AIRTENTION

CBTA
Pilot Training
Assistance

Evaluation Study

I. THE AGE OF COMPETENCY-BASED TRAINING AND ASSESSMENT

"flight crew resilience can be substantiated by raising the level of competence and by achieving the appropriate level of confidence (trust)"

SAFETY IN AVIATION

Commercial aviation is arguably the safest of all modes of transport today, with far less than one accident per million flights (Boeing, 2019). In the 1960s, this figure was 20-30 times higher. This progress is largely due to new, more reliable technologies and automation in the cockpit, but also to advances in training and improved procedures[1].

As a result of technological change, aircraft have become more complex and with them the amount of information a pilot needs to carry out a flight safely. The development is moving away from manually flying the aircraft towards constant monitoring and control of aircraft systems[2].

The term resilience has become widely used in recent years, and not only in aviation. Resilience is used to qualify and evaluate human performance when faced with unexpected disruptions in operation. EASA has defined flight crew resilience as, "the ability of a flight crew member to recognize, absorb and adapt to disruptions".

Evidence- and Competence-based Training Concepts represent an approach towards training and assessment that is characterized by the focus on the development of underlying competencies instead of superficial performance thresholds. The goal of Competency-Based Training and Assessment (CBTA) is to provide a competent workforce for the sake of a safe and efficient air transportation system.

1. Peysakhovich, V., Lefrançois, O., Dehais, F., & Causse, M. (2018). The Neuroergonomics of Aircraft Cockpits: The Four Stages of Eye-Tracking Integration to Enhance Flight Safety. Safety 4(1), 8; https://doi.org/10.3390/safety4010008.
2. Škvareková, I., Ažaltovi, V., Pecho, P., & Kandera, B. (2020). Eye Track Technology in Process of Pilot Training Optimization. 2020 New Trends in Aviation Development, (S. 206-210).

FROM TASK-BASED TO COMPETENCY-BASED TRAINING

Flight crew training is evolving from a task.based approach to competency-based approach, which places greater emphasis on training and assessing a limited number of competencies than on task performance alone.

Traditionally, training is developed by breaking down jobs into tasks. An assigned learning objective with associated elements is attached to each task, and the training plan ensures that all learning objectives are met.
In complex systems, or when jobs evolve rapidly, it may not be possible to teach and assess every task.

This task-based training method can only be used to predictable scenarios by nature. This task-based approach must be used by flight crews as they build their capacity to also consider the operational situation.

A COMPETENCY-BASED APPROACH TO TRAINING

Competency is described by ICAO as „a factor of human performance used to predict successfully successful performance on the job. A competency is demonstrated and witnessed by actions that mobilize the necessary knowledge, abilities, and attitudes to perform tasks or activities in a given environment.

In other words, observable behaviors serve as a sign of a person's ability to perform their work with proficiency. It is possible to learn about these behaviors by observation, which depends on having the necessary Knowledge, Skills, and Attitudes (KSA).

In Competency Based Training and Assessment (CBTA), the training objective is to prepare the flight crew for an infinite number of situations by establishing a limited number of competencies rather than to train them to react to every individual event. The assessment and training of a limited set of competences are given precedence over the training of tasks. This should make it possible for pilots to operate effectively in a challenging and dynamic operating environment. Additionally, they must be capable of handling unexpected duties and circumstances for which they have not received special training. This fosters powerful resilience.

Task-Based Approach	Competency-Based Approach
➔ Ever growing number of tasks to train	➔ Finite number of competencies to train
➔ Train only for predicted situations	➔ Train for unpredicted situations
➔ Isolated task training: difficulty to adapt	➔ Multi scenario-based training: strengthens ability to adapt
➔ More time spent on checking	➔ More time spent on training
➔ Generic training	➔ Individualized training
➔ Limited level of performance in complex and evolving environments	➔ Increased level of performance in complex and evolving environments
LOW RESILIENCE	HIGH RESILIENCE

HISTORY OF CBTA

Since the late 1950s, competency-based training has been a strategy. Since the 2000s, it has been gradually used in the aviation sector. The Multi-crew Pilot License (MPL), the first CBTA program for license training, was established in 2006. Evidence-Based Training (EBT), the first CBTA program for repeat training, was developed in 2013.

A universal set of CBTA rules were introduced with the publication of ICAO Doc 9868 Procedures for Air Navigation Services - Training (PANS-TRG) Amendment 5 in 2016. The application of CBTA as a guiding principle for training in a variety of other aviation disciplines, including air traffic control, aircraft maintenance, and flight dispatch, is encouraged by the modification of ICAO Annex 1 that was released in 2020.

The CBTA training approach is further developed in the most recent PANS-TRG edition, which was released in 2020, and is a crucial instrument for ensuring safe operations. Pilots must „show resilience when confronted with an unexpected event," according to the requirement.
These CBTA standards support the IATA Total Systems Approach (TSA), which stands for the application of CBTA across all aviation disciplines in general, and to all modules and roles in a pilot's entire career. Hence, the defined competencies for pilots, instructors and evaluators should consistently be applied throughout pilot aptitude testing, initial (ab-initio) training, type rating training and testing, command upgrade, recurrent and evidence-based training and instructor and examiner selection and training.

IMPACT OF CBTA

Safety

The pilots' competencies serve as their strongest defense against prospective threats and operational faults. The change from classic prescriptive task-based training to CBTA in terms of safety benefit is primarily attributable to the expansion of the scope and character of the training as well as the improvement of the measurement of performance.

The three primary technical elements—handling skills, automation management, and process application—are the core focus of traditional training, which is task- and hour-based. The substance of the subsequent checking (skill test or proficiency check) is based on the redoing of particular tasks that have these 3 components. The primary specified fixed criteria used to measure performance are represented by the flight test tolerances.

In contrast, CBTA aims to evaluate, develop, and improve a set of critical competences needed to carry out the pilot work. These skills—which are regarded as non-technical but are essential for operational safety—include situational awareness, communication, workload management, leadership, and decision making.

Furthermore, under CBTA, the pilot's performance is more precisely assessed using objective, visible performance criteria that indicate whether or not the desired level of performance has been reached.

Trainee Centric

Each pilot's competencies are considered at all training phases and stages via Trainee Centric CBTA, which follows a training schedule with some built-in flexibility. As a result, the pilot:

- Makes faster progress;
- Increases confidence in ability to handle the unexpected and develops resilience;
- Is more motivated due to individualization of training and use of applied and relevant scenarios;
- Is supported and mentored to continuously improve in all areas, and, where practical, the training plan and time allocation is shifted toward the trainee's weak points and/or concerns, maximizing the effectiveness of the training;

Efficiency and Effectiveness

Because it adheres to the instructional system design principle, CBTA implicitly offers dynamic, effective, and efficient programs. CBTA encourages and facilitates pilots to perform at their optimum level during all phases of training and possibly even when performing operational tasks beyond training.

The success and efficiency of CBTA is also predicated on the constant application of the same set of abilities throughout the pilot's whole career path, from aptitude testing to operator training, PPL, CPL, MPL, and ATPL, as well as for pilot Instructor/Evaluator.

The following are the areas where CBTA can enhance training effectiveness and efficiency:

- Development of a progressive training continuum that ensures cross-linkage of recurrent and additional courses
- Optimized course design through iterative course improvement via feedback and data analytics as well as by adaptation
- More training and assessment allows for tailored supportive development
- More operational realism and application in training, ensuring that the learning objectives can be put into practice, that competencies are advanced, and that resilience is built.

Transparency and Accuracy

According to its definition, CBTA is distinguished by a performance orientation that places a focus on performance standards and their measurement. As a result, the CBTA establishes precise performance standards for evaluating competency. An observable behavior, a condition or conditions, and a competency standard make up each performance criterion. Tests and exams are also used in several phases of professional flight and type training to assess the knowledge learning objectives.

To have a clear understanding of the overall goals, those criteria are generally aligned and accepted by all parties involved, including the CAAs, ATOs, AOCs, pilots, and instructors.

The instructors consistently and regularly evaluate the trainees' competencies in a wide range of situations. Additionally, the instructors and evaluators used in CBTA are „calibrated" to produce a high level of concordance (inter rater reliability). The transparency and precision of the training and assessment process have been greatly improved by these CBTA concepts.

EYE TRACKING AS PARADIGM SHIFT TOWARDS CBTA

NEW INSIGHTS IN STUDENT PERFORMANCE

Flight instructors sit next to or behind pilot students in the simulator or airplane and take notes on their strengths and weaknesses and discuss them in a adjacent debriefing. This feedback is based on and limited by the information that the instructor could observe from pilot behavior, monitor from callouts and communication as well as read from the cockpit instruments.

This process doesn't preclude the possibility of misinterpretations by the instructor and also does not provide deep insights into underlying behavioral and perceptional patterns that cause observabel task performance. An imperfect execution of a flight maneuver can easily be wrongly assigned to the fact that the pilot has a theoretical knowledge gap whereas in fact it may be due to faulty scanning behavior. Such misinterpretations can be reduced by analyzing a broader range of observable factors.

With the analysis of the visual attention of pilots, a further step towards more efficient pilot training could be taken and the human factor as a source of error could be further reduced. By using modern eye trackers, it will be possible to track and analyze various conditions based on eye movements (Rudi, Kiefer, & Raubal, 2019). This provides new insights into the students' flying performance to instructors and allows certain strengths and weaknesses to be recognized earlier.

Eye Tracking as a window into perceptional behavior

Eye Trackers allow deep insights into the way students obtain information in the cockpit and interact with their environment. This allows shortcomings to be better and more precisely classified, which means that the feedback for the pilot can also be more targeted and relevant, increasing training efficiency and flying performance (Rudi, Kiefer & Raubal, 2019).

Eye Tracking allows deep analysis of pilot performance in the fields of
- Situational Awareness
- Workload
- Cognitive processing of information
- Anxiety and Stress
- Automation of task execution
- Exhaustion

EYE TRACKING AS A PARADIGM SHIFT

EYE TRACKING TECHNOLOGY OVERVIEW

REMOTE & INTEGRATED EYE TRACKERS

Remote eye trackers are (infrared) cameras which are installed in the simulator or training environment. The cameras are calibrated in the scene so as to enable the spatial interpretation of eye tracking results.

Advantages

- Comfort and Natural Behavior - The pilots do not wear any additional cameras or sensors on their bodies themselves, which results in a natural experience and comfort for the pilots.

Disadvantages

- Scalability - The installation and calibration of the hardware setup requires enormous amounts of effort. This effort needs to be repeated for every single installation. Hence, the system cannot be easily ported to a different cockpit and cannot be scaled easily
- Accuracy & Data Quality - Remote eyetrackers work from a distance of about 1-2 meters. This significantly reduces the resolution of the recorded pupils, and hence also negatively affects the level of accuracy of both eye tracking and assessment of pupil dilation.
- Potential loss of certification - Simulators are certified to be equivalent to real-world environments. Any alteration of the cockpit can cause the loss of this certification. This has an immense impact on the training as the performed training courses cannot be assigned to and counted as experience in certified environments.

MOBILE EYE TRACKERS

Mobile eye trackers usually have three cameras, two of which are infrared cameras aimed at each eye and assessing pupil position and dilation. The third camera records the field of view of the wearer (world camera). This data allows for a direct analysis of the gaze position in the 2D world camera video, gaze behavior as well as pupil diameter.

Advantages

- Flexibility and Scalability - Mobile eye trackers require a minimum of infrastructure that can be quickly installed in a simulator
- Accuracy and Data Quality - The close vicinity to the eyes allow for a high data quality and accordingly high accuracy in gaze analysis.
- Costs - Mobile eye tracking devices are significantly cheaper than remote and integrated eye tracking solutions

Disadvantages

Comfort - In spite of the low weight and the effort towards user-friendly design, the need to wear glasses will be inconvenient and in the beginning distracting for users.

- Spatial Mapping - The freedom in head movements of pilots poses a challenge towards automated analysis of gaze behavior in a physical cockpit as the head and gaze position need to be put in relation to the instruments and devices.

II. AIRTENTION
TRUE COMPETENCY-BASED PILOT TRAINING OF THE FUTURE

ENABLING INDIVIDUALIZED PILOT TRAINING

The job of an Aviation pilot is one of the highest demanding in modern society with regard to the level of responsibility associated with the pilot task. In combination with the high demands on cognitive capabilities (cognitive load, visual attention and perception), the fatal impacts of attentional errors (missing or misinterpretation of critical information or events, making procedural errors in the execution of flight manoeuvres, etc.) have lead to plane cockpits being equipped with the most comprehensive assistance systems. As described in the previous chapter, the assistance systems aim to (i) simplify the flying task, (ii) indicate critical situations or (iii) document the events in a cockpit for future error prevention.

The general task to pilot training is to (i) teach the correct understanding and handling of an aircraft, (ii) continuously increase the level of automation as to (iii) enable correct decision-making and task execution even under high pressure.

Shortcomings of current Pilot Training

To avoid attentional and procedural errors, the whole concept of pilot actions is completely fixed in pre-defined processes. While this approach successfully avoids procedural errors, there is no adaption to individual capabilities in training, putting invested hours on the same level as developed skills. In more detail, pilot training:

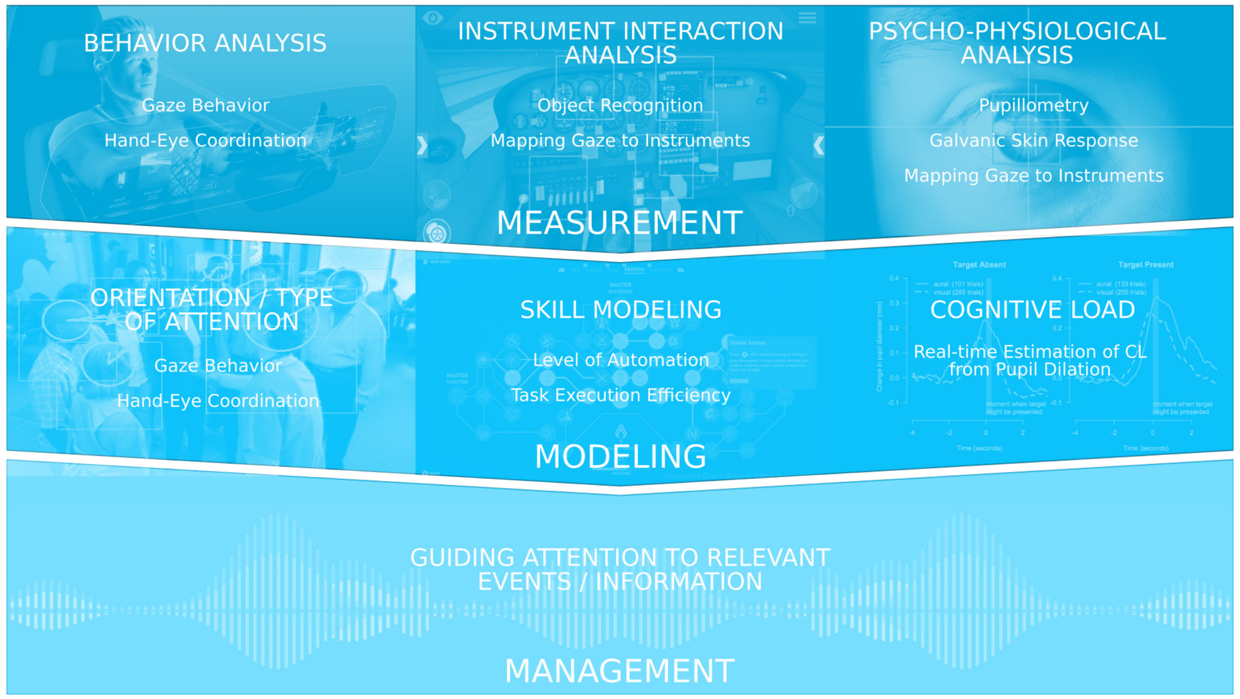
• is only based on indirect measures of trainee performance via quantifiable results (errors in task results, deviation from specified default execution)
• only enables a subjective interpretation of individual performances via experienced flight instructors, without any hard data on stress levels, etc.
• does not monitor the actual visual perception, automation of behavior or stress levels
• does not provide active, direct attention management support to adapt to individual performance differences

"It's time to stop teaching people to pass tests and start teaching them to become competent professionals.[1]"

Vision

The Airtention project will drive forward sensor-based assistance systems for the pilot training of the future enabling the substantial adaption of training processes to individual skills and progress in automation of learned processes. The assistance system includes (i) sensorial assessment and interpretation of visual perception, visual attentional behavior, executive behavior and cognitive load levels, (ii) modeling of the trainee's skill and automation levels in the specific tasks and (iii) enable a fact-based adaptation of training procedures, truly realizing Competency-Based Training (CBT) principles.

1 https://www.civilaviation.training/pilot/competency-based-training-future-aviation/



PIONEERING IN COMPETENCE-BASED PILOT TRAINING SYSTEMS :: In this context, the Airtention project has been pursuing the following goals:

Creation of an unobtrusive assistance system - The prevailing goal of the Airtention project is to provide the next level of assistance systems in air traffic control, aiming at monitoring inner states, skill and automation levels of trainees learn about their learning performance and learning curve. Based on the modelling results, the training schedule can be adjusted according to the individual progress levels
• Assessment and Modeling of high-level performance indicators - The sensorial assessment of cognitive and behavioural states allows the interpretation of underlying performance
• Monitoring of performance results for individualization of training - Monitoring the modelling results provides quantifiable metrics of trainee performance beyond the pure measurement of numeric manoeuvre measurements
• Ensuring Acceptance / Trust / Unobtrusiveness - The development of systems which evaluate intimate inner levels of stress and performance requires a suitable and adequate system design and data usage.

Assessment and Modelling of high-level, cognitive performance indicators - The adequate assessment and interpretation of behavioural and psychophysiological expressions of attention and task execution:
• Modelling of Gaze Behaviour - patterns in gaze behaviour (saccades, fixations, nearest neighbour index),
• Modelling of Visual Attention - combination of gaze orientation with head location and orientation to enable the computation of a spatial (3D) visual attention
• Modelling of Instrument Interaction - Mapping computed 3D gaze locations enables the analysis of interaction with specific areas of interest
• Modelling of Cognitive Load - The analysis of psychophysiological indicators allows the interpretation of cognitive load, i.e. based on pupillometric measures

Optimization and Individualization of pilot training - The application of competence-based training systems provide substantial benefits in training quality and trainee integration:
• Provide direct individual monitoring of trainees
• Direct, real-time feedback of trainee performance to a supervisor allows a more profound individualization
• Saving Costs & Increasing Efficiency
• Provide the next level of assistance for safety in air traffic by detecting and avoiding attentional errors

TECHNOLOGICAL SETUP

WHAT LIES BENEATH

The underlying technological framework in the Airtention project inlcudes the following hardware requirements:

- awearable eyetracker,
- a smartphone for power supply and connectivity
- processing unit (laptop, desktop computer)

Eye Tracking

As decribed before, Airtention supports currently three eye tracking devices available from Pupil Labs:

(i) Pupil Core: the open sourced Pupil Core is on the market now for several years. It provides deep insights and access to all data streams for professional users

(ii) Pupil Invisible: On the other hand Pupil Invisible offers a machine learning based closed system which follows an easy-to-use strategy (e.g. free of calibration).

(iii) Pupil Neon: the latest eye tracker by Pupil Labs, a modular, updated version of the Pupil Invisible

Computation Hardware

As a common setup, the simulator consists of the cockpit for two pilots and a simulator control station behind the actual cockpit. The computing unit requires GPU power for computation of the localization results.

The eye tracker is connected to a smartphone, which (i) provides power to the eye tracker unit, (ii) connects via WIFI to the processing unit and (iii) transfers all relevant data streams live to the desktop processing unit.

This setup allows the usage and integration of the Airtention asssistance technologies WITHOUT any fixed installations in the cockpit (visual markers, cables, power supply, etc.), which allows te system to be highly flexible and transferable between simulators. This allows for an easy and cost-effective integration of the Airtention assistance technologies into existing simulator hardware as well as into prevalent processes.

Data Processing

Data processing involves sensor data synchronization, filtering and feature extraction. Data modeling covers spatial analysis of visual attention, cognitive load analysis, process and interaction analysis. Information feedback is provided via the developed Flight Analyser application.

Data Management

• Recording session - data recorded for a certain time period that can be grouped together as a session; a training flight in either a simulator or an aircraft (Block Off to Block On). The recording session stores date, time, involved users (see below) and other session related information and is referenced by stored data.

• Data - recorded sensor values, generated values and features, labels or actions that happen during a recording session (timestamp (for synchronization), source identifier (for sensor/device assignment)).

• User - people and can be used by software components for authorization, and roles, used for defining them as Pilot Flying, Pilot Monitoring/Pilot Non Flying and Instructor for a specific session in the Airtention context.

• Setting - key-value-pairs that are of a general nature or assigned to environments or users. accessible for any connected software component and therefore not limited to a single application (like a property file).

Technical Specifications

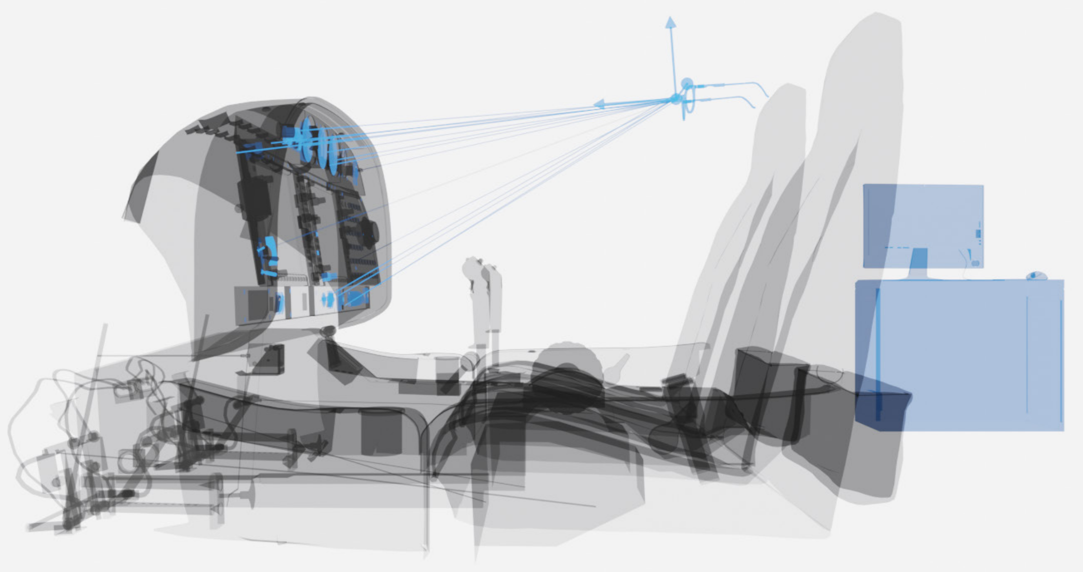
Eye Tracker:

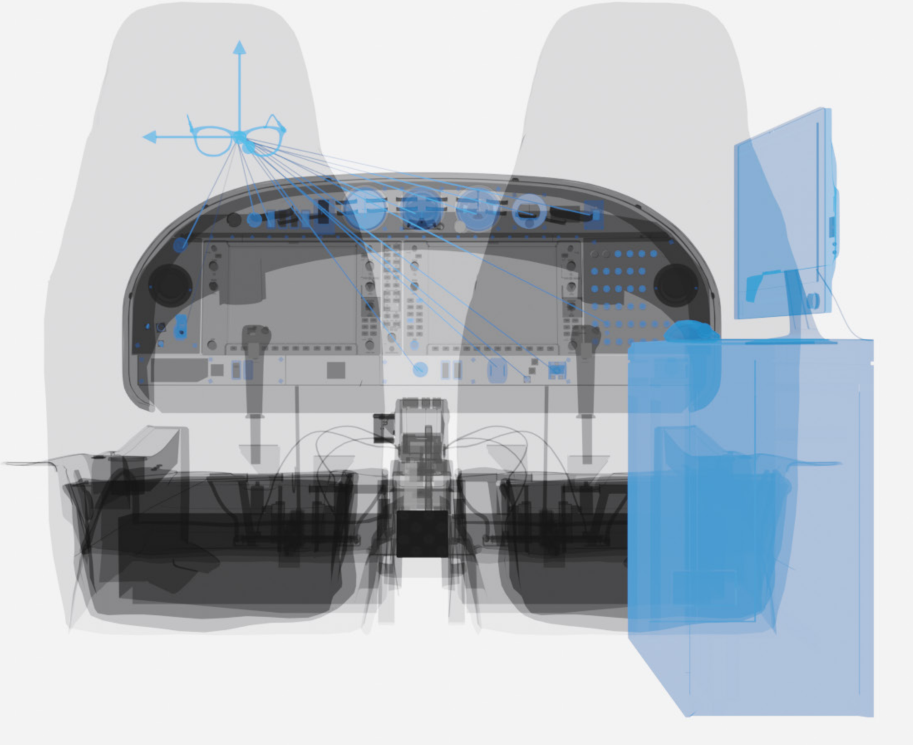
Pupil Core
- Gaze Tracking at up to 200Hz with up to 0.60° accuracy and 0.02° precision
- Scene Camera at 1080p, 30Hz

Pupil Neon
- Calibration-free
- Gaze Tracking at up to 200Hz with up to 2.4° accuracy (uncalibrated)
- Scene Camera at 1600x1200, 30Hz

Processing Platform

- Windows or Linux
- CPU: min. 4 Core, 2Ghz, Intel or AMD
- RAM: min. 8GB
- GPU: only Nvidia supported, min. 4GB





TECHNOLOGICAL SETUP

3D GAZE MAPPING

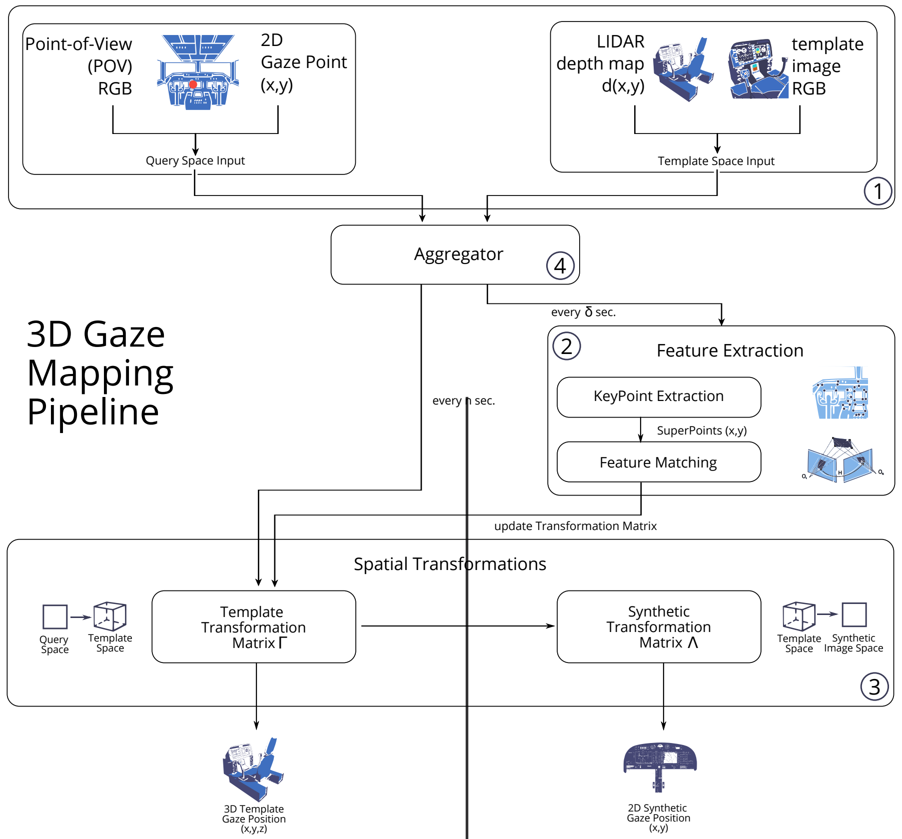
The main challenge in the analysis of visual attention lies in the degrees of freedom in head movement. Small head movements can be compensated by software and 2D heatmaps are mapped to a stitched 2D image for analysis.

6 DOF Pose Estimation targets the ability to detect the position and orientation of the object in a three dimensional vector space. To be able to map the gaze estimates to its 3D coordinates , it is essential to estimate the pose of the object in the 3D pose and project the gaze data to the 3D space as well by which we could retrieve the 3D gaze position in the model space. Estimating the pose also finds an important place in monocular indoor navigation or in any type of Industrial robotic tasks. Pose of an object can be determined by moving the object relative to the camera or vice versa.

3D gaze mapping in the cockpit environment is achieved by using the output from the eye tracker: the world view image from the front-facing camera, together with the 2D gaze position that is localized within this world view image. Furthermore, the mapping algorithm relies on the depth map of the cockpit generated by lidar, together with an associated template RGB image. The abstract cockpit environment is localized within the coordinate frame of the lidar depth map.

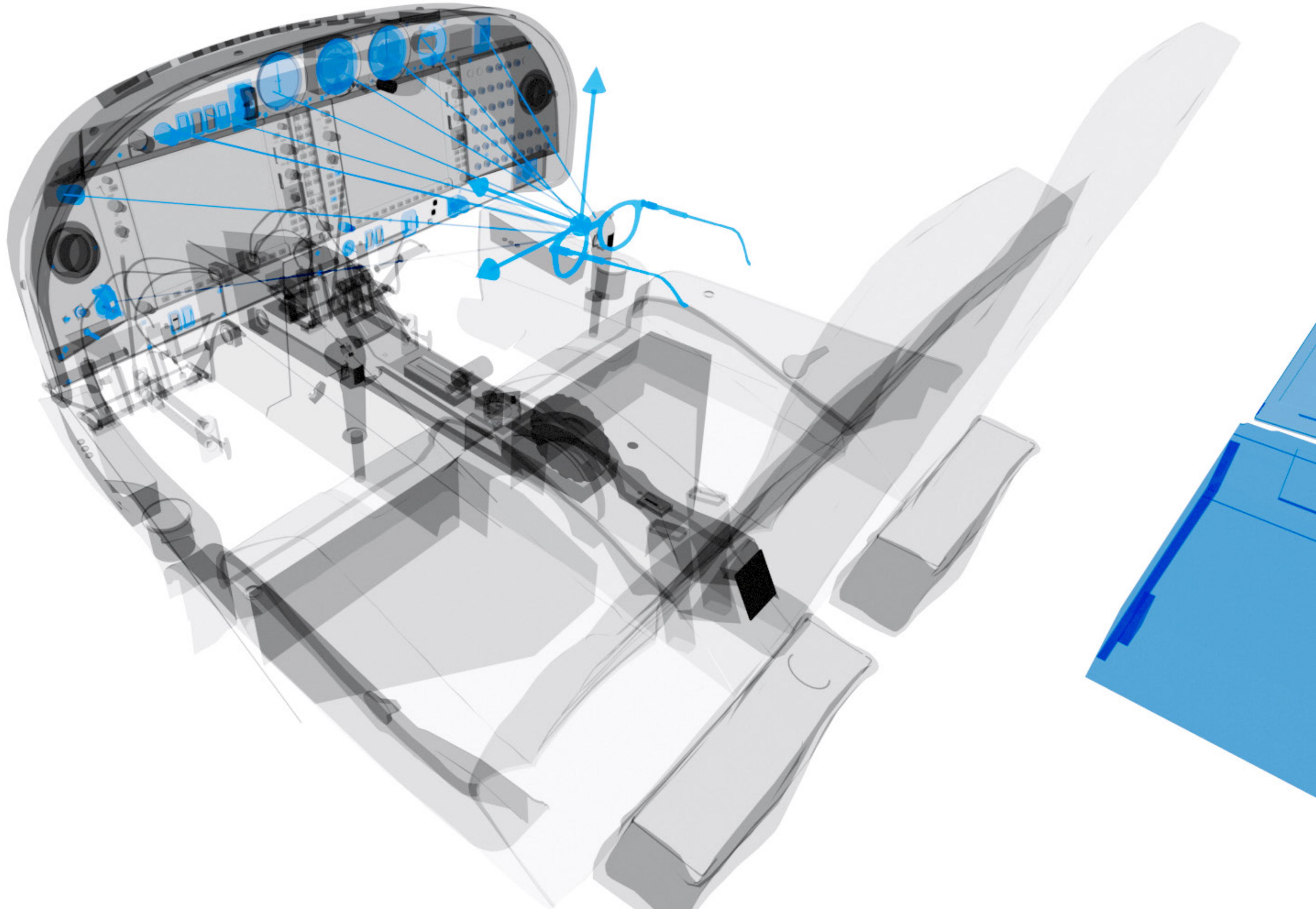
Once the data stream to the eye tracker has been established, each element from the stream contains one world view image and associated 2D gaze coordinates.

In the world view image, key points are calculated using the graph neural network. The network allows for a comparison of image features between the query image and the template image showing the cockpit environment. This way, the homography between these two images is obtained, which allows for the transformation of the gaze point from query space into local space: the coordinate frame of the template image.



From the 2D local space, the depth map is used to obtain the associated depth value of the 2D gaze coordinate, which then localizes the gaze point in 3D local space. From the depth map generation using the lidar, the reference camera pose is known, which consists of a translation vector t and a rotation matrix. It is then straightforward to transform a vector in local 3D space to the 3D global space of the cockpit.

Finally, with the gaze position known in 3D space, the gaze can also be mapped onto static image space, an abstract 2D representation of the cockpit elements. This has the advantage of only showing the interaction of the gaze with the cockpit elements of interest, and constitutes a complementary visualization of the pilot's gaze behaviour.



ANALYSIS SOFTWARE

The **Flight Analyser** software is the software solution which has been developed in the Airtention project. It is designed to run on a laptop or desktop computer in the simulator to provide relevant insights to the supervisor. Furthermore, it allows recording a training session as a database for statistical analysis and in-depth debriefing.

LOADING & STORING SESSIONS

The Flight Analyser software allows to comfortably record, playback and manage current and previous sessions, enabling the usage in both live as well as debriefing mode.

INTERACTIVE TIMELINE

The Flight Analyser provides an interactive timeline, which (i) visualizes data quality of the available sensors, (ii) shows progress in the session and allows the navigation towards different timestamps via a simple click on the timeline, as well as (iii) visualizes events and flight phases which can be labeled automatically or manually.

MAPPED GAZE & INTERACTION VISUALIZATION

The second screen on the right can be configured to show the 3D corrected mapping onto the cockpit. This projection compensates head movement in relation to the flightdeck and thus allows for automated interaction analysis with pre-defined areas of interest.

STATISTICS & ANALYTICS

As another option, the second screen can be toggled to show the statistical analysis of gaze behavior (search efficiency, dwell time durations, heatmaps, etc.) which can be computed over the overall session or for individual flight phases.

LABELING OF FLIGHT EVENTS

Flight sessions can be structured for better visual interpretation or automated statistical analysis with events. To enable intuitive interaction in the cockpit, the most prevalent and frequent events are available as push buttons for the supervisor.

1ST PERSON PERSPECTIVE WITH GAZE OVERLAY

The main view on the left side shows the 1st person field of view of the trainee with the detected gaze point and fixation and saccade interpretations as overlay.

LABELING OF FLIGHT PHASES

Similar to flight events, flight pahses can be labeled for better visual interpretation or automated statistical analysis with push buttons by the supervisor.

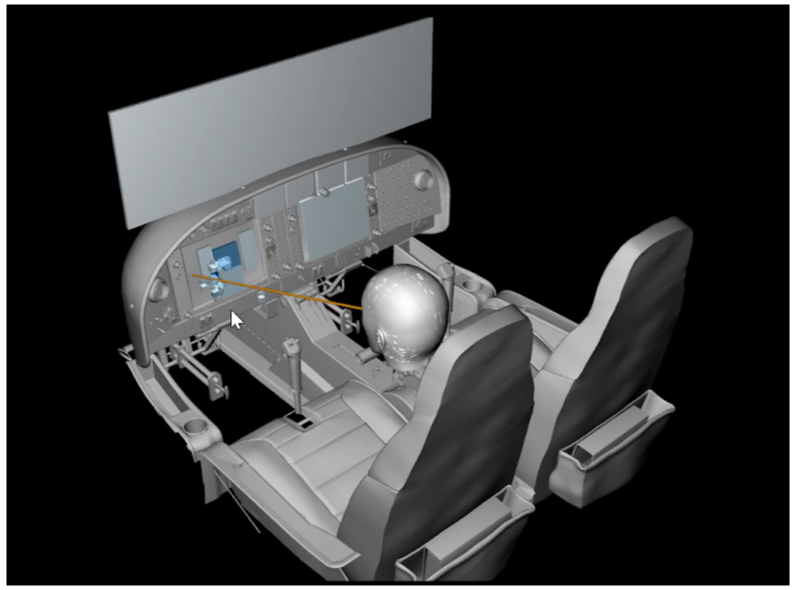
DATA ANALYTICS

HEATMAPS

Heatmaps represent the most intuitive was to visualize human gaze behavior with respect to where visual attention was focused on and which areas where disregarded.

As cockpits are complex environments with numerous instruments, controls, and displays, heatmaps offer a spatial awareness of where a pilot is looking, allowing for a better understanding of attention distribution across different cockpit elements. This information is crucial for designing effective training programs and optimizing cockpit layouts.

In pilot training, it's essential to assess how well individuals are absorbing information and interacting with the cockpit environment. Heatmaps can be used to evaluate training scenarios by analyzing where a pilot's attention is concentrated. This information can guide instructors in refining training materials and scenarios.

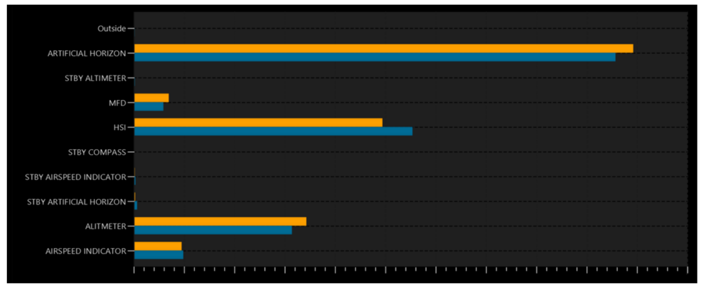


3D VISUAL ATTENTION ANALYSIS

The unique developed 3D mapping of pilot gaze in the Airtention project provides a more comprehensive and realistic understanding of where a pilot is looking in three-dimensional space within the cockpit. This technology allows for a detailed analysis of eye movements and gaze behavior, offering several benefits in the context of pilot training.

The compensation of head movements allows pilots to move freely and naturally, while at the same time allowing long-term and continuous cata analytics - in contrast to current technologies which are very limited to detection of overlays with recognizable areas of interest.

The high accuracy and continuity of tracking data represents a crucial advantage regarding the quality and the type of data analytics that can be provided to the users.



Gaze
shows
refere

Transition Matrix

	O	MFD	SAI	SAH	SA	SC	HSI	AI	A	AH
O	.000	-.001	-.002	-.000	-.000	.000	-.000	-.004	-.002	-.002
MFD	-.000	.000	-.002	.001	-.001	.000	.002	.000	-.002	.003
SAI	-.002	-.001	.000	-.000	.000	.000	-.000	-.000	.001	-.001
SAH	-.000	-.000	.000	.000	-.001	.000	-.000	.000	-.000	-.000
SA	-.000	-.001	-.000	-.001	.000	.000	-.000	.000	.001	-.000
SC	.000	.000	.000	.000	-.000	.000	.000	.000	.000	.000
HSI	-.000	-.001	-.000	-.000	-.000	-.000	.000	.007	.011	-.013
AI	-.004	-.000	-.000	.000	-.000	.000	.009	.000	-.001	.013
A	-.001	.008	-.000	-.001	-.000	.000	.004	-.002	.000	-.008
AH	-.002	-.001	-.000	-.000	.000	.000	-.011	.016	-.008	.000

Transition Matrix Density: 0.290 0.700 (+0.410)
Gaze Transition Entropy (GTE): 0.940 0.921 (-0.019)
Lempel-Ziv Complexity (LZC): 0.683 0.702 (+0.019)

Transition metrics with reference values and difference to the reference value in blue

STATISTICS & INTERACTION ANALYTICS

Eye gaze data analytics in pilot training can provide valuable insights into interaction and information perception. As key metrics and analyses that are important in understanding and optimizing pilot training, the Airtention project has realized:

- **Dwell Time:** refers to the duration a pilot fixates on a specific area of interest.
- **Scan Patterns:** analyzing scan patterns helps assess the efficiency of visual scanning techniques and identifies potential gaps in coverage.
- **Transition Analysis:** transitions between different areas of interest helps identify potential delays or inefficiencies in visual processing.
- **Cognitive Workload Assessment:** cognitive workload can help assess the mental demand associated with different phases of flight or specific tasks.

COMPARISON OF INDIVIDUAL PERFORMANCES

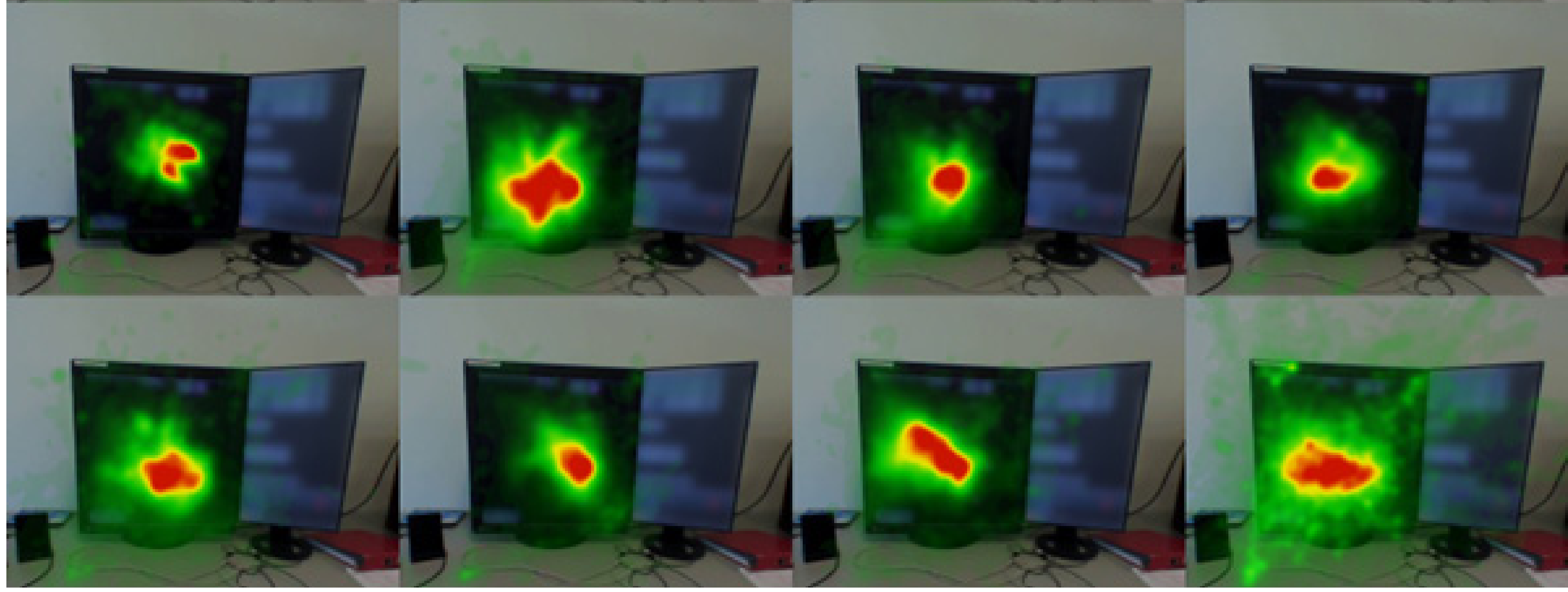
Comparing individual performance is a valuable aspect of pilot training as it allows for the identification of strengths, weaknesses, and areas for improvement.

Understanding individual performance differences enables instructors to customize training interventions. Pilots with similar challenges or strengths can be grouped together for targeted instruction, allowing for a more personalized and effective learning experience.

Individual performance data helps instructors adapt the progression of training. Pilots who demonstrate quicker mastery of certain skills may progress to more advanced training scenarios, while those facing challenges can receive additional support and practice before moving forward.

Difference heatmap for approach: red shows "lacking areas", yellow shows "additional areas" and black "matching areas"

CONFORMITY TO REGULATIONS



ASSISTANCE IN FLIGHT SIMULATOR TRAININGS

Pilot training in flight simulators is used to train the candidates in the execution of flight using the instrument ads, or to verify on an ongoing basis later.

The pilot must capture the instrument indicators, as well as some switches and lever positions. When taking off and landing it is also necessary to visually capture the runway and to correct any layers. In addition to observing the necessary viewing positions, so-called scanning is also important, i.e. the regular viewing sequence between the ads according to a specified pattern.

The training in the simulator is required primarily for the acquisition of the instrument flight qualification. This qualification is mainly acquired by aspiring professional pilots. The equipment used is representative of a class of aircraft, mostly smaller two-engine aircraft and hot FNPT (Flight and Navigation Procedure Trainer).

In a later phase of training, more complex simulators are used, which depict a special aircraft pattern with high accuracy. There are these FTD (Flight Training Device), as well as FFS (Full Flight Simulator).

In the course of the Airtention project, Austro Control as project partner conducted an evaluation of the project concepts and results to ensure the conformity to current regulations.

In the framework of the Airtention project, data in simulators were collected on the following occasions:

- Official evaluations in various FNPT II, representative of a Diamond DA-42. In these evaluations, test flights are carried out in the simulator to assess the behavior of the device.
- Training units for a test flight in a FNPT II, representative of a Diamond DA-42. Since later flights were also made with the same pilots with real DA42, direct comparison data were also obtained.

The results of these simulator efforts are:

- pilots and examiners of the ACG did not feel affected, as mostly no aviation headsets were worn and only the glass frames were noticed.
- In instrument flight, the eyes are very focused on a limited area, so the coverage of the peripheral field of vision is not a major limitation.
- There is enough space in the device and in the simulator room to operate any hardware for viewing and evaluating the data.
- The use of such equipment is not prohibited by the Technical Regulations for Synthetic Flight Training Equipment (CS-FSTD) or requires no separate approval.

EVALUATION OF APPLICATION IN AVIATION SECTOR

From the perspective of the Aviation Agency, we generally see a high potential for detecting pilot weaknesses and stress exposure as part of the training. This applies for use in simulators and aircraft. The system can be used to increase flight safety in operational applications with procedures to look at the attention of pilots and detect stress limits, such as stress or fatigue.

The use within the framework of certifications for human-factor analyses in aviation and cockpit designs is conceivable.

The issue of data protection must be considered in all applications and anchored in a user's safety management, similar to the evaluation of flight data records.

The use of the system in the current addendum, is not covered or prohibited by the technical construction regulations for aircraft in Europe (Certification Speifications of the EASA). It would be considered a PED (personal electronic device), similar to a mobile phone or tablet. In commercial operations (Regulation (EU) 965/2012) it is only necessary to determine by means of a risk analysis from the operator that the device does not interfere and does not pose any danger even in emergencies (e.g. pressure loss). If this is guaranteed, the handling must be shown in the company's operating manual.

The question remains whether a user of the system can save training content or time by doing so, or his advantage would only lie in more efficient and safer operation. The legal framework for such "credits" must be developed in cooperation with the European authorities.

EVALUATION OF APPLICATION IN AVIATION SECTOR

Eyetracking hardware and software in training for air traffic controllers (Air Traffic Controller) were tested in different situations in over 400 hours of man-work. A radar workplace was replicated during the training. The lot is sitting in front of several screen displays and has to make input and evaluate radio speeches according to the situation, as well as turn off itself.

- Firstly, the uncomplicated operation and the, de facto, unnecessary calibration were noted positively.
- The carrying comfort was also fine, only the cable could have been a little longer.
- Unfortunately, there was no possibility to test the eye tracker with optical glasses, so glasses were excluded for the time being.
- The accuracy was fine, but could be better. The size of the point of view was too large. A precise measurement, like in a cockpit, would be necessary here.
- The battery life was also good and is not a problem due to a possible change of the smartphone.

From the point of view of flight control, we see a high potential for detecting weaknesses and stress exposure of the ATCOs in the context of training and deployment.

The system can be used to increase safety in operational procedures, to look at the attention of the loot and to detect stress limits, such as stress or fatigue.

The issue of data protection must be considered in all applications and anchored in the management of the plant.

MARKET POTENTIAL

THE FUTURE OF THE AVIATION INDUSTRY AND THE PILOT OF THE FUTURE

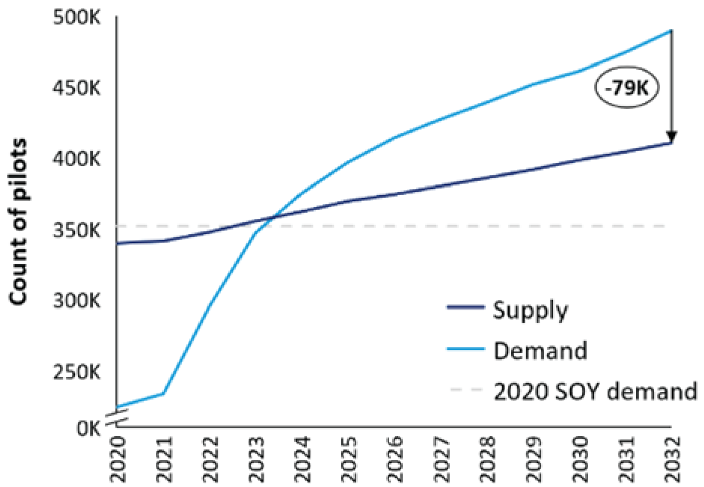
TThe global aviation industry is currently undergoing a transformation. While passenger air transport was once an almost unaffordable luxury, it has long since become a means of mass transport at knock-down prices – initiated by the deregulation of American air traffic in the 1970s, followed by the liberalization of (European) aviation in three liberalization packages in 1987, 1990 and 1992 . Until recently, the industry was an attractive and sought-after employer; practically everyone wanted to work in aviation. Today, this industry – like the economy as a whole – is suffering from a massive labour shortage.

Exogenous shocks such as COVID-19, the current wars in Ukraine and the Middle East or high kerosene prices are also hitting the industry hard, while the need for transformation through innovation in climate-friendly propulsion technologies and lightweight construction methods, which is becoming increasingly important and accelerating due to the climate crisis, is forcing the global aviation industry to rethink.

Pressure on the pilot market is increasing

The aviation industry is already severely affected by a persistent shortage of personnel, particularly in the area of cockpit crews. Many airlines are struggling to find enough qualified pilots to fulfil their operational requirements . This in turn causes dissatisfaction among customers, who have to put up with delays or cancellations. As a result, this also has an impact on the airlines' profit situation, as they loose revenue due to flight cancellations and reduced service. All in all, this has become a major challenge for the industry, especially as demand for air travel continues to rise (again) worldwide.

The pilot shortage is a global phenomenon that has a significant impact on the growth of airlines and the overall performance of the industry. According to estimates, there will be a shortage of around 79,000 pilots worldwide by 2032, while the demand for pilots will be as high as 649,000



by 2042. In North America, for example, Boeing forecasts that around 127,000 new pilots will be needed between 2023 and 2042, and as many as 143,000 in Eurasia . In addition, the number of pilots retiring is also increasing. According to industry estimates , around 42% of current pilots will retire within the next decade.

The demand for pilots will continue to increase dramatically generally have to fly with three pilots due to their more restrictive flight duty and rest period regulations. This pilot shortage also has a massive impact on the development of salaries. American Airlines already offers up to USD 590,000 per year to a captain on long-haul flights. On short and medium-haul routes, they are paid up to USD 475,000 . This is putting the pilot market under considerable pressure.

The pilot shortage in North America is expected to hit regional airlines the hardest. Regionals are also paying higher salaries to keep pilots — a blow to their smaller operating budgets and thinner margins. If regionals are unable to recruit and retain enough pilots, they may face the need to ground aircraft and fly reduced schedules or routes, with the most impact felt by smaller communities and regional centers of commerce and industry.

TRAINING AS A BUILDING BLOCK FOR SOLVING PROBLEMS

As the consultancy Oliver Wyman in the inaugural edition of its Flight Operations Survey report stated, „that new pilots will join airlines that are larger than ever before, making it more difficult to build a connected and engaged workforce. And overhanging all of this is an evolution in technology set to usher in augmented and autonomous flying – fundamentally altering the cockpit working environment. "

With these perspectives in mind, leading airlines have to rethink the way flight operations departments are designed and managed, with the goal of balancing and improving operational, cost, and employee requirements. Flight Operations departments are being compelled to develop clear, supported strategies focused on pipeline and training, pilot connectivity and engagement, and the best use of new data and technologies.

A number of measures are therefore required to counter this shortage of pilots. This is a complex problem that requires a multi-layered solution. However, as described above, pilot education and training in particular are key elements in attracting young people to this profession. Financial incentives can be provided for prospective pilots or companies can offer to cover the costs of training, but above all it is essential to reorient training towards the technology-savvy „pilots of the future".

THE PILOT OF THE FUTURE

Oliver Wyman summarized a survey with the outcome , that as you look forward, the number of younger, more diverse pilots will only continue to grow. This new generation will learn and fly differently. They will be more adaptable to evolving technologies and they may demonstrate greater individuality and less conformity with command-and-control models.

Demographics-related changes are increasing focus on emerging technologies. Younger pilots are more likely to prefer shorter "micro-learning" sessions and more interactive training. New technologies such as virtual and augmented reality not only will enable airlines to provide more and faster training, but allow them to implement the latest evidence-based and situational training methodologies to maximize flight safety and efficiency.

Also the upcoming issue of a future „single pilot operation ", currently addressed by Airbus (among others) in connection with the new Airbus A350 Freighter shows, that in the future new training, additional requirements for redundancy and new systems in the cockpit are inevitable to maintain the level of safety equivalent to existing operations.

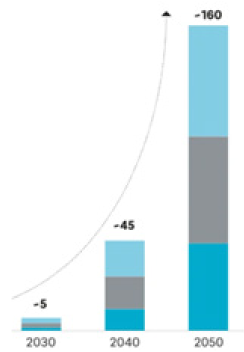
The issue of future urban mobility also poses corresponding challenges for future pilots. Roland Berger estimates that there will be 160,000 high-tech, urban aircraft by 2050, which will move differently to current air traffic, will have to comply with a different safety level during operation and will be flown by pilots with special training. While operating a helicopter in urban areas today is a highly specialized procedure that requires years of special training, it is already possible to outline the challenges that future pilots of urban aircraft will face.

Following technological and regulatory trends

In order to do justice to the future mobility behavior of society in the field of air transport, to be able to guarantee airlines an appropriate pool of pilots in the future and to not only maintain safety levels at the current level, but to increase them, training must be adapted not only to operations (flight execution), but rather to the pilots of tomorrow, who will be more technology-savvy and more individual.

It is important to follow technological trends. While new technologies e.g. in the field of augmented reality and the associated new generations of simulators are already being used today, international developments in the field of competency-based training as future regulatory requirements by the ICAO and thus also by the EASA and FAA in the field of pilot training will bring disruptive approaches in the training sector.

This not only maintains or increases the safety level, but also increases the efficiency of the training, customizes it to the individual pilot and, as a result, reduces the costs of training and ongoing training. Airlines and training institutions must therefore work together to invest in the development of high-tech, individualized and therefore more efficient and cost-effective training programmes while maintaining strict regulatory safety levels.



Urban aerial vehicles in operation between 2020 and 2050 (in 1.000)

AIRTENTION

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