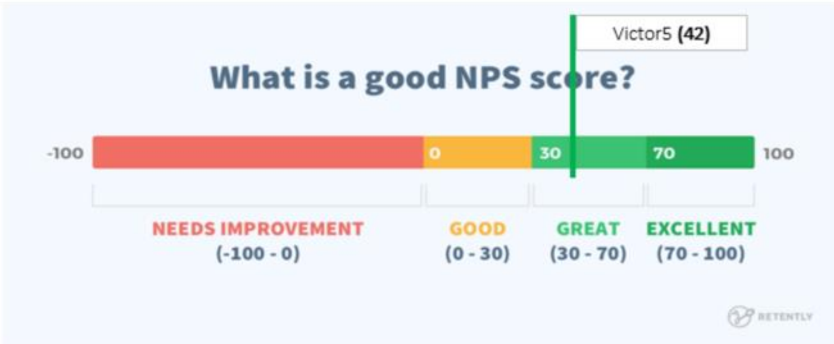


Figure 18 "Net Promoter Score (NPS)" assessment

2.2.2 Additional feedback

In addition to the closed questions, participants were given a text box to express additional comments through free responses. In order to protect the confidentiality of the replies, the replies are presented below in an aggregated manner per block of questions.

- **Comments about the HMI**

The HMI was considered to have a very clean design and easy-to-use as it is similar to their consoles, although some respondents declared to need some additional training to make the most of it.

The following comments were received suggesting potential improvements if Victor5 was to be used at an executive position:

- Use additional colours to highlight labels under control
- Zoom and filters buttons should not be needed if used in an executive position
- Identify point of crossing or minimum distance.

The current Victor5 version does not plan to be used by the executive or planner but for supervisors and post-analysts. Also, Victor5 is not expected to be integrated in the console. Accordingly, these comments are not applicable at the current stage but should be considered in case the executive position was targeted. Related to identifying point of crossing or minimum distance, this is already displayed. Probably more training could be needed to explore the full potential of the HMI.

- **In general, what is your opinion of this HMI (Human-Machine-Interface)?**

The HMI was very positively evaluated (excellent, very easy to use, clear and clean…) and was considered intuitive. As in the previous question, some of the respondents were evaluating Victor5 considering it as a tool for the executive controller. While this use was explicitly excluded from the potential applications of Victor5 (in the short-medium term), those replies are collected below for completeness:

- Include the possibility to add instructions.
- Even though most of the participants found the number of PCDs well balanced, some found it too high. This is related to the establishment of 9NM monitoring separation and the time parameters as triggers to display the PCDs. These variables can be adapted to the user's need.
- The current version is not considered suitable for an executive position as controllers lacks some of the tools they currently use to separate.
- Possibility to adapt the zoom at sector level to display just the portion of the airspace that the executive is controlling.

- **Do you consider digital assistants a technical improvement for ATCOs?**

The 13 participants replied YES. Some of them stated that they saw a special interest for contingency and post-analysis, adding an additional security layer.

- **If you had to describe Victor5 to a colleague in 1 or 2 sentences, what would you say?**

The most popular features highlighted in the description and the commonalities found among them are:

- Basic ATC system offering more advanced functionalities than the common ADS-B interfaces but less sophisticated than an ATC console, especially interesting for contingency applications in case of radar failures.

- The active detection of potential conflicts and non-conflicting traffic is considered an added value.

- **What do you like the most about Victor5?**

Eight (8) of the thirteen (13) participants consider the automatic conflict detection the most interesting feature of Victor5, providing conflict alerts to controllers. One controller also highlighted the wind layer and its integration in the calculations as an added value of Victor5.

- **What do you like the least?**

Most of the respondents considered the main drawback of Victor5 the lack of a functionality that allows centering the screen on their particular sector, being able to differentiate the assumed traffic under their responsibility. The default zoom was considered too large for them (as they were considering an executive controller application). Some other shared the opinion that the possibility to enter data (e.g., their own instructions) should be added, even enabling integration and/or interaction with the ATC system. One of the participants declared no trust on the system.

- **If you had the chance, what would be the first thing you would change in these tools?**

The replies received for this question is linked to the previous question: selecting/highlighting traffic on their frequency and pre-define sectors, insert clearances. It was also mentioned the need to integrate Flight Plans.

Some other concrete improvements mentioned include:

- Flight level filter could be faster and more convenient.

- The link of the label can be confused with the speed vector.

- Possibility to hide or filter non-conflicting traffic labels.

- Zoom should not change tag's size.

- Enable a filter to hide all flight paths.

- Enable the possibility to show the tag even in a zoom-out display.

- The indication that the handcuffs have been fixed to a given flight should be shown in the symbols of the aircrafts.

- Need to be displayed in a larger screen.

- **Is there anything you miss in Victor5?**

Most of the replies received are consistent with the 2 previous blocks of questions and answers (integration and interaction, mainly). The only new input received was that Victor5 was considered a tool to be used for short periods of time, so the application should be adapted to this restriction, in his/her opinion. Additionally, it was again mentioned the need to include additional sources of data (e.g., flight plans).

- **About PCDs (Potential Conflict Detection), do you find the parameters are adequate?**

12 out of 13 participants responded positively to this question. In addition, two participants stated that they found too many alerts and suggested to reduce the threshold to 8NM.

- **Do you find the HMI shows too many or too few PCDs?**

Nine ATCOs found the quantity of the PCDs was well balanced while two considered them too many. For another two, it was too early to say and form an opinion.

- **Is there any other remark you would like to tell us about digital assistants?**

Two of the participants added in this text box that Victor5 should be a good option for a contingency scenario. Another one added that this technology is promising and could be a game changer for air traffic control.

2.2.3 Conclusions and recommendations

2.2.3.1 Conclusions

Based on the results obtained, we can conclude that the Victor5 digital assistant has a design with a usability that is approved by the users who have tested it.

We found great product promotion data among users of the Victor5 digital assistant to other professionals.

The display of mode-S data is highly appreciated by users as an added value of Victor5.

Users consider Victor5 digital assistant a more useful tool than other commercial apps such displaying ADS-B information. In addition, they consider the weather information layer a very useful asset for controllers.

Victor5 is considered a functional system complementing existing ATC systems and adding an additional security layer to their operations.

As for the use of the Victor5 by other than aeronautical management professionals and supervisors, users consider that this digital assistant could be very useful for the day-to-day of the planner controller and the executive controller.

Although in general good results have been obtained, there is room for improvement in terms of the assessment of usability by users. Continuing to apply the design and research methodology based on Human Factors Engineering will allow progress in achieving better metrics related to this area.

2.2.3.2 Recommendations

Incorporating human factors design expertise in the next upgrades of Victor5 would enable an improved user experience.

By analysing in depth, the scores obtained by the different functionalities, together with the adoption of human factors design principles, upcoming versions will be able to improve its weakest points and provide improved functionalities.

By analysing the responses on the suitability of the proposed uses cases and applications, Victor5 can focus on the application that would enable a more seamless integration in the operational room and address users' challenges.

3 Human factors design principles for en-route digital assistants

3.1 HF Design principles: general framework

The current expectations for digital assistants for traffic control rooms (https://www.sesarju.eu/news/full-sesar-3-ju-multi-annual-work-programme-now-published) include a number of features that provide automatic monitoring of the traffic situation, detecting potential conflicts among pairs of aircraft as well as identifying those traffic that are predicted to cross a sector without interfering with any other traffic. Advanced features like providing recommendations about how to monitor and manage workload, assist in emergency situations, traffic coordinations with others sectors and ultimately, provide recommendations on how to separate tactical traffic are concepts that are now being discussed in the context of applicability of AI to ATC operations. These tasks are currently performed using low automated procedures and technology, as air traffic controllers manually monitoring the position, flight level and trajectory of the aircraft on their Controller Working Position screen, lacking even simple conflict detection anticipation (except for short term conflict alerts).

Current technology is based on local equipment with limited computing capacity that would not allow the automatic distance monitoring among pairs of aircraft enabled by modern cloud platforms by benefiting from computing scalability, either using a remote cloud, edge computing or a hybrid computing paradigm. While a potential final vision for digital assistants would be that they provide recommendations to air traffic controller to solve tactical conflicts among traffics and instructions are updated through CPDLC after the human ATCO has approved even after the ATCO has not vetoed the decision after certain time (Level 6, see figure 19), human factors research have to find the way to validate that the controller has the skills and knowledge to review and accept the instructions.

A SCALE OF "LEVELS OF AUTOMATION"

1. Computer offers no assistance: human must do it all
2. Computer suggests many alternative ways to do the task
3. Computer prioritizes alternative ways to do the task
4. Computer recommends one way to do the task
5. Computer executes that recommendation when and if the human approves
6. Computer allows a restricted time for human veto prior to automatic execution
7. Computer chooses a method, executes and necessarily informs the human
8. Computer chooses a method, executes and informs the human only if requested
9. Computer chooses a method, executes and ignores the human

Figure 19 Scale of levels of automation (Parasuraman et al. 2000).

Therefore, in order to safely incorporate higher levels of automation, collaboration among human factors experts, users and technology developers is essential. The human factors perspective **should guide the adoption of automation technology in order to maintain, or further increase, current levels of safety and performance.**

Human factors experts are developing in SafeTeam WP2 a step-by-step guide for human factors design principles supporting developers in the definition of the appropriate levels of collaboration and distribution of tasks between humans and technology. In this section, the current (still preliminary) version of the guide will be applied to the en-route digital assistant. The results of these application will serve a double purpose:

1. Derive a number of requirements for the digital assistants' concepts in order to ensure a safe and efficient collaboration between controllers and Victor5. The requirements derived, together with those collected from the users (Section 2), will be collected, and prioritized at a later stage, for its implementation in the upgraded versions of the DataBeacon Victor5's platform. Higher levels of automation for the different tasks shall be carefully considered and designed taking into account the human factors principles together with the users' feedback in terms of technology usage and adoption.
2. Provide feedback to WP2 on the applicability of the current version of this guide to facilitate an iterative cycle of improvements in the final version of the document that shall be again tested in the other two SafeTeam use cases.

The preliminary version of the **SafeTeam HF Design Principles framework** can be seen in figure 20. The framework is currently being developed with the aim of enabling the efficient and effective development of automation systems through a **human-centric approach**. The framework draws from existing ones and emphasizes close collaboration among stakeholders, as well as early evaluation and feedback of human factors design principles throughout the development process. By frequently evaluating concepts, development costs can be reduced and potential design issues that may result in automation and interaction issues can be identified.

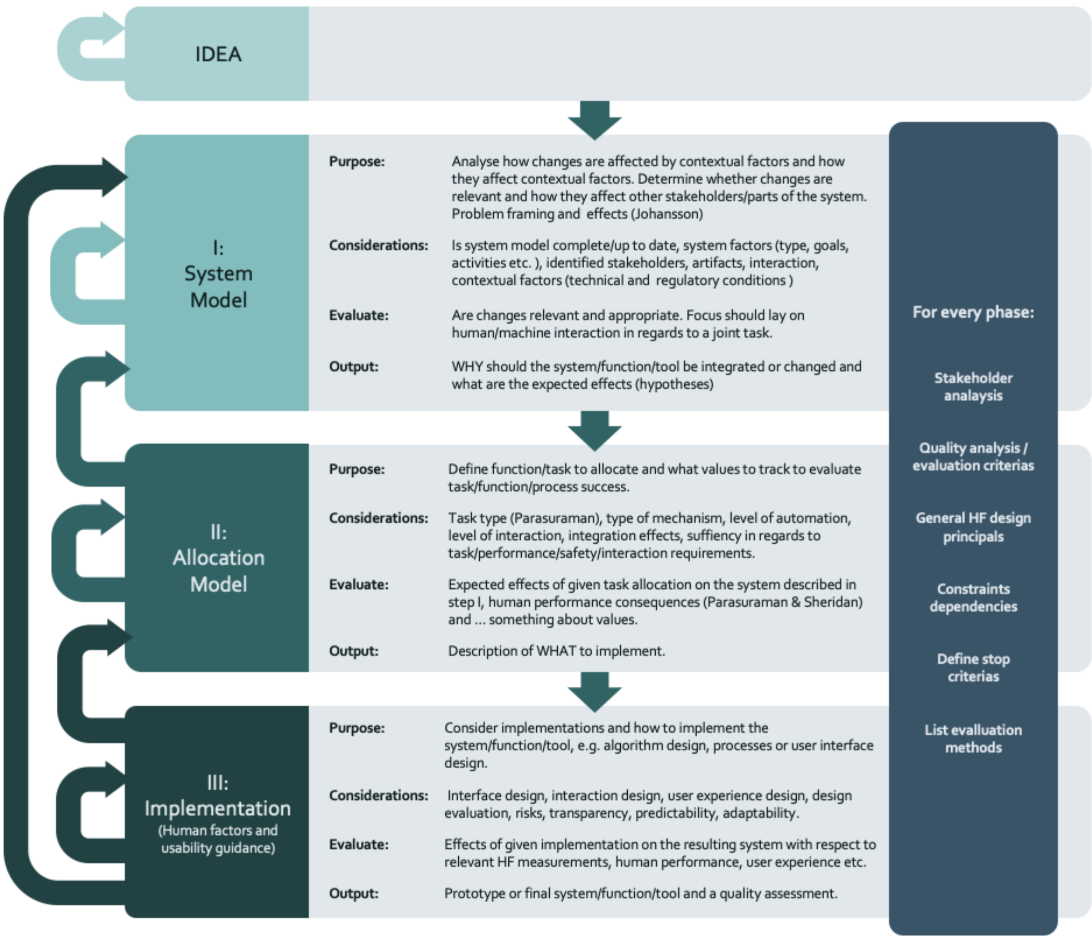


Figure 20 SafeTeam preliminary HF Design Principles framework

The proposed framework suggests an idea generation phase followed by **three analytical phases** when incorporating an idea into a system or designing an entirely new system.

- **Idea:** The proposed idea could be an update of the current system or the introduction of new functions within the already existing system. The ideas can come from several different sources (e.g., end users, product owners, regulatory experts or system designers).
- **System Model:** This first phase aims at developing an understanding of the system's components and their interactions, as well as contextual necessary factors. It also indicates how the idea would affect the system and vice versa
- **Allocation Model:** The second phase objective is to generate a task allocation that optimizes the performance of the human-automation system, while also preventing possible risks. This allocation can either be based on the outcome of the previous step or entirely determined in this step. The chosen allocation's effects should be carefully evaluated to avoid possible issues such as decreased situational awareness and work overload
- **Implementation:** The third phase aims to apply the findings from the previous phases and decide how to accomplish the identified goals. The development team aim on designing solutions which are e efficient, effective, and satisfactory, while also avoiding potential issues that may arise due to automation, such as skill degradation, complacency effects, or decreased situational awareness.

The proposed framework's human-centric approach emphasizes the importance of considering human factors in designing automation systems. The model highlights the significance of stakeholder cooperation and early evaluation and feedback to reduce development costs and prevent automation and interaction issues. The three analytical phases provide a systematic approach to designing automation systems, where each phase has specific considerations and requirements. Identifying relevant stakeholders and determining quality criteria, metrics, and methods is crucial for each phase. The cyclic nature of the model and the inclusion of general Human Factors principles further enhance its effectiveness in facilitating effective human-automation interaction. Applying the model can increase the quality of the product or service developed from a human factors and usability perspective. However, the framework is not a complete design guide; rather, it is a general framework that does not assume available resources, competencies, or technologies. It can be applied as loosely or thoroughly as required, challenging assumptions and inspiring new ideas.

Overall, the preliminary proposed framework offers a flexible and adaptable approach to designing automation systems, enabling designers to consider human factors, cooperate with stakeholders, and provide early evaluation and feedback throughout the development process. By following the guidelines outlined in the proposed framework, we seek to increase the quality of the tool developed and ensure an effective human-automation interaction.

3.2 Enroute DA design principles: a HF perspective

3.2.1 Idea generation

3.2.1.1 Source

Victor5 has been exposed to a consultation process as reported in section 2. The functionality that has been more appreciated by air traffic controllers participating in the consultation is the automatic conflict detection.

3.2.1.2 Context

According to this strong users' interest and in collaboration with product owners, this functionality, has been decided to be reinforced as follows:

- Medium-Term Conflict Detection (MTCD): By continuously monitoring the distance between pairs of flights in an automated manner, those pairs that will cross below 9NM of distance are identified and presented to the controller. The MTCD will be improved by **combining**

navigation data with flight plans and wind information. Flight Plans are important to improve the predictability of the future trajectory and, accordingly, the potential conflicts in the medium term. Flight Plans are currently available for the US airspace only. Wind information (wind speed and direction) is a very relevant factor in the time to the crossing calculation and, accordingly, essential for the accuracy of the system and its trustworthiness. A wind model is already available in Victor5 based on mode-S data from the aircraft. This information provides real time data per flight level. The calculation of potential conflicts will always be based on deterministic physical models with no AI, with the aim of ensuring no potential conflict is missed.
- Non-Conflicting Traffic (NCT): For the identification of flights that are expected to cross a certain region of the airspace without interfering with other aircraft, the **introduction of AI-based prediction** is considered to improve the current predictions. As distance between flight-pairs is constantly monitored, the situation of an NCT can change at any time and conflicts would be marked accordingly. NCTs will also use flight plans and wind information.

3.2.1.3 Goal

Having trustworthy real time calculations of MTCDs and NCTs for any airspace region enables an improvement of the workload metrics, a very relevant indicator for the aviation human factors discipline. Controllers' workload is the key metric for the resources' allocation in air traffic management. However, there is not a single, commonly adopted, metric, but many different metrics to estimate the workload (from hourly entry counts to very complex indicators). It is believed that Victor5 will be able to provide a workload metric that is more representative of the actual sector complexity as it will be based on real time conflict/non-conflict detection counts. Elaborating a new complexity metric with these characteristics will support several applications:

- Supervisory tool: A tool for the supervisor controller to have real time information on the complexity of all sectors under his supervision together with a prediction on how will they evolve through time and the possibility to test different configuration to improve workload balance across sectors.
- Post-analysis tool: in line with the supervisory tool capabilities, this information might be used by safety analysts in their post-analysis of certain traffic scenarios.
- Traffic replay: Supporting the post-analysis tool, Victor5 may offer safety analysts the possible to run certain traffic scenarios they need to investigate in a very simple, handy manner. Current tools enable this option but require huge efforts to recover and compile all data.

3.2.2 System modelling

In this section, it will be considered how the idea previously described (section 2.3.1): the automatic detection of potential conflicts and non-conflicting traffic, would modify, alter or interfere with its operational, organizational and regulatory context. These considerations are expected to set up the basis of the following task allocation model.

Item	Questions and considerations	Victor5 PCDs and NCTs
Idea	Describe your idea in terms of the initial and targeted level of autonomy. Is this idea automatizing a task that is currently performed by humans or is it an upgrade of an already automatized task?	The idea targets the development of a complexity metric based on real time labelling of potential conflicting and non-conflicting traffic to support the monitoring of the workload per sector. When applied to the supervisory tool, and providing a prediction of the future workload per sector, it will be possible **to suggest the optimal configuration**. At a later stage, the PCDs and NCTs could support executive operations to, first, increase situation awareness (level 2) and, second, serving as a baseline

Item	Questions and considerations	Victor5 PCDs and NCTs
		to suggest conflict resolution to controllers. For this project, we won't be considering the implementation of automation at an executive level since making changes to safety-critical procedures would require a significantly longer process. A gradual introduction of autonomy in the Air Traffic Management sector, starting from **non-safety critical applications** is considered a more adequate roadmap to facilitate user acceptance and trust.
Agents	Identify the agents whose current operation would be affected by the introduction of this automation level. Include human and autonomous agents, if any. Identify primary agents: those who will be directly impacted by the introduction of the idea (typically the users). Identify secondary agents: those who will not directly interact with the system but who will benefit from it, modify its current responsibilities or duties, alter its current way of operation, supervise it. How would the system affect the maintenance/technical team? If the system is significantly changed with regards to current technology, the acceptance from the IT team would need to be considered.	In section 1.1.2 an initial list of potential users and roles directly affected by the introduction of the Victor5 tool can be found. The main agent envisaged to work directly with the tool would be the **supervisor** who are responsible for assigning resources across the airspace sectors to balance demand and capacity at sector level. Equipping the supervisory position with predictive tools capable of anticipating future traffic levels and complexity will enable a better use of the resources and increased levels of safety. The solution can provide supervisors with real-time information on the complexity of all sectors under their supervision, as well as predictions on how they may evolve over time. Additionally, it may offer the opportunity to experiment with different configurations to enhance workload balance across sectors. While the supervisor ATCO would be the direct user of the solution, other **primary agents** who would be directly affected by it include: **executive ATCO**, **planner** and **safety analysts**. In the case of executive ATCOs, due to the tactical and safety-critical nature of their tasks, they do not interact directly with the solution. Although the solution's functionalities are not tactical or time-sensitive, they will directly affect executive ATCOs. Executive controllers will be allocated to airspace sectors according to the expected evolution and complexity of the traffic at a certain airspace configuration. The solution will be able to better configure the airspace enabling a balanced distribution of the traffic complexity and avoiding peaks of workload. As an example, merging two sectors with low complexity would enable those two free ATCOs to be assigned to a different sector that is foreseen to be highly complex in the next time window. The solution would also support a Multi-sector planner solution by adding an additional safety layer improving the awareness on the potential conflicts. Finally, the solution may also serve as a valuable post-analysis tool for safety analysts, enabling them to scrutinize specific traffic scenarios. Alternatively, it could provide a simple and practical means of conducting investigations by allowing analysts to simulate and assess particular traffic scenarios. **Secondary agents** who will not directly interact with the system but will benefit from it will be mainly **pilots** and **passengers**. The implementation of a Medium-Term Conflict Detection (MTCD) tool can significantly enhance the safety of air traffic control operations. The tool can detect potential conflicts between flights in advance and provide timely alerts to pilots and air traffic controllers, allowing them to coordinate and adjust their course or altitude to avoid conflicts. This proactive approach can also save valuable time and fuel by optimizing flight paths while improving the overall efficiency of the system. The Non-Conflicting Traffic (NCT) tool can also bring advantages to both pilots and passengers. It can minimize the likelihood of flight delays and disruptions to passengers' travel plans by identifying flights that are not anticipated to cause interference with other aircraft. The idea is conceived as a total independent system, therefore, no integration with current systems is foreseen. The implementation of this

Item	Questions and considerations	Victor5 PCDs and NCTs
		solution tools as standalone systems will not have a major impact on the **maintenance/technical team** responsible for their upkeep. The tool would be designed to be self-contained and run independently on an iPad or computer, requiring no integration with existing air traffic management systems. The technical team will only need to be trained on installation and basic troubleshooting.
Tasks	Identify the task or tasks whose level of autonomy would be modified. Identify other tasks that would indirectly be modified as a result of this.	**Supervisor:** the modified level of autonomy would be in the corresponding assessment tasks of sector complexity and workload balance. The introduction of a tool that provides real-time information and predictions would allow the supervisor controller to rely more heavily on the system's output for decision-making. Additionally, the tool's ability to predict how sector complexity will evolve over time and suggest alternative configurations to balance workload across sectors would also indirectly modify other tasks. For example, the tool's output may impact staffing decisions. When Victor5 is used as a **post-analysis tool** and **traffic replay capability,** would modify the level of autonomy of the safety analysts' task of investigating certain traffic scenarios. With the post-analysis tool, safety analysts could rely on the system's output to support their investigation, increasing their level of autonomy in the task. The traffic replay capability would also make it easier and more convenient for safety analysts to run certain scenarios, increasing their level of autonomy in this task as well. Other tasks that would indirectly be modified as a result of this include data recovery and compilation efforts, which would be reduced with the use of the traffic replay capability. This would lead to increased efficiency and productivity for safety analysts. Additionally, the post-analysis tool may impact the safety analysis process by providing new insights into the safety implications of certain traffic scenarios, potentially leading to changes in safety policies and procedures. While not expected at the short-medium term, a brief analysis for other control positions is provided in order to have the potential implications into consideration. Controllers are continuously monitoring the traffic crossing their sectors in a "manual" way: i.e. they go over the whole sector identifying traffics that may have potential conflicts with other traffics. Their CWP (Controller Working Position) have a functionality to manually click on pairs of aircraft whose distance is to be monitored by the ATCO. They currently lack of autonomous tools that monitor pair-wise distance and triggers an alert when a loss of separation is likely to happen. The MTCD concept proposed by Victor5 and the identification of non-conflicting would imply a modification in the level of autonomy for the aircraft separation monitoring task. Although some tools currently exist for MTCDs, the main difference with the Victor5 approach would be the introduction of wind and flight plans information to improve the predictability of the future trajectory, enhance the accuracy and predictability. The introduction of these functionalities should start by the planner position in order to facilitate a gradual introduction of the technology starting from non-safety critical applications. Whenever a new automated system is implemented to take over tasks that were previously performed by humans some **skill degradation** is to be expected. Over time, human operators may become less proficient in performing these tasks manually, as they rely more and more on the automated system to do the work for them. This can lead to a loss of skills and experience, which may in some cases become a problem if the automated system fails or is unavailable. Another potential consequence of

Item	Questions and considerations	Victor5 PCDs and NCTs
		automation could be the emergence of new types of errors and/or biases that were not present before the automation was introduced. This can happen when the automated system is based on faulty assumptions or incomplete data, or when it is not designed to handle certain types of situations. To prevent this skills degradation and new risks, it is important to provide **ongoing training and education for human operators** especially those of the primary agents identified (planner ATCO, supervisor and safety analysts), even if some tasks are being automated. This will help them maintain their proficiency in the tasks that are still performed manually and develop new skills that will be required to operate and maintain the automated system. Additionally, human operators should be encouraged to **actively monitor the automated system** and intervene when necessary to correct any errors or biases that may arise.
Processes	Analyse which procedures and process will be modified as a result of the introduction of the idea. Include not only operational aspects but also maintenance or IT support as needed. Differentiate among tasks directly and indirectly modified. Focusing on the agents identified above would help this task.	The introduction of Victor5 will require modifications in several procedures and processes. These modifications will affect not only operational aspects but also maintenance and IT support. The procedures/processes can be categorized as directly and indirectly modified tasks. The implications in terms of support and maintenance will depend on whether the installation is cloud or local-based. Cloud-computation multiplies the computing capacity offering high levels of resources flexibility and enabling new data services. There are currently no cloud-based systems in ATM and its adoption would imply a change at all different levels (IT skills required, installations, servitisation models, etc.) Directly modified procedures/processes: • **Supervision**: Supervisors will have access to real-time information on the complexity of all sectors under their supervision, which they can use to predict the future situation and test different configurations to improve workload balance across sectors. This will require supervisors to use a new tool and undergo training to interpret the new complexity metric. • **Post-analysis:** Safety analysts will have access to more detailed information on certain traffic scenarios, which will support their post-analysis activities. They will use a new tool to run certain traffic scenarios that they need to investigate in a simple and handy manner. • **Monitoring**: Continuously monitor the distance between pairs of flights and potential conflicts. Operational users (planner ATCO) will receive real-time information from the tool when there is a potential conflict (MTCD) and of flights that are expected to cross a certain region of the airspace without interfering with other aircraft (NCT). Indirectly modified procedures/processes: • **Maintenance**: System maintenance will depend whether the user requires a local or cloud installation. Given the nature of the system functionalities, cloud-based systems would be a more robust and consistent solution to access a data architecture and data services with high-intensive computation resources (to continuously monitor the data among data pairs requires a high number of computations every second). Cloud infrastructure also facilitates remote maintenance and upgrades. ANSPs are more familiarized with local installations and their system maintenance staff would be more comfortable with it. In both cases, the involvement of the ANSP IT departments would be essential for the successful

Item	Questions and considerations	Victor5 PCDs and NCTs
		implementation and maintenance. This will include ensuring that the system is correctly configured and updated, monitoring data ingestion (e.g., wind, flight plans, trajectory data, etc.), physical and AI models or ETL (Extract, Transform and Load) and data processing pipelines. • **IT support**: Coordination between the Victor5 technical team and the IT team responsible for the users. Among others to ensure that the system integrates correctly into your operating environment and that it runs without any issues. • **Training**: The introduction of Victor5 may require training for ATCOs, supervisors, safety analysts, and IT maintenance staff. Training will be required on how to use the new system, interpret the new complexity metric, and analyse the new data. Training process will, however, be much simpler than usual training programmes for other ATM systems.
Organization	Understand the context where the idea/system would be integrated: the organization(s), how are them organized, how are the factors of influence (public/private bodies, potential user acceptance, training needs, certification and regulatory aspects...)	The new Victor5 tool functionality outlined would be integrated into **ANSP (Air Navigation Service Provider)** which are the ones responsible for the provision of air traffic control services in a given airspace region. These organizations could be either public or private bodies, depending on the region and jurisdiction. In terms of factors of influence, there are several considerations that should be taken into account. First and foremost, there would be a need to **ensure user acceptance** of the new tool, among ATCOs, supervisors, safety analyst but also management and across the organization. This would require effective communication actions and training programs to ensure that all stakeholders understand the benefits of the new tool and how to use it effectively in their respective capacities. In addition, there would also be some **regulatory** and **certification** aspects to consider. The new tool could need to be approved by relevant aviation authorities to ensure that it meets all necessary safety and performance standards. This would involve a rigorous testing and a validation process. Another important factor would be the **availability and accessibility of the necessary data** for training purposes. Finally, there would be a need to consideration with regards to the impact the new tool has on the **workload metrics and the allocation of resources** within the ANSP. The new tool has the potential to provide a more representative workload metric that could be used to balance workload across different sectors. However, this would require a significant change in the way that workload is currently measured and managed, which could have implications for staffing and resource allocation within the organization.
Regulation	Foresee the regulatory process, if any, that would need to be undertaken. Identify the regulatory bodies competent for these systems. Identify the existing relevant regulation and outline its compliance.	**Regulatory** and **certification** aspects are crucial considerations in the implementation of any new system in the aviation industry. Currently, aviation systems cannot be certified in a way that can be used by any Air Navigation Service Provider. While the "Conformity assessment framework for ATM/ANS systems and ATM/ANS constituents" was initiated by EASA in 2022, the development and full implementation of this new certification process will still take several years. By the moment, the introduction of a new system into the OpsRoom will require a safety case to be approved by the corresponding authority. In this assurance process, the safety-criticality level of the application will be a crucial factor. Accordingly, its use at the executive position is not foreseen by the moment. This technology should be introduced in a gradual way to build its trust. It is to be expected that an operational deployment of Medium-Term Conflict Detection (MTCD) and Non-Conflict Traffic (NCT) functionalities in

Item	Questions and considerations	Victor5 PCDs and NCTs

		Victor5 will first be used for the workload estimation and applied at supervisor position. A safety case will be needed. The regulatory process would likely involve the following actions such as:
		• **Development and testing**: The functionalities would need to be developed and tested to ensure that they meet the required safety standards.
		• **Approval**: Once the systems have been developed and tested, they would need to be approved by the relevant regulatory body to ensure that they comply with the safety regulations.
		• **Deployment**: After approval, the systems would be deployed and put into operation.
		• **Monitoring and evaluation**: The regulatory body could monitor the operation of the systems to ensure that they continue to comply with the regulations and are functioning effectively.
		• **Change Management** All ANSPs must have a documented Change Management Procedure which has been approved by the CAA. An example of which is captured in regulation EU 2017/373: Air Traffic Management Implementing Regulation. Many of the factors identified above would be captured in these formal procedures.
		  ◦ Changes to the functional system will require prior approval before implementation and may be subject to review:
		  ◦ The functional system is defined as 'a combination of procedures, human resources and equipment including hardware and software organized to perform a function within the context of Air Traffic Management/Air Navigational Services (ATM/ANS) and other ATM network functions' and can be broken down as follows:
		  ◦ changes to the way the components of the functional system are used.
		  ◦ changes to equipment, either hardware or software.
		  ◦ changes to roles and responsibilities of operational personnel.
		  ◦ changes to operating procedures; Supplementary Instructions
		  ◦ changes to system configuration, excluding changes during maintenance, repair and alternative operations that are already part of the accepted operational envelope.
		 • changes that are necessary as a result of changing circumstances to the operational context under the managerial control of the provider that can impact the service, e.g., provision of service under new conditions.
		 • changes that are necessary as a result of changing circumstances to the local physical (operational) environment of the functional system; and
		 • changes to the working hours and/or shift patterns of key personnel which could impact on the safe delivery of services.
		 • Where the notified change is a major project such that it may contain multiple changes within the project implementation period, approval of the overall change will be based on the outcome of the review of the sampled submitted safety assurance documentation requested by the authority.
		 • The sampling of the safety assurance documentation will be directed at the validity of the safety arguments. ANSPs should be

Item	Questions and considerations	Victor5 PCDs and NCTs
		aware that this is an oversight sampling process and that the risk of implementing the change ultimately remains with them. • To prevent delays occurring safety assurance documentation should be submitted as early as possible within the project. It is mandatory for ANSPs to notify changes to the ATMFS (ATM functional system) and use the process above. We believe that there is a point of discussion worth exploring in regard to 'tools' either being part of or not part of an ATFMFS; certainly, the experience and policy of ATM does bring tools into the full rigor of the identifying the hazards and risks of implementation. Tools perhaps could be described in some ways as safety nets such a STCA or GPWS have been, but even with the use of these systems there has always been an expectation that core procedures should be able to provide a safe service without them, even if is expected that a safety case to capture any newly introduced hazards and risk mitigations. However, everything in ATM is pointing to much greater reliance on tools of the future as these will ultimately be the core of how air traffic is managed. One of the most fundamental challenges to CAAs and ANSPs is understanding what safety arguments are necessary for regulatory approval when even as a "tool", a function could be core to an ATM system. The regulatory bodies competent for these systems (National Authorities) would depend on the region where the systems are being deployed. It is worth mentioning here that one of the objectives of this project, and which will be explored in Work Package 5, is precisely how such tools should be evaluated and approved by the relevant bodies. The SafeTeam project aims to address the importance of increasing the regulatory preparedness of digital assistants with predictive capabilities through research on their successful certification as AI-based products. The probabilistic nature of their predictions may require the introduction of new liability models, regulations, processes, and risk assessment methodologies. The project aims to identify key certification criteria, develop a certification framework, assess existing regulatory approaches, and develop new approaches as needed to ensure responsible and ethical development and deployment of digital assistants with predictive capabilities.

3.2.3 Allocation model

The purpose of the Allocation Model is to identify and assess the functions/tasks that need to be allocated to the new tool such as to **maximize performance of the human-automation system** while also safeguarding against potential hazards and identifying any relevant metrics that should be tracked to evaluate the success of the solution. In this use case "Enroute DA", the end goal is to ensure that the new tool is designed to improve the supervisors' ability to adequately and efficiently assign resources across the airspace sectors to balance demand and capacity at sector level through the use of the provided real-time conflict/non-conflict detection counts as well as with real-time information on the complexity of all sectors under their supervision and how they may evolve over time.

To maximize the performance of a human-automation system, it's a crucial first step to analyse the current tasks performed and systems used by the supervisor without the introduction of the new tool. This analysis will help better identify/validate which tasks should be susceptible of being automated, and which system can provide effective support for the tasks. By automating appropriate tasks and selecting a supportive system, the human-automation system can operate at maximum efficiency. The **tasks performed by the supervisor** are numerous and are not specified in any document as they vary according to different conditions, such as operational or geographical. Independently of the numerous tasks a supervisor manages in terms of the pure operation (e.g., assistance to emergencies, high level coordinations with other facilities, etc), in line with the idea of the tool presented in section 3.2.3.1 we are going to focus on the process the supervisor follows to sectorize and allocate ATCOs in the operating room under standard conditions. In general, the supervisor performs the following tasks:

1. **Receives a pre-plan prepared by the Operational Manager**. This pre-plan covers the opening and closing of sectors and the necessary number of ATCOs to execute the plan.
2. Is responsible to either **find a new controller or manage the OpsRoom** to minimize the damage in terms of safety and delays, with any last-minute issues (e.g., sick leave).
3. **Prepares an initial roster** for the duration of the shift. The ATCOs check the roster to know where they have to work.
4. **Receives real-time information from Flow Control**, that allows to change the initial roster for a better adjustment to the life traffic. This could translate into:

    a. Not to open a sector or keep it merged with another because the incoming traffic for a defined period of time is under capacity.
    b. To split a sector into two if more traffic than initially planned.
    c. Options a and b. Merging two sectors in a certain volume under capacity could free ATCOs that can be used to open another sector where they will be needed (dynamic sectorization).
    d. Some ACCs are also flexible in the use of planner controllers: depending on the number of incoming aircrafts, the planners need to stay or not.

5. **Initiates a sector regulation** in case the number of ATCOs cannot manage the number of open sectors and any closing would mean overcapacity as defined by the Operational Manager. The regulatory rest of the ATCOs must be taking into account.

Several functional allocations methods have been developed through the years. Most are based on the compensation or substitution principle initially proposed by Paul Fitts in 1951. Fitts compiled a list of 11 statements that recommend assigning functions and responsibilities to humans or machines based on their respective strengths and weaknesses (Fitts 1951), see figure 21. Today, these lists are known as **HABA-MABA, or 'Human Are Better At - Machines Are Better At',** and have appeared in various forms over the decades as the basis of more modern approaches adapted to current technology. The HABA-MABA approach is still widely used due to its comprehensibility, simplicity, and ability to increase performance and situational awareness. By considering the strengths and limitations of both humans and machines, this approach encourages designers to allocate functions more effectively. Therefore, the HABA-MABA method remains a valuable starting point for any design process.

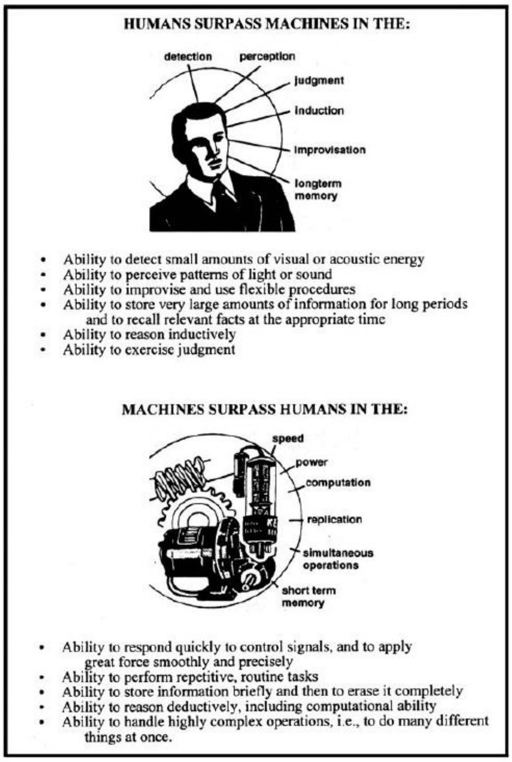


Figure 21 Fitts 11 statements HABA-MABA (Fitts 1951)

However, despite its benefits, the method has received criticism, and some authors have attempted to highlight its shortcomings. The main criticism that it overly relies on a presumption of a set of fixed human and machine strengths and weaknesses and suggest a quantitative division of work (Dekker & Woods 2002). Additional tasking design principles have been developed based primarily on HABA-MABA and seeking to extend it and overcome some of its limitations. One of the most widely implemented is the one developed by Parasuraman, Sheridan & Wickens (Parasuraman et al. 2000) which propose that designers divide tasks between humans and machines by considering four different **groups of system functions**:

1. Information acquisition (**Acquisition**)
2. Information analysis (**Analysis**)
3. Decision and action selection (**Decision**)
4. Action implementation (**Action**)

One of the advantages of this approach is that it can be combined with an assessment of the level of autonomy of the solution at each of the defined system functions. Automation is usually defined as a spectrum of levels, ranging from manual operations to what we can call "full" automation where the human is completely removed from the whole process. To represent this spectrum, several different scales have been proposed in the literature under the term **"Levels of Automation" (LOA)**. One commonly used example is a 10-point scale (Wickens 1998) based on the LOA taxonomy developed by Sheridan and Verplanck(Sheridan & Verplanck 1978), where higher values indicate less human involvement. The LOA scale can be seen in table 2 with a description of the automation status for each of the levels.

Table 2 The 10 levels of automation (Wickens 1998)

Level of Automation	Description
HIGH	10 The computer decides everything and acts autonomously, ignoring the human
	9 informs the human only if it, the computer, decides to
	8 informs the human only if asked, or
	7 executes automatically, then necessarily informs the human, and
	6 allows the human a restricted time to veto before automatic execution, or
	5 executes that suggestion if the human approves, or
	4 suggests one alternative, and
	3 narrows the selection down to a few, or
	2 The computer offers a complete set of decision/action alternatives , or
LOW	1 The computer offers no assistance: human must take all decisions and actions

Even with these finer-tunning of the HABA-MABA method, some of its criticisms remain at some level. Such as the building on the misconception that humans and computers have unchanging strengths and weaknesses, that leveraging a particular automation strength does not ensure to eliminate a human weakness but may introduce new strengths and weaknesses in humans or the possible arbitrariness of the division of the system into the four functions mentioned above (Dekker & Woods 2002). The main conclusion that can be extracted from the state-of-the-art is that there is no single perfect solution to this design problem. This is why finally, the methodology followed has been a novel methodology combining the HABA-MABA and LOA design principles but also taking into account the qualitative effects (e.g. limitations, new strengths and weakness or biases) the automation solution can introduce, possible limitations and biases. The final methodology is the scope of the SafeTeam Deliverable 2.1 that will incorporate the results and experience of this first application. The methodology is currently being developed and will be refined after this first application. Table 3 shows the **assessment of the proposed Victor5 tool**. In it, a high-level analysis of the strengths and weaknesses of both the human user, the tool and the possible future combination of both has been carried out, as well as the establishment of a first objective in terms of the level of autonomy for each of the four groups of system functions.

Table 3 Victor5 HABA-MABA/LOA assessment

System functions	Human (Supervisor)	Machine (Victor5)	Future system (Supervisor + Victor5)
Information acquisition	**Strengths**: Humans operators are able to acquire information through various means such as reading, listening, observing, and experiencing. **Weaknesses**: However, operators are limited by their cognitive capacity and susceptibility to biases and cognitive errors. Humans can	**Strengths**: Machines acquire information through programmed data inputs and are able to process vast amounts of data quickly and accurately. One of the strengths of machine information acquisition is its consistency and objectivity. Machines can be programmed to	**Positive impact:** As mentioned previously, this tool is not intended to replace any currently existing tool. The idea is to generate one more layer of information with which the supervisor can make decisions more efficiently and effectively. The tool will not be connected to any elements of the system, so the information acquisition will be separated and will not affect the supervisor's current tasks. This tool will leverage on trying to acquire huge amounts of currently

System functions	Human (Supervisor)	Machine (Victor5)	Future system (Supervisor + Victor5)
	become fatigued, distracted, or overwhelmed, which can impair their ability to acquire and process information accurately.	process data without biases or subjective interpretation. **Weaknesses**: Machines are limited by their programming and the quality of the data they are fed, and may miss important information if this is not included in their data.	available data (flight tracks, flight plans, meteo data…) which at the moment in some cases are not readily available to the supervisor, usually due to their size, making human processing of it impossible. **Possible issues:** Data quality is key to any data-driven tool. The acquisition of data is not a task that the supervisor has to actively monitor but it is possible that some training about the data origin and the overall processing carried out may be necessary for the supervisor to have a better understanding of the system and to increase confidence and trust in it. **Expected level of automation**: 7 or 8 - The acquisition and processing of the data needed for the tool should be as automatic as possible, with little or no involvement of the end-user (supervisor). There may be situations where the end-user wants to know more about the process, but this should be the exception rather than the rule.
Information analysis	**Strengths**: Human operators information analysis involves a wide range of cognitive processes, such as perception, attention, memory, and reasoning. They are able to process information in a more holistic way, taking into account contextual factors or experiences, and apply their existing knowledge to understand new information. **Weaknesses:** Human operators have limitations in their information analysis capabilities, such as the limited capacity of working memory and again the potential for cognitive biases and errors. They are limited by their physical and mental endurance and may become fatigued or overwhelmed, which can impact their ability to analyse information effectively.	**Strengths**: One of the major strengths of machines in information analysis is their ability to process vast amounts of data in a relatively short amount of time. Through the use of complex models like Artificial Intelligence (AI) and Machine Learning (ML), machines can sift through large datasets, extract relevant information, and analyse it quickly and accurately. They excel in performing complex calculations and identifying patterns that may be difficult for humans to recognize. Additionally, machines can use AI and ML algorithms to learn and improve over time, making them more efficient and effective in their analysis. **Weaknesses:** They are heavily dependent on the quality and accuracy of the data they are fed. If the data is flawed or biased, the results of the analysis can be inaccurate or incomplete. Furthermore, complex models like AI and ML can be difficult to interpret, making it challenging to understand how the machine arrived at its conclusions.	**Positive impact:** Again, this tool is not intended to replace any existing equipment or information analysis process. The aim is to leverage on all data retrieved and based on advanced data analysis and processing techniques, such as AI/ML, to extract useful and accurate information and in some cases prediction from it and present it in a visual interface to the supervisor. **Possible issues:** It is not necessary for the end-user to have a deep technical understanding of how the information or predictions have been calculated, although some high-level training and basic familiarisation may be necessary to give them an overview of what the process does, in order to better understand any potential shortcomings and build confidence. **Expected level of automation:** 7 - The analysis of information from previously acquired data should be as automatic as possible. Although it may be necessary in this aspect to have some feedback from the tool to the user in order to verify and evaluate, if necessary, the accuracy of the information and predictions presented.

System functions	Human (Supervisor)	Machine (Victor5)	Future system (Supervisor + Victor5)
Decision and action selection	**Strengths:** Human decision-making and action selection lie in the ability to integrate multiple sources of information. They can also take into account ethical and moral considerations, and make judgments based on values and principles. They are able to consider context and subjective experiences, recognize outliers, and adapt to new information. **Weaknesses:** Human decision-making and action selection is limited by cognitive biases, subjective interpretations, and the capacity of the human brain. Humans can become fatigued, distracted, or overwhelmed, which can impair their ability to make accurate decisions and take effective action. Additionally, human decision-making may be influenced by emotions and personal biases, leading to suboptimal outcomes.	**Strengths:** The strengths of machine decision-making and action selection lie in their ability to process large amounts of data quickly and consistently. Machines can make decisions without being influenced by biases or emotions. They are able to perform complex calculations and identify patterns that would be difficult or impossible for humans to recognize. **Weaknesses:** Machine decision-making and action selection is limited by the quality of the data and the programming of their algorithms. If the data is flawed or biased, the machine's decisions may be inaccurate or incomplete. Additionally, machines may not be able to recognize patterns or factors that fall outside the scope of their programming, leading to suboptimal decision-making. Machines are also not able to take into account the full range of contextual factors and subjective experiences that are important in human decision-making.	**Positive impact:** The end goal of the proposed tool is to enhance decision-making for supervisors by providing accurate traffic data, workload metrics, and forecasting trends over time. By using this tool, supervisors will have access to more precise and useful metrics during their shifts, leading to more informed and effective decisions. Additionally, the tool is expected to offer the ability to test different scenarios and provide potential solutions, resulting in more efficient planning. **Possible issues:** Similar to the previous cases, user training and familiarisation may be necessary. Having some degree of understanding of how the metrics, predictions or solutions have been calculated can be needed in order to better understand any potential shortcomings and build confidence. Thus, employing some degree of human oversight to ensure that the results are accurate and reliable could be needed. **Expected level of automation:** 3 or 4 - In the case of suggested solutions, the tool may be able to analyse the current situation based on the available data and be able to recommend one or a series of possible decisions. But these should always be contrasted and validated with the user.
Action implementati on	**Strengths:** Human action implementation is often characterized by flexibility and adaptability. Humans are able to adjust their actions based on changes in the environment or new information that they receive. They can also use their intuition and creativity to come up with new solutions to problems that may not have been considered before. Additionally, humans are able to collaborate and communicate with each other, enabling them to work together effectively and efficiently. **Weaknesses:** Human action implementation can also be limited by physical and cognitive constraints. Humans may not have the physical	**Strengths:** Machine action implementation is often characterized by precision and consistency. Machines can perform the same task over and over again with a high degree of accuracy, without becoming tired or distracted. Machines can communicate with each other and share data, enabling them to work together in a coordinated manner. **Weaknesses:** Machine action implementation can also be limited by the complexity of the task. Machines may not be able to adjust their actions based on changes in the environment or new information and may not be able to respond to unexpected events or situations, which can lead to errors or inefficiencies.	**Positive impact:** Throughout the process of using the envisioned tool, the objective has always been to enhance the user's capabilities based on data-driven solutions, thus enabling the supervisor to have a more efficient and effective decisions-making process. **Possible issues:** The tool is not designed to directly apply the possible solutions suggested. Overreliance could occur as long as the supervisor continuously uses it to improve the workload balance in the different sectors. However, this is considered a low risk as the supervisor makes use of other tools and as well as take into account factors that affect the decision-making process. **Expected level of automation:** 1 - The tool is not designed to execute any action, but only to assist and help the supervisor in decision making. Any action derived from it should be done only by the human supervisor.

System functions	Human (Supervisor)	Machine (Victor5)	Future system (Supervisor + Victor5)
	strength or endurance to perform certain tasks for long periods of time or under certain conditions. Additionally, humans may be prone to making errors or mistakes due to fatigue, stress, or distractions.		

3.2.4 Implementation

The implementation phase is a critical step in the development of any human-automation system, and it is particularly important when developing tools that support air traffic management such as Victor5. The purpose of this phase is to **turn the previously described system into a working tool**, ensuring that the identified goals are achieved efficiently and effectively. The implementation phase also aims to guide the development team in ensuring the designed solutions usable for the end-users. One of the primary considerations during the implementation phase is ensuring that the tool is designed with the **end-user in mind (Human-Centred design)**. This means that the development team must have a well-grounded understanding of the users and their needs. While most of this information has been gathered during the idea and system modelling phase, it is also possible that new information will be gained during future user evaluations during the development process. As new information is gathered, it is essential to reassess the prerequisites to ensure that the tool remains efficient and effective. It is also essential to consider any potential risks or other issues of importance that may have been identified during the earlier stages of development. For instance, the design solutions should be checked against issues that may arise due to automation, such as skill degradation, complacency effects, or decreased situational awareness.

There are several useful resources in the literature that can guide the development team in the implementation phase. One of these is the 10 Usability Heuristics for User Interface Design (Nielsen 2014), which provides ten rules of thumb that can be used when designing interfaces, such as keeping users informed, preventing errors, supporting undo and redo actions, and offloading the user's memory. Another useful source is the Human Factors Design Guidelines by Federal Aviation Administration (Wagner, D., et al. 1996), which provides design principles on simplicity, consistency, and safety. Evaluation is also a crucial aspect of the implementation phase. Users can inform the design process through development, and the evaluation should show the effects of the given implementation, user performance, and satisfaction. There are various evaluation methods, such as prototyping, usability testing, thinking aloud, and evaluation experiments or simulations. The results of the evaluation must be analysed to determine what needs to be improved, and the severity of the usability problems must be rated.

Additionally, during the implementation phase, the design team must consider how to implement the tool or function, such as algorithm design, processes, or user interface design. They must also be aware of the potential of the aforementioned possible pitfalls, such as introducing issues that might leave the operator out of the loop and lack situational awareness, complacency issues or degrade of cognitive skills. A well-designed interface or system architecture could help with awareness and reduce the out-of-the-loop phenomenon. One of the key outcomes of the implementation phase is a usable and **safe human-automation system** that is designed to meet the needs of the end-users. The system should have a well-designed interface, be transparent and predictable, and provide users with situational awareness. The development team must also be aware of potential issues that could arise due to automation and evaluate the system to ensure that it meets the identified.

There are different actions that can be taken to ensure the objectives of the tool are met and that can, and should in some cases, be carried out throughout the development and implementation process. The following is a list of some of the envisioned actions to be carried out during the development of the Victor5 tool:

- **Conducting user research**: This should be done before the implementation phase begins. It is crucial to conduct user research to understand the needs and requirements of the end-users. This work has already been carried out to a greater extent through a questionnaire open to different stakeholders. The requirement capturing methodology used as well as the results obtained can be found synthetised in section 2 of this deliverable.
- **Prototyping**: During the implementation phase, it is beneficial to create various prototypes of the tool to test its usability and identify potential design flaws early on. Prototypes can be both low-fidelity (e.g., paper prototypes or simple visuals) and high fidelity (e.g. digital interactive models). Prototyping allows for early adaptation to changes and user feedback, leading to a solid foundation for improvements and minimizing errors before product release. It also provides insights into less-obvious areas of users' needs and can even help foster emotional investment in the product's success. Victor5 is developed as a cloud-based data platform to enable fast prototyping and will serve as the supporting platform to build the supervisory tool over it through iterative cycles.
- **Usability testing**: Usability testing can be conducted to evaluate the tool's effectiveness, efficiency, and user satisfaction. This can be done through user testing or demo sessions, where users are given or provide specific tasks to perform using the tool, and their actions and feedback are observed. The questionnaire in section 2 includes the assessment of the Victor5 usability metric-based SUS scale, reaching a score of 75/100 (a B score). This usability metric refers to the Victor5 platform v1.0.0 and, therefore, not including the supervisor application. The validation exercises to be performed after its implementation will re-evaluate the user experience with the participating ATCOs.
- **User-centred design workshops**: User-centred design workshops can be conducted to involve the end-users in the design process actively. These workshops can also be used to gather information on the users' needs, preferences, and pain points, which can then inform the design process. Involving end-users in the design process can help ensure that the final product meets their needs and expectations, leading to higher levels of overall user satisfaction. A number of workshops are planned during the whole SafeTeam duration.
- **Expert reviews**: Expert reviews can be conducted by individuals with expertise in human factors, aviation, or air traffic management. The review can provide valuable feedback on the tool's design, usability, and safety. Expert reviews will be made available throughout the different tasks scheduled in the project to be performed by SafeTeam partners (including Human Factors experts, technology developers, safety and regulatory agencies and aviation operational experts), but also during the mentioned workshops.
- **Consultations with stakeholders:** Including air traffic controllers, supervisors, and aviation authorities, can provide insights on regulatory requirements, potential risks, and system limitations. The workshops' main objective is to engage with stakeholders and regularly consult the SafeTeam developments making sure the alignment with their needs and challenges.
- **Questionnaires and surveys**: Questionnaires and surveys can be used to gather feedback on the tool's design, usability, and satisfaction. The survey can be distributed to end-users and stakeholders to gather information on their experience with the tool. A first questionnaire was proposed in section 2 covering both the user experience as well as the expected usages of the system.

4 References

[1] (DIS, ISO) "Iso/iec 25062: 2006 software engineering-software product quality requirements and evaluation (square)-common industry format (cif) for usability test reports." *International Organization for Standardization (ISO). Switzerland* (2006).

[2] (Brooke 1986) Brooke, John. "System usability scale (SUS): a quick-and-dirty method of system evaluation user information." *Reading, UK: Digital equipment co ltd* 43 (1986): 1-7.

[3] (Reichheld 2003) Reichheld, Frederick F. "The one number you need to grow." *Harvard business review* 81.12 (2003): 46-55.

[4] (Parasuraman et al. 2000) Parasuraman, Raja, Thomas B. Sheridan, and Christopher D. Wickens. "A model for types and levels of human interaction with automation." *IEEE Transactions on systems, man, and cybernetics-Part A: Systems and Humans* 30.3 (2000): 286-297.

[5] (Fitts 1951) Fitts, Paul M. "Human engineering for an effective air-navigation and traffic-control system." (1951).

[6] (Dekker & Woods 2002) Dekker, Sidney WA, and David D. Woods. "MABA-MABA or abracadabra? Progress on human–automation co-ordination." *Cognition, Technology & Work* 4 (2002): 240-244.

[7] (Wickens 1998) C. D. Wickens, A. Mavor, R. Parasuraman, and J. McGee, The Future of Air Traffic Control: Human Operators and Automation. Washington, DC: National Academy Press, 1998.

[8] (Sheridan & Verplanck 1978) T. B. Sheridan and W. L. Verplank, "Human and Computer Control of Undersea Teleoperators," MIT Man-Machine Systems Laboratory, Cambridge, MA, Tech. Rep., 1978.

[9] (Nielsen 2014) Nielsen, J. "10 Usability Heuristics for User Interface Design (online)." (2014).

[10] (Wagner, D., et al. 1996) Wagner, D., J. A. Birt, M. D. Snyder, and J. P. Duncanson. *Human Factors Design Guide (HFDG) for Acquisition of Commercial off-the-shelf Subsystems, Non-Developmental Items, and Developmental Systems*. No. DOT/FAA/CT-96/1. 1996.

5 List of Abbreviations

Abbreviation	Definition
ACC	Area Control Centre
ACFT	Aircraft
ADS-B	Automatic Dependent Surveillance–Broadcast
AI	Artificial Intelligence
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATM	Air Traffic Management
CWP	Controller Working Position
DA	Digital Assistant
EASA	European Union Aviation Safety Agency
ETL	Extract, Transform, Load
FPL	Flight Plan
HABA-MABA	Human Are Better at - Machines Are better At
HF	Human Factors
HMI	Human-Machine Interface
IFATCA	International Federation of Air Traffic Controllers' Associations
IT	Information & Technology
LOA	Levels of Automation
MSP	Multi Sector Planner
MTCD	Medium-Term Conflict Detection
NCT	Non-Conflicting Traffic
NM	Nautical Mile
NPS	Net Promoter Score
NSCAS	Non-Safety Critical ATM Screen
PCD	Potential Conflict Detection
STCA	Short-Term Conflict Alert
SUS	System Usability Scale
UAC	Upper Air Control centre
WP	Work Package

6 Annex I. Instructions for users

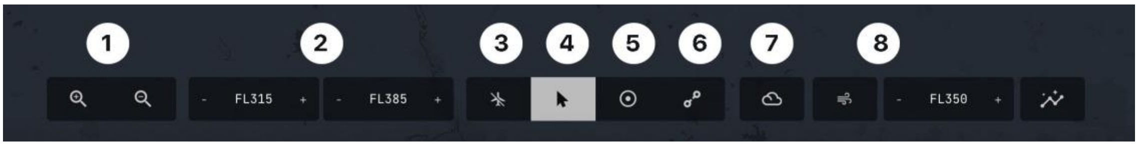
Victor5 is **not** an Air Traffic Control system but an additional support system to the current ATC consoles. Victor5 can be used in a variety of scenarios, for example:

- by the supervisors to anticipate workload,
- for planners to support coordination with adjacent ACC units,
- for executive controllers, as a support tool, providing an accurate MTCD with real wind data,
- for everyone in an operational room, as a transition-to-contingency resource in case of major radar/console failures and other adverse events.

The current version displays real-time traffic information from a terrestrial ADS-B data feed but it is also compatible with other data sources, like radar or satellite ADS-B data sources.

Some of the Human-Machine Interface characteristics are:

- The target includes a 1-minute speed vector.
- The label is pretty standard: callsign, real flight level, selected flight level from mode-S, ground speed in KT (adding a zero) and destination (where available).
- A lower bar that encapsulates most of the functionalities, avoiding complex menus, includes from left to right:



1. Zoom in and out (when using an iPad, the "pinch to zoom" gesture works perfect as well),
2. Lower and higher filters for the traffic
3. Option of showing no planes (i.e. only wind)
4. Back to the default mode (arrow pointing up and left)
5. Option to show a halo, adding a 5NM circle around a plane: just tap on the halo on the lower bar and then on the label of the desired ACFT; to remove the halo, just repeat the previous process),
6. Handcuffs to link two traffics – The handcuffs manually link two ACFTs to provide the same information the automatic interaction detection displays (current distance, minimum distance and time). The procedure is simple: tap on the handcuffs, tap on the label of the first ACFT (the lower circle of the icon will become black), tap on the label of the second ACFT and a dashed orange segment will be displayed. To remove the dashed segment, just tap on the information in the middle of the segment.
7. Weather layer (cloud icon)
8. Real-time wind information coming from the aircraft sensors at all levels, and the selected flight level to show the wind on the map.

The current version of Victor5 divides traffic in 3 groups:

1. **Interacting traffic:** Traffic that will "interact" with other traffic by crossing with it below 9NM at the same level or crossing levels (using mode-S information). These aircraft will **automatically** be displayed with an orange segment providing the users the current distance in NM, minimum distance in NM at the crossing, and time to minimum distance if such is above 5NM or time to 5NM if the minimum distance is below 5NM (time to lost separation). Additionally, the target of the aircraft who passes first at the crossing will be marked in orange to facilitate vectoring to the tail.

2. ***Cleared traffic:*** *Traffic that will require no instruction for the next 30 minutes unless the pilot requests it. The algorithm takes into account that these traffics are not near destination, flying at cruise FL, are not blocking the descents of others, and other traffic interactions. The display shows them in green color. As the evolution of traffics is dynamic the "cleared status" could change and therefore an ACFT considered "green" at certain stage could change for different reasons – a pilot request for instance. The system acknowledges that and advises with an automatic halo when losing the green stage ahead of time.*
3. ***Other type of traffic –*** *they are not interacting but the traffic situation is dynamic enough so it is not classified as cleared.*

We hope you find the HMI very easy to use. It has been ***designed by controllers for controllers****. Now, feel free to play around with it and once you feel confortable, we would appreciate if you could help us answering a few questions related to digital assistants. Thank you for your cooperation.*

6.1 Annex II. Questionnaire System Usability Scale (SUS)

System Usability Scale *

	Totally disagree	Disagree	Neither agree to disagree	Agree	Totally agree
I would often use the digital assistant to complement information from the ATC console	○	○	○	○	○
I find the digital assistant very complicated	○	○	○	○	○
The HMI (Human-Machine-Interface) was easy to use.	○	○	○	○	○
I think I would need help from an expert to start using the digital assistant.	○	○	○	○	○
Functionalities are well integrated.	○	○	○	○	○
I find the HMI inconsistent.	○	○	○	○	○
I imagine other ATCOs would learn to use digital assistants very fast.	○	○	○	○	○
I find digital assistants very difficult to use and redundant with information from the console.	○	○	○	○	○
I felt very confident using a digital assitant like Victor5.	○	○	○	○	○
I needed to learn many things before start using these tools.	○	○	○	○	○

6.2 Annex III. Questionnaire About the interface

About the interface

The questions below try to find your opinion about the different elements of the interface.

According to your experience as a Victor5 user:

	Totally disagree	Disagree	Neither disagree or agree	Agree	Totally agree
The control buttons (filters, halos, meteorological information...) are located on the best place of the screen.	○	○	○	○	○
The left to right order of these buttons is the correct one.	○	○	○	○	○
The control buttons are properly grouped according to their functionality.	○	○	○	○	○
The zoom buttons are clear and well designed.	○	○	○	○	○
The buttons to manage the Flight Level filters are clear and well designed.	○	○	○	○	○
The buttons to interact with the flights (halos, forced PCDs...) are clear and well designed.	○	○	○	○	○
The buttons related to met information are clear and well designed.	○	○	○	○	○
The button to display the wind information is clear.	○	○	○	○	○
The wind information displayed on the screen is easy to read and understand.	○	○	○	○	○
The labels to display traffic information are easy to read and understand.	○	○	○	○	○
It is easy to identify NCTs (Non Conflicting Traffic) with the green colour.	○	○	○	○	○
The interface shows clearly the PCDs (Potential Conflict Detection).	○	○	○	○	○
The information related to PCDs is clear and easy to understand.	○	○	○	○	○
In general, the letter font used is easy to read.	○	○	○	○	○
In general, the colours used by the interface are easy to see and are useful to distinguish the most critical issues.	○	○	○	○	○
In general, the symbols used on the screen are easy to see and understand.	○	○	○	○	○
In general, the symbols used in the control buttons are easy to understand.	○	○	○	○	○

Comments about the HMI

Your answer

Open comments about the interface

This part of the test is about the impact of Victor5 on the users in their own words, therefore the answers to the questions below will be open.

In general, what is your opinion of this HMI (Human-Machine-Interface)? *

Your answer

Do you consider digitial assistants a technical improvement for ATCOs? *

Your answer

If you had to describe Victor5 to a coleague in 1 or 2 sentences, what would you say? *

Your answer

What do you like the most about Victor5? *

Your answer

What do you like the least? *

Your answer

If you had the chance, what would be the first thing you would change in these tools? *

Your answer

Is there anything you miss in Victor5? *

Your answer

About PCDs (Potential Conflict Detection), do you find the parameters are adequate? *

Your answer

Do you find the HMI shows too many or too few PCDs? *

Your answer

Is there any other remark you would like to tell us about digital assitants? *

Your answer

6.3 Annex IV. Questionnaire About digital assistants' efficiency

About digital assistants' efficiency

The following questionnaire tries to find the impact of the digital assistant on the efficiency of the ATCOs' daily tasks.

According to your experience:

	Totally disagree	Disagree	Neither disagree or agree	Agree	Totally agree
The digital assistant would help me take the right decisions.	○	○	○	○	○
The digital assistant would help me avoid mistakes and/or incidents.	○	○	○	○	○
Showing mode S information on the label, such as the cleared FL, helps the controller.	○	○	○	○	○
Showing meteorological information is useful for the controller.	○	○	○	○	○
Digital Assistants are more useful for ATCOs than other commercial apps such as FlightAware/FlightRadar24 as last resource tools.	○	○	○	○	○

After using the digital assistant you think this tool...

	Totally disagree	Disagree	Neither disagree or agree	Agree	Totally agree
Could be useful for the planner controller.	○	○	○	○	○
Could also be useful for the executive controller.	○	○	○	○	○
Could be useful for the supervisor.	○	○	○	○	○
Shows improvements to other current systems.	○	○	○	○	○
Adds another layer of safety to the ATC system.	○	○	○	○	○

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