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D4.2 - Traffic Management Intrusion and Compliance System

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Executive summary

This deliverable describes TraMICS, the Traffic Management Intrusion and Compliance System. TraMICS serves as detector for potential security incidents. An instance of TraMICS is dedicated for a specific air traffic controller's area of responsibility. It analyses the traffic situation and the voice of the radio-communication users, it aggregates the amounts of five different kinds of indications to a security situation indicator.

Chapter 1 introduces TraMICS and puts it into the context of SATIE. Chapter 2 describes the system and its functions, chapter 3 its verification environment. Chapter 4 contains a brief user manual for the Air Traffic Controller and describes also the messages sent out to the Correlation Engine, SATIE's central tool for collecting and correlating alerts, to support the operators of Security Operation Centres (SOC). TraMICS' verification is documented in chapter 5, starting with a table (Table 5.1) providing an overview of the test cases and their status. The Key Performance Indicators (KPIs) evaluated for TraMICS are summarised in section 5.7. This document closes with conclusions in chapter 6.

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List of Acronyms

Acronym	Definition
AC	Aircraft
ANSP	Air Navigation Service Provider
A-SMGCS	Advanced Surface Movement Guidance and Control System
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
CL	Clearance Monitoring Module
CMCD	Conflict Monitoring and Conflict Detection Module
CORE	Correlation Module
CWP	Controller Working Position
DB	Database
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
DNN	Deep Neural Network
DoA	Description of Action
EDDH	Hamburg Airport
EER	Equal Error Rate
FAR	False Acceptance Rate
fn	false negative
fp	false positive
FRR	False Rejection Rate
GSR	Galvanic Skin Response/Skin Conductivity
GMM	Gaussian Mixture Models
GUI	Graphical User Interface
HMI	Human Machine Interface
HR	Heart Rate
ICAO	International Civil Aviation Organization
IT	Information technology
JSON	JavaScript Object Notation

Acronym	Definition
KPI	Key Performance Indicator
PLDA	Probabilistic Linear Discriminant Analysis
SAV	Slovenská Akadémia Vied (Slovak Academy of Sciences)
SD	Stress Detection
SOC	Security Operation Centre
SpV	Speaker Verification
tp	true positive
TraMICS	Traffic Management Intrusion and Compliance System
UB	Unusual Behaviour
UHF	Ultra-High Frequency
VAD	Voice Activity Detection
VHF	Very High Frequency
VoIP	Voice over IP

1 Introduction

The structure of this chapter reflects the structure of D6.2 (1) chapter 3, which gives a short introduction to all the SATIE Tools. This structure is pretty well fitting for the introduction of this deliverable dealing with TraMICS.

1.1 What is TraMICS?

The Traffic Management Intrusion and Compliance System (TraMICS) serves as a detector for potential security incidents. TraMICS analyses different indicators of the traffic situation combined with analysing voices participating in radio-communication. This leads to five different kinds of alerts which TraMICS aggregates to a security situation indictor. One instance of TraMICS is dedicated to a specific Air Traffic Controller's (ATCO) area of responsibility.

TraMICS is a joined work of the Slovak Academy of Sciences (Slovenská Akadémia Vied, SAV) and the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt, DLR). SAV designed and developed all functions dealing with voice analysis whereas DLR focused at the traffic situation and the determination of the security situation indicator.

A specific, well adapted instance of TraMICS needs to be configured for each area of responsibility of air traffic controllers. In accordance with the DoA (2), one instance of TraMICS is built for SATIE and T4.2 started with the selection of the area of responsibility TraMICS shall work at in SATIE. This selection was required to guarantee that the necessary human-in-the-loop real-time simulation environment is available to verify TraMICS and prepare the validation.

If "TraMICS" is mentioned in the further document, it means the SATIE's TraMICS instance for Hamburg Airport (ICAO code EDDH) ground control. The following reasons led to that decision:

- TraMICS shall cover a controller working position located in an Air Traffic Control (ATC) tower or at the airport to enable Scenario #5.
- Apron and ground control (as task for an ATCO) may be combined, depending on the specific airport; and apron control could be done by the airport itself and not necessarily by the ANSP (Air Navigation Service Provider).
- EDDH's topology was already implemented in the Tower Simulator of DLR's Air Traffic Validation Center.
- Due to available data, DLR was able to derive a realistic traffic scenario.

For operational use TraMICS needs a requirement to be fulfilled which is not yet established: It is the enrolment and management of authorized speakers (i.e. ATCOs and pilots) in the tool. During the enrolment process a so called 'X-vector' (comparable to a fingerprint) is determined (cf. section 2.5) which is uniquely associated with the ATCO or pilot. The idea is to save the ATCOs' enrolments on their working position ID cards assuring privacy and data protection (3). The pilots' ones are attached to the flight plans which are shared on a need-to-know basis (i.e. only with sectors and airports the flight passes).

1.2 What is its role in the context of SATIE?

As sensor for potential security incidents happening in the responsibility of the ANSP, but using airport's surface, TraMICS is the bridge from the ANSP to the airport. All security related findings will be reported to the Correlation Engine to (1) widen the spectrum of awareness and to (2) establish a fast and automatic communication. Figure 1.1 shows TraMICS in the context of the other the architecture elements of SATIE.

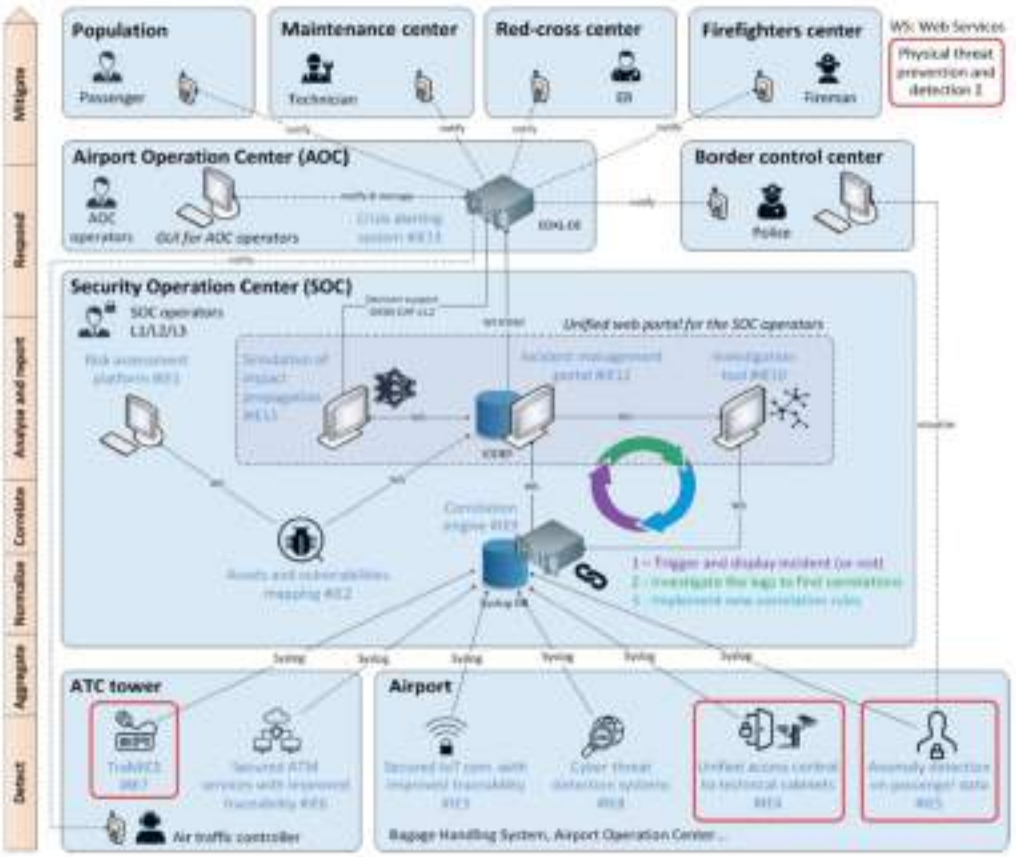


Figure 1.1: SATIE architecture elements and their communication

1.3 What are its SATIE-related test objectives?

The verification of TraMICS is part of this deliverable. The related test objectives are listed in Table 5.1 in chapter 5.

1.4 What are the KPIs to be measured?

TraMICS will measure and evaluate the following KPI:

- **Time_until_security_situation_update$_{TraMICS}$**: This is the (configurable) period, a user has to wait until TraMICS updates the security situation indicator, considering latest findings of the single indicators.
- **Equal_Error_Rate$_{SpV}$**: This is the Equal Error Rate (EER) measured for the speaker verification functionality of TraMICS. The Speaker Verification Module creates models of captured/incoming voices and compares them with the model of voices of enrolled speakers. This comparison gives a similarity score. A binary decision of a match or mismatch is performed by comparing the score with a **threshold**. The rate of incorrect decisions (in %) is called Error Rate. The optimal value of the threshold depends on the application as it

influences the behaviour of the system. With decreasing threshold, the recall of a biometric system increases and precision is lowered[1], False Acceptance Rate (FAR) will rise and False Rejection Rate (FRR) will drop. Conversely, with increasing threshold the precision is increased and the recall is lowered, FAR will drop and FRR will rise.
The **Equal Error Rate (EER)** is the Error Rate obtained with a specific value of the threshold at which the False Rejection Rate (FRR) and False Acceptance Rate (FAR) are equal. Speaker verification systems generally do not use this threshold setting in their real operation, because the setting would not be suitable for security applications (FAR would be too high). This setting of the system is only used to compute the EER. The EER is used in most laboratory experiments to describe the overall accuracy of the speaker recognition system (4). Therefore, it was decided to stick to this practice and evaluate the speaker verification functionality with respect to EER.

- **$Accuracy_{SD}$**: This is the Accuracy measured for the stress detection functionality of TraMICS. If the affiliation of individual test samples to the particular classes (e.g. neutral, stressed, or highly stressed) is annotated in the test database, this annotation can be taken as ground truth or reference, and the correctness of the classification can be evaluated using the measure of "Accuracy". Accuracy is the ratio of the number of correct results to the number of all tests performed. If the measured phenomenon (e.g. stress) is not annotated in the database by class affiliation, but is expressed by numerical value, regression can be applied and the result will reach values on a continuous scale. In this case it is possible to define the maximum allowed deviation (tolerance) of the measured (predicted) value from the reference value given in the annotation. If the difference is smaller, the result is correct, if it is greater, the result is considered incorrect.
- **Non_Compliance_Detection_Rate**: This is the number of observed detections found by the conflict detection, the conformance and clearance monitoring functionalities of TraMICS, divided by all observed conflicts, non-conformances and clearance issues.

1.5 How is TraMICS organized?

Figure 1.2 shows TraMICS' architecture. TraMICS consists of the following main modules:

- Conformance Monitoring and Conflict Detection (CMCD),
- Clearance Monitoring (CL),
- Speaker Verification (SpV),
- Stress Detection (SD),
- Correlation module (CORE) determining the security situation indicator.

It is supported by auxiliary modules:

- Autorouter: This module sets initial taxi routes to each flight.
- Traffic View Message Interface: This module enables communication between TraMICS and the Traffic View, which is the Human Machine Interface (HMI) used to show the traffic situation.

Figure 1.2 shows the architecture of TraMICS integrated in the verification environment (Data Sources and CWP (Controller Working Position)). The Stress Detection Module is not depicted in this

[1] *Precision = tp/(tp + fp); Recall = tp/(tp + fn)*; where *tp* is the number of true positive decisions; *fp* is the number of false positive decisions and *fn* is the number of false negative decisions (2).

figure, as it belongs to the TraMICS **concept**, but it shall not be used in the TraMICS **tool** verification due to ethical concerns. It is not possible to expose participants in verification tests to higher levels of real stress. Therefore, the SD module is not integrated into the actual TraMICS **tool** and its functionality will be verified via laboratory tests using databases at SAV.

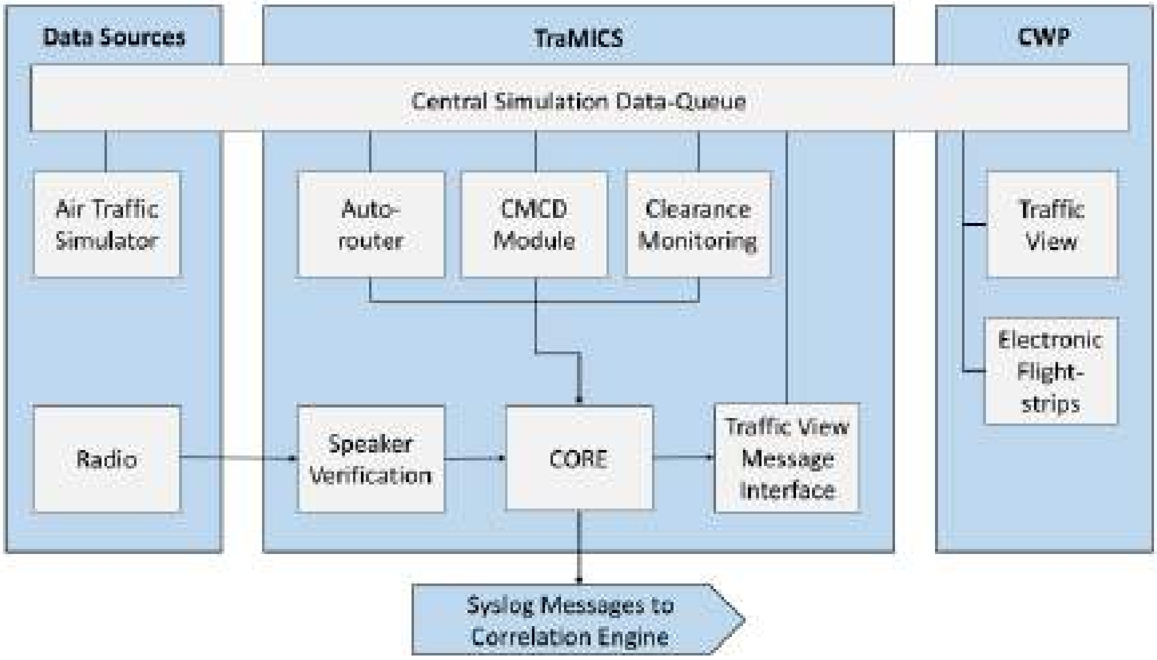


Figure 1.2: Architectural overview of the TraMICS tool

2 Modules descriptions

This chapter describes the TraMICS modules (Figure 1.2 + SD module). Sections 2.3-2.6 describe the modules detecting single indications, whereas the module determining the security situations indicator is described in section 2.7. The connection to the HMI and the integration is described briefly in the sections 2.8 and 2.9.

The following sections will use the words “flight” and “aircraft”. In general, a flight is a logical entity, whereas an aircraft is a physical one. Each flight is operated by an aircraft. In the following sections, the word “aircraft” is sometimes used as synonym to flight, as e.g. position data are aircraft-related, but - being strict - the route is flight related. It is assumed that each aircraft has also a flight plan (callsign, destination, …) which is shown to the ATCO. In the simulation environment used for verification, the aircraft-flight assignment is one-to-one.

2.1 Central Simulation Data Queue

The TraMICS’ modules are connected to a central data queue that also interconnects the simulation data sources and the CWP to allow for data exchange between the different software subsystems. The data is exchanged in a message format, where the data is encoded as a JSON string in the message body and the topic of the message encodes the data type of the message body.

The aircraft positions are updated by the Air Traffic Simulation and used by the Traffic View for visualizing the current traffic situation as well as the CMCD and CL module for detecting conflicts and non-conformance situations. Both, CMCD and the CL modules use the clearance entries in the electronic flight system as input.

2.2 Autorouter

As soon as a new flight appears in TraMICS, the Autorouter calculates the shortest route for this flight from the stand to the runway in case of a departure and for an arrival vice versa.

2.3 Conformance Monitoring and Conflict Detection Module (CMCD)

Non-conformant movements and especially potential aircraft conflicts are for sure safety related issues but might also be security relevant indications. Therefore, TraMICS monitors and compares the clearances and the traffic situation to detect the mentioned indications.

The Autorouter module of TraMICS assigns a route to each flight. The ATCO can change the route at any time in the CWP. The CMCD is triggered by updated aircraft position data provided by the verification environment to

- monitor conformance of the aircraft movement to the planned route.
- monitor conformance to given clearances (This includes monitoring of movement to not yet given clearances, e.g. taxi clearance is not given, but aircraft starts taxiing.).
- detect potential conflicts with other aircraft.

The distances used to detect route deviations or conflicts are configurable. A potential conflict is detected when the separation falls below a minimum value. This differs whether both aircraft (AC) are taxiing (minSeparation) or whether one AC holds (holdSeparation). The configuration used within SATIE is listed in Table 2.1. Table 2.2 lists all alerts, the CMCD could detect.

Table 2.1: Initial values used for CMCD module

Name	Initial value	Description
allowedRouteDeviation	30.0 [m]	Permitted deviation of the current AC position from the planned route.
minSeparation	100.0 [m]	Permitted distance between two taxiing AC.
holdSeparation	44.0 [m]	Permitted distance between a taxiing and a stopping AC.
timeDistance	20.0 [s]	As no time-based planning is performed, a minimal forecast is done for crossings/merging points. If two aircraft will be with less than timeDistance on one of those points, it is rated as potential conflict.

Table 2.2: Overview of alerts from CMCD module

Short name	Description	Triggered by
ROUTE DEV	AC is deviating from planned route.	Position data
ROUTE DEV [opposite heading]	AC is on planned route but with opposite heading.	Position data
NO ROUTE	AC is taxiing although no planned route is available.	Position data
NO CLR	AC is either pushing back or taxiing without the appropriate clearance.	Position data
Conflict with <callsign of other AC>	AC is conflicting with the other AC.	Position data

2.4 Clearance Monitoring Module (CL)

The clearance order monitoring, which is one task of the CL, is an example to detect unusual behaviour. Depending on the airport and the specific parking position, a well-defined order of clearances is used to process the flight.

The CL is triggered by clearance input and updates of aircraft position data provided by the verification environment to

- monitor conformance to given “hold immediately”-clearances.
- monitor the order/fitting of clearances.

The CL uses given clearances to verify that they match the specified, but configurable, clearance sequences. Arrivals and departures with rollout or pushback positions are distinguished. Additional clearances like HOLD or CONTINUE are possible. The configuration settings used within SATIE are listed in Table 2.3. Table 2.4 lists all alerts, the CL could detect.

Table 2.3: Initial settings used for CL module

Name	Initial setting	Description
pushBack	[STARTUP, PUSHBACK, TAXI, LINEUP, TAKEOFF]	Clearance order for a departure on a pushback position.
rollOut	[STARTUP, TAXI, LINEUP, TAKEOFF]	Clearance order for a departure on a roll-out position.
arrival	[LANDING, TAXI]	Clearance order for an arrival.
possClear	HOLD	Additional clearance which could be given at any time.
ClearAfterPoss	CONTINUE	Clearance which has to follow possClear.

Table 2.4: Overview of alerts from CL module

Short name	Description	Triggered by
No appropriate CLR	Pushback clearance is given for AC at a rollout stand.	Clearance input
NO PUSH CLR	AC has no pushback clearance but taxi clearance instead.	Clearance input
NO TAXI CLR	AC has no taxi clearance but line-up clearance instead.	Clearance input
NO LND CLR	AC has not received landing clearance but taxi clearance instead.	Clearance input
TX instead of HLD	The AC has received a “hold immediately” command, but its speed is increasing. (This may happen either without having stopped or the AC has stopped and starts moving again without clearance to do so.)	Position data
Not Stopping	AC is not stopping after a “hold immediately” is given and moves constant. (This will also happen, if the AC has decreased its speed but moves constant with low speed instead of stopping.)	Position data

2.5 Speaker Verification Module (SpV)

The Speaker Verification Module (SpV) continuously listens to the audio stream of the air-ground voice communication. Further, the voices of all speakers taking part in this communication are compared with the actual list of authorized speakers (whitelist). Voice samples of all the authorized speakers have to be collected in advance to be able to create their models/templates for comparison with the incoming tested voice samples. The process of introducing the voice templates of the authorized speakers is called enrolment.

The challenge of various signal qualities had to be solved due to different channels used in the verification environment and the expected conditions of deployment in real operation. The DLR Tower Simulator, which is the verification environment of TraMICS, uses VoIP channel for voice communication, so the version of the SpV module used in simulations at DLR was optimized for the wide-range VoIP channel speech (the functionality was tested in SpV.1 (5.1.1) and SpV.2 (5.1.2) test cases). However, SAV has also performed tests to confirm the system's ability to work with the speech signal on the analogue radio channel, which has narrow spectral range and is noisy (SpV.3 (5.1.3) test case).

In speaker verification, the claimed identity of a speaker is confirmed or refuted. There are two types of speaker verification: text-independent speaker verification verifies the identity without constraint on the speech content, and text-dependent speaker verification requires the speaker uttering exactly the given password. The approach used in SATIE is text-independent.

Speaker authorization is the ability of the system to know the voices of the persons that are authorized to speak on the channel, so that the voices that the system doesn't know are designated as intruders by the system.

Technically, in the process of authorization, the software compares the incoming sample voice to the group of models belonging to the authorized persons.

The list of authorized persons is called a “whitelist” and a group of the authorized persons a “whitelist cohort”.

The speaker recognition can generally be done on a *closed set* of speakers, in which all the possible speakers are known, or on an *open set*, where the test sample may belong to a speaker that is unknown to the system. We therefore take speaker authorization as an open-set task that can be considered as group-detection or group-verification problem. There are dozens of speakers, that are authorized to communicate in a certain flight sector in one moment and the number of potential violators is practically unlimited.

From a theoretical point of view, this is very similar to a multi-target detection task (5) or open-set, text-independent speaker identification (6). The actual incoming spoken utterance is compared to the models of all the speakers of the actual whitelist cohort. If the maximum score of all these comparisons is lower than a pre-defined threshold, the speaker is considered an unauthorized person.

The illustrative schematic diagram of the architecture of the SpV module is presented in Figure 2.1

Technically, the SpV is based on an up-to-date approach using so called “X-vectors”. A Deep Neural Network (DNN), which was trained to discriminate between speakers, maps variable-length utterances to fixed-dimensional embeddings that are called X-vectors. As it can be challenging to collect substantial quantities of labelled training data, data augmentation was used, consisting of adding noise and reverberation (7). The module was created in the Kaldi environment (8). During the training phase, the definitive version of X-vector extractor based on DNN and PLDA (Probabilistic Linear Discriminant Analysis) modules were trained on the extra-large speaker-verification databases: VoxCeleb1 (9), having 1250 speakers and 150 000 utterances, and VoxCeleb2 (10) having 6000 speakers and 1.1 million utterances. Reverberation and noising were used for data augmentation.

Simply put, the X vector serves as a model of the speaker.

In the verification phase, an X-vector is extracted from the current utterance and the PLDA module is then used to calculate similarity score against the whitelist cohort. A decision is made by comparing the maximum similarity score with a threshold.

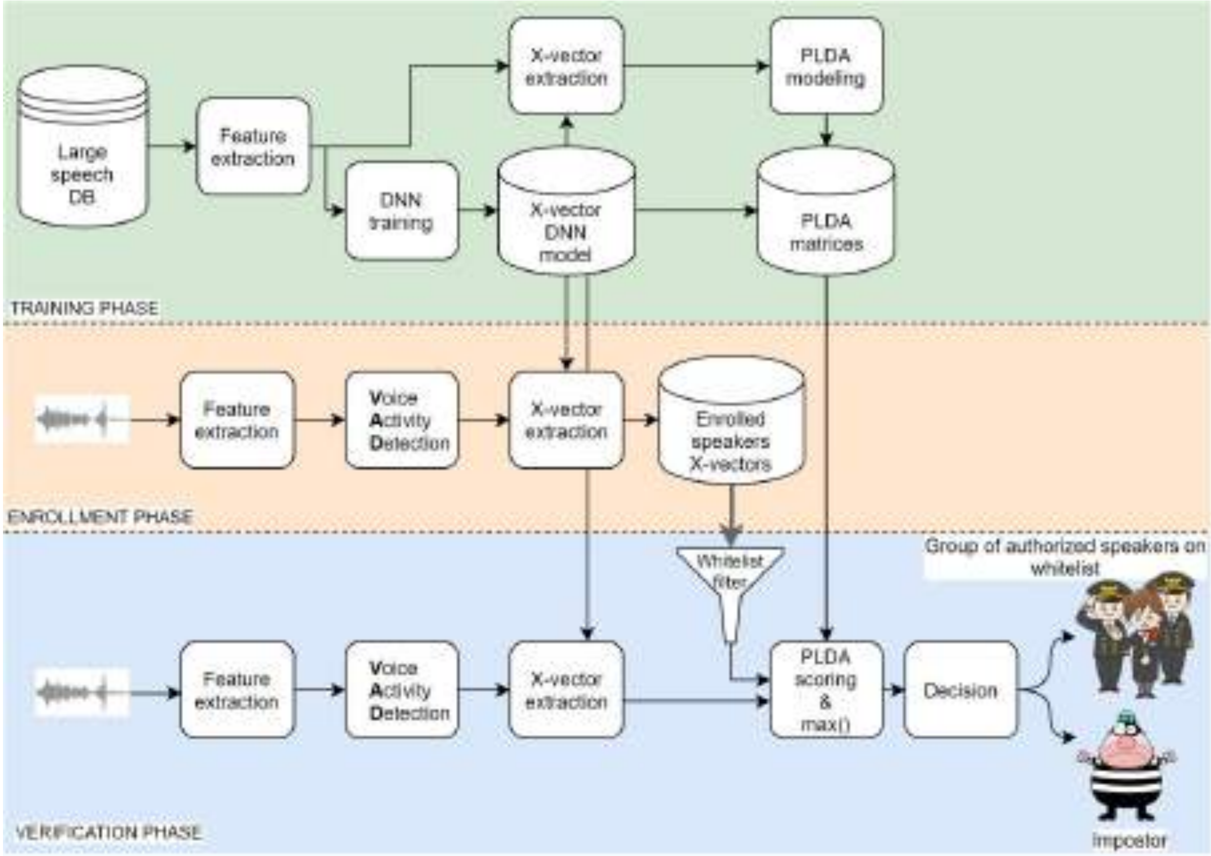


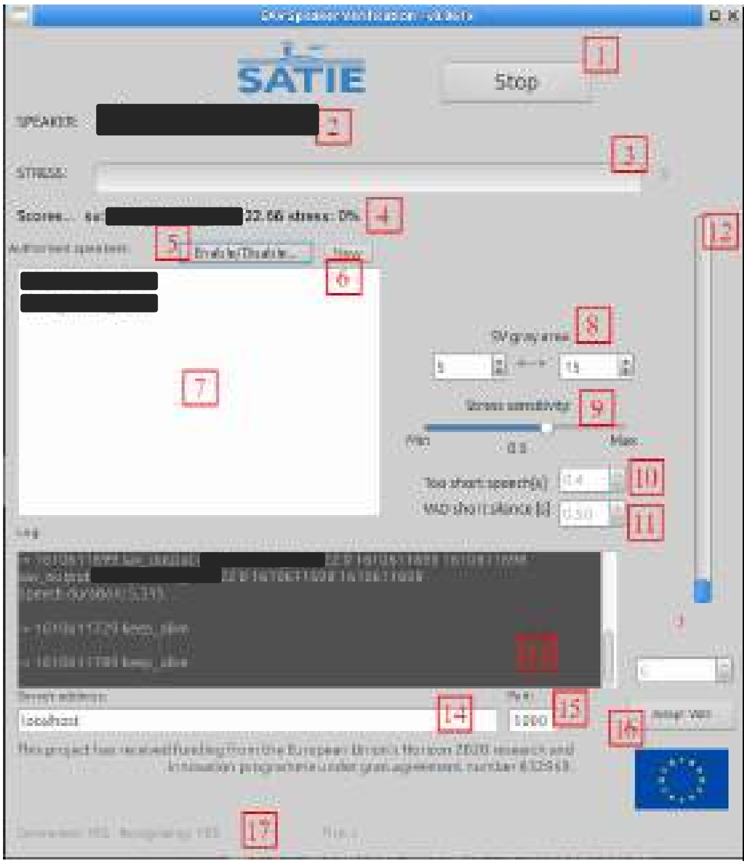
Figure 2.1: Schematic diagram of the Speaker Verification Module – training phase, enrolment phase and verification phase

The output of the SpV module is in the form of a score, representing the probability, that the actual speaker is one of the authorized persons on the whitelist. Two configurable thresholds T1 and T2, intended for setting the sensitivity of the system, are set by the user. If the score is higher than T1, the "authorized speaker" (AUTHORIZED) message is generated. If the score falls in the interval T1-T2, the INDETERMINATE alert message is generated, and if the score is lower than T2, the “speaker not authorized” (NOT_AUTHORIZED) alert message is generated. In the case the received utterance is too short for a reliable decision, the TOO_SHORT_FOR_EVALUATION message is generated and sent to the TraMICS’ CORE module. An overview of messages sent by SpV module can be found in Table 2.5.

Table 2.5: Overview of messages from SpV module

Short name	Description
NOT_AUTHORIZED	Speaker does not belong to the current whitelist.
AUTHORIZED	Speaker belongs to the current whitelist. Speaker ID is returned.
INDETERMINATE	The value of similarity score doesn’t allow to make a reliable decision.
TOO_SHORT_FOR_EVALUATION	The utterance is too short for a reliable decision.

As the pre-requisites of the operational use are not yet established (cf. section 1.1), a developmental graphical user interface (GUI) for SpV and SD modules in TraMICS is needed. This GUI and a brief description of its controls and information is presented in Figure 2.2. The GUI is used by the exercise leader during experiments: It enables setting of configuration parameters for the SpV and SD modules, enrolment of speakers and management of the white list entries. The speakers could be enrolled with clear (real or fantasy) names as well as pseudonymized to get the speaker ID. For operational use it is expected that the employers enrol their pilots/ATCOs and know the relation of person to speaker ID. They are the only ones needing this knowledge and expected to comply with personal data protection regulations as they have to do today as well.



1. SpV-SD module Start/Stop button
2. ID of currently recognized speaker
3. Continuous stress level indicator
4. ID of last recognized speaker and stress level
5. Button to manually add/remove speaker to/from whitelist
6. Create new enrolment button
7. List of speakers in whitelist
8. T1 and T2 Thresholds
9. Stress Detection sensitivity
10. Too-short-utterance duration threshold
11. Too short silence duration threshold
12. Voice signal level meter
13. Message logging area
14. IP address of the TraMICS server
15. Port of the TraMICS server
16. Button to start VAD - voice activity detection sensitivity adaptation
17. Status area

Figure 2.2: Graphical user interface for SpV and SD modules in TraMICS

2.6 Stress Detection Module (SD)

The Stress Detection Module (SD) continuously monitors the radio voice communication. It searches for known voice qualities and patterns that are typical for speech under stress. This function estimates the stress level of each utterance and provides a stress score. It is expected that unusual/emergency situations like security and safety events lead to stressful situations on the pilot's and controller's side. The stress may be reflected in the person's voice. The measured stress score can contribute to a correlation process and therefore helps to identify such situations.

The term "stress" covers an extremely wide range of phenomena and the definition of stress depends on the area of interest of the researcher and on the application. One of the widely accepted definitions (11; 12) states that stress occurs when a person perceives the demands of an environmental stimuli to be greater than his/her ability to meet, mitigate, or alter those demands.

The stress response is the way the human body responds to common challenges, but also to extreme threats. Challenge states occur when individuals appraise their resources as exceeding the demands of the task, whereas threat states occur when situational demands are perceived to exceed resources (13).

Measurement of stress is inherently complex because stress is experienced on multiple levels – social, psychological, and physiological. The stress-inducing events or situations that happen to a person, are called “stressors” or “stressor exposures”. The cognitive, emotional, and biological reactions that such situations evoke are called “stress responses”.

Stress can be induced by physical threat, danger, social, or professional status threat, humiliation, entrapment, and many more.

Affective states are an umbrella term for all emotional experiences. Measures of perceived psychological stress capture a mix of affective states and cognitions (problems with memory, information processing, etc.) in response to a situation. Acute psychological stress responses are often measured by detecting specific emotional states. This is because negative emotional responses (fear, anxiety, sadness, anger) to an acute stressor are considered a core component of an acute stress response. Furthermore, emotions can be measured acutely and precisely as immediate responses to an eliciting event (13).

The stress assessment window used in the SATIE project is extremely short. It corresponds to the length of one to several utterances, i.e. one to several seconds.

The understanding of stress used in SATIE is determined by purposes of this solution and may not be applicable in other contexts. Stress can be also defined as a state in which physiological or psychological integrity of an individual is threatened via external or internal means (14). In this case, external or internal adverse forces that serve as threatening stimuli are referred to as stressors. When using the term “speech under stress”, we assume that the speaker is in a state of stress, therefore some form of pressure applied to the speaker results in changes of his psychical state, perturbations of the speech production and consequently the acoustic signal (15). Although stress-reaction was originally considered a non-specific response, changes in speech that are a result of both involuntary or autonomic bodily changes and voluntary effort, are dependent on a particular stressor. Hansen et al. (16) proposed a taxonomy of stressors, based on the mechanisms in which they influence speech process. For example, stressors with direct physical impact on speech (e.g. acceleration, vibration) are considered “zero order”. Following are chemical and biological stressors – “first order”, perceptual stressors (e.g. noise, Lombard effect) – “second order”, and psychological and emotional stressors – “third order”. All of these types of stressors should be taken into consideration in ATM security. Moreover, due to conscious and unconscious interpretation of the stressful stimuli (16; 17) all lower degree stressors may be accompanied by a third level emotional effect. Currently, a number of research works examined speech under stress (18; 19), while other studies examined emotions in speech (20; 21). Although, these two lines of research have been done separately, there are many common points in both approaches. In psychological theory, concepts of emotions and stress are largely interconnected (17). Based on dimensional models of affect (22), stress may be associated with high arousal (physiological activation) and low emotional valence (unpleasantness).

The authors of the SD module participated in the GAMMA project (23), the “predecessor” of SATIE, focused on ATC, where changes in arousal were used to measure momentary stress (24). The speech database used for training and testing contained read security warning messages at three levels of arousal. Although this design has its limitations, using acted stress or emotion is a standard procedure in study of emotional speech (25). The technical solution of GAMMA’s SD was using Gaussian Mixture Models (GMM).

In the SATIE project, a newer technology of Deep Neural Network (DNN) modelling and so-called X-vectors (7) was applied and also a wider definition of stress was adopted. The stressful situation is defined as a substantial deviation from the normal, usual, standard operating state, and the stress is operationalized as a substantial deviation from the neutral values in the two-dimensional affective space defined by valence and arousal, as presented the circumplex model of affect (22) (see Figure 2.3).

Stress and emotions are very closely related. Distress is sometimes considered an emotion. For example, when the stressor is an emergency situation, the person is stressed, he/she is worried about his life, he is scared, he feels fear emotion, fear is also manifested in his voice. Vocal cues of affective-response, stress-response, and emotional-response are the same. It is just as common to express stress in the same two-dimensional affective space as emotions. This space makes it possible to link the stress caused by different stressors with the emotions that are also the result of these stressful situations. It is therefore reasonable to use speech databases designed for emotion research to train and test a stress recognizer. In order to use them to research higher levels of stress, the emotions represented in the databases must also be strong and full-blown.

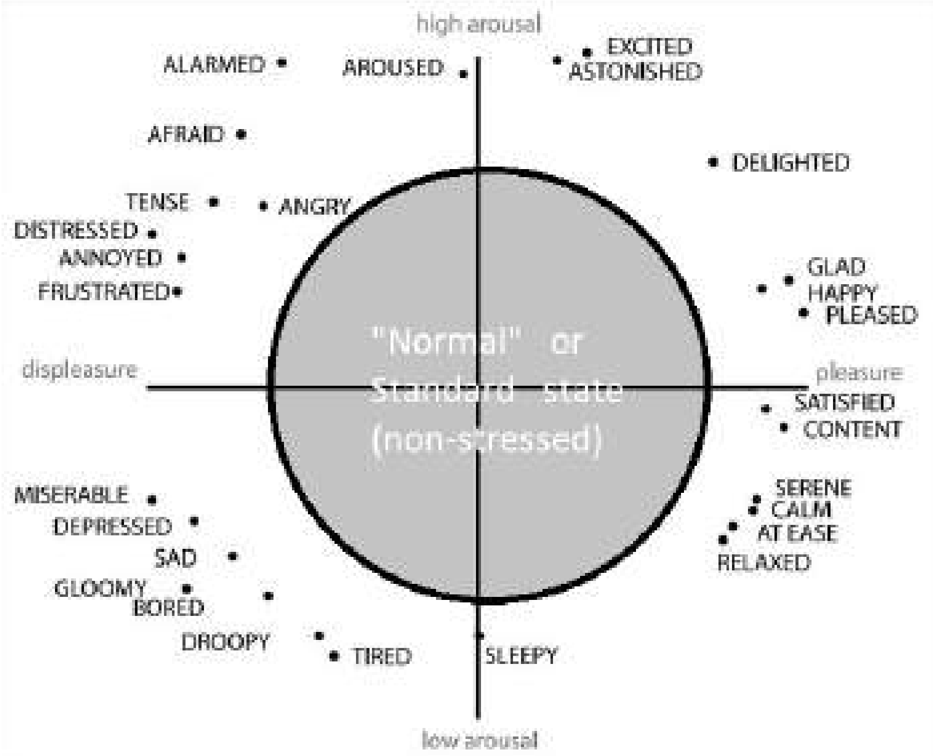


Figure 2.3: Placement of emotions in the two-dimensional affective space defined by valence and arousal (22) with a schematic presentation of an area with a “normal” level of stress (inside the grey circle) and “increased” level of stress (outside the grey circle)

High stress can sometimes manifest itself in, for example, unjustified cheerfulness and excitement, or depression and sadness. Due to the planned use of the SD to detect emergency situations, this project places the greatest emphasis on affective manifestations with high arousal and negative valence (displeasure), i.e. affective states in the upper left quadrant of the affective space, that will probably occur in speakers during security threats.

SD module architecture is similar to that of the SpV module. It is technically based on DNNs and X-vectors (7). The X-vector extractor is created in the Kaldi environment.

As there is no emotional and/or stressed speech database available that would be large enough and suitable for DNN modelling, it was decided to train the X-vector extractor on the speaker-verification databases VoxCeleb1 and VoxCeleb2. Reverberation and noising were used for data augmentation.

The PLDA module that was used in SpV is here replaced by a regressor. The training and testing sets are organized in pairs of features representing particular utterances – an X-vector, and the corresponding value of the perceived stress. This stress value is a mean of the subjective evaluations from five annotators on the scale 0-100. The X-vectors have a dimension of 100. The Scikit-learn - library (26) was used for training of the random forests regressor (27).

The illustrative schematic diagram of architecture of the SD module is presented in Figure 2.4.

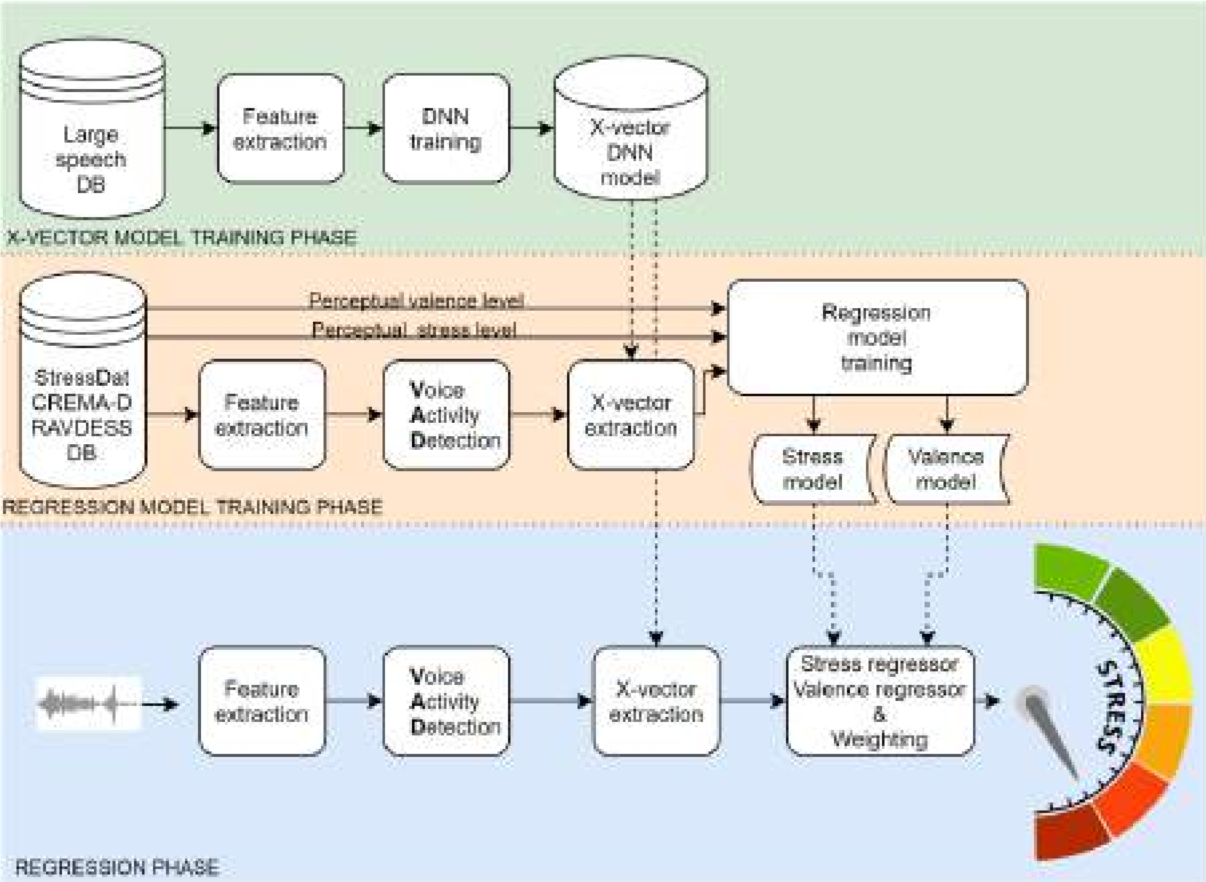


Figure 2.4: Schematic diagram of the Stress Detection Module – training phase, enrolment phase, and regression phase

The output of the SD module is a value representing the level of stress in the speaker. Two configurable thresholds TS1 and TS2 are set by the user and intended for setting the sensitivity of the system. If the measured value is higher than TS2, the VERY_HIGH_STRESS alert message is generated. If the measured value falls in the interval TS1-TS2, the INCREASED_STRESS alert message is generated, and if it is lower than TS1, the NEUTRAL_SPEECH message is generated. If the received utterance is too short for a reliable decision, the TOO_SHORT_FOR_EVALUATION message is generated and sent to the CORE module. Table 2.6 lists the messages from the SD module.

Table 2.6: Overview of messages from SD module

Short name	Description
NEUTRAL_SPEECH	Speech shows no signs of high level of stress.
INCREASED_STRESS	Speech show signs of increased stress.
VERY_HIGH_STRESS	Speech shows signs of high level of stress.
TOO_SHORT_FOR_EVALUATION	The utterance is too short for reliable decision.

2.7 Correlation of indications to a current security situation indicator (CORE)

The above-mentioned modules/functionalities CMCD, SpV, SD, and CL detect single indications, which could be caused by bad or unlawful intentions. It is commonly known, that accidents and incidents can happen by human mistake, without any bad intention. This is also true for route deviations and even conflicts on the airport surface. The only indication of the set TraMICS detects, which is for sure security related, is the unauthorized speaker. All others must not necessarily be security related. Nevertheless, if unusual and/or safety relevant situations happen more often than usual, this should be noticed and evaluated by a human operator, if it might be a security issue. For example: A flight deviates from its route. This is a safety issue and TraMICS will display a route deviation alert to the ATCO. It is expected that the ATCO will adapt the flight's route to the situation. If the flight is still deviating from the route (for whatever reason; could be that the ATCO did not adapt the route, or the flight took another one), this might indicate a security issue additional to the safety issue. Two examples can be found later in the document: (1) In test case CMCD.2 and Figure 5.5. Here, the ATCO redirects the flight to the planned route. The route deviation (safety issue) is shown to the ATCO, but the security situation indicator stays green. (2) In test case CORE.3 and Figure 5.39. Here, the ATCO did not adapt the route of the flight and the flight deviates for a long time. The deviation leads to so many alerts, that the threshold for the red security situation indicator is exceeded. Even if the flight is back on its route and there is no safety issue any more, the security situation indicator keeps being red as it may indicate a security issue.

For TraMICS, two kinds of human operators are concerned: (1) The Air Traffic Controllers (ATCOs) working at TraMICS-equipped working position; and (2) any other possible downstream operators, dealing with security; in case of SATIE the SOC operator.

The TraMICS CORE module is designed to support the security situation awareness of the operators. It takes all single indications the other modules have detected and calculates the current security situation indicator. This indicator will be displayed to the ATCO and send to the Correlation Engine; the central SATIE Tool collecting and processing all alerts from different detectors. It is shown as red, yellow, or green dot to the ATCO which corresponds to "high", "medium", or "low severity" in the messages to the Correlation Engine. As the current security situation indicator is processed/interpreted data, the raw data (i.e. single detection alerts) used for calculation are additionally shared with the Correlation Engine and displayed to the ATCO, to support situation awareness and decision making.

In contrast to the GAMMA project, where a weighted function had been used to calculate the correlation value (28), the approach in SATIE is based on counting the amount of different kinds of alerts, thresholds, and a rule set. This approach is expected to be more transparent and adjustable to the user. For the determination of the security situation indicator, the alerts from CMCD, CL, and SpV Modules are divided into the following alert types:

- alert_CM: all types of conformance monitoring alerts. The detection of these alerts is triggered by receiving updates of aircraft position data (each x seconds; x depending on the environment).
- alert_CL: wrong clearance order or mismatching clearances. The detection of these alerts is triggered by receiving an inserted clearance (depending on the clearance order model it should be less than 10 times per flight).
- alert_CD: conflict detection alerts. The detection of these alerts is triggered by receiving updates of aircraft position data (each x seconds; x depending on the environment).
- alert_SP: speaker verification alerts. The detection of these alerts is triggered with each radio communication. It is not flight dependent.

Alerts of types alert_CM and alert_CD will occur each time a new position data is received *and* the deviation/conflict still exists. If just the number of alerts is taken, one information might get lost:

how many cases of deviations/conflicts happened. In contrast to the system, the ATCO would describe a deviation/conflict as a single event with a duration. Therefore the term "case" is defined: For the given ordered set of timestamps $t_{j_1} < t_{j_2} < \cdots < t_{j_k} < \cdots < t_{j_n}$ when a particular alert was created, a subset of consecutive alerts with the timestamps $t_{j_i} < t_{j_{i+1}} < t_{j_{i+2}} < \cdots < t_{j_u} < \cdots < t_{j_m}$, where $j_1 \leq j_i$ and $j_m \leq j_n$, is considered as a **case**, if for any consecutive pair $(t_{j_u}, t_{j_{u+1}})$, $i \leq u \leq m-1$ the difference $t_{j_{u+1}} - t_{j_u}$ is less or equal to a predefined time constant T, however when $i > 1$ is $t_{j_i} - t_{j_{i-1}} > T$ and when $m < n$ is $t_{j_{m+1}} - t_{j_m} > T$. In other words, the time difference between two consecutive timestamps of the considered subset is less than the given constant value and the difference between the first timestamp of the subset and its predecessor and between the last timestamp and its successor in the given ordered set of timestamps exceeds the given constant value. The definition is depicted in Figure 2.5.

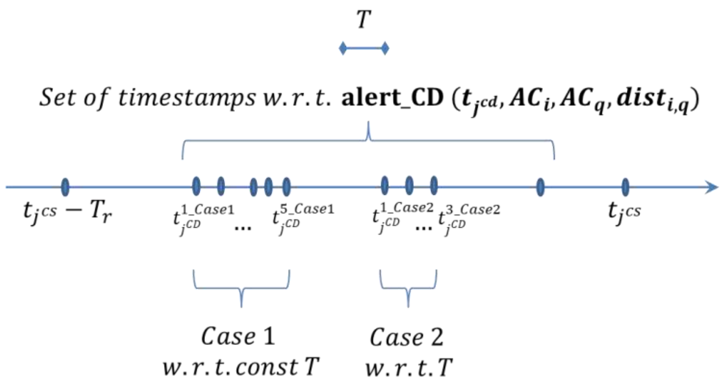


Figure 2.5: Schematic of the case definition

For counting the alerts and cases as well as accessing the security situation indicator several configuration values have to be set:

- The time window *W*: This is a time period spanning from the current time now into the past (e.g. the last 10 minutes). All alerts detected in that time window *W* will be considered for determining the security situation indicator.
- The re-assessment period *P*: This is time period how often the determination of the security situation indicator is triggered and an update is sent out (e.g. each minute).
- The case separation timespan *T* (e.g. 15 seconds).

Table 2.7 lists the conditions leading to a red, yellow or green security situation indicator. The conditions are *or*-linked. The thresholds for each condition are listed in Table 2.8.

Table 2.7: Conditions used to determine the security situation indicator

State	Conditions
● High severity/red	**[unauthorized speaker/too low score speaker]:** In the time window *W* the number of unauthorized speaker alerts (type: alert_SP) originating either from an unauthorized speaker alert or a too low score (i.e. the score is less than the corresponding red threshold *spv.score.red*) is not less than the red threshold *global.alert.red.Nspeakerunauthorized*.
	[too many very low score speaker]: In the time window *W* the number of speaker verification alerts (type: alert_SP), indicating a very low score (i.e. a score below the threshold *spv.score.yellow* but above *spv.score.red*), is not less than the red threshold *global.alerts.red.Nspverificationlowprob*.

State	Conditions
	[too many CD alerts per AC]: In the time window *W* the number of conflict detection alerts (type: alert_CD) for one particular aircraft is not less than the red threshold *perAC.alerts.red.Nconflict.*
	[too many CD cases per AC]: In the time window *W* the number of cases of conflict detection alerts (type: alert_CD cases) for one particular aircraft is not less than the red threshold *perAC.cases.red.Nconflict.*
	[too many CM alerts per AC]: In the time window *W* the number of conformance monitoring alerts (type: alert_CM) for one particular aircraft is not less than the red threshold *perAC.alerts.red.Nallcmalerts*.
	[too many CM cases per AC]: In the time window *W* the number of cases of conformance monitoring alerts (type: alert_CD cases) for one particular aircraft is not less than the red threshold *perAC.cases.red.Nallcmalerts*.
	[too many CL cases per AC]: In the time window *W* the number of cases of clearance alerts (type: alert_CL cases) for one particular aircraft is not less than the red threshold *perAC.cases.red.Nallclalerts*.
	[too many CM alerts for all AC]: In the time window *W* the number of conformance monitoring alerts (type: alert_CM) for all aircraft is not less than the red threshold *global.alerts.red.Nallcmalerts*.
	[too many CM cases for all AC]: In the time window *W* the number of cases of conformance monitoring alerts (type: alert_CM cases) for all aircraft is not less than the red threshold *global.cases.red.Nallcmalerts*.
	[too many CD alerts for all AC]: In the time window *W* the number of conflict detection alerts (type: alert_CD) for all aircraft is not less than the red threshold *global.alerts.red.Nconflict*.
	[too many CD cases for all AC]: In the time window *W* the number of cases of conflict detection alerts (type: alert_CD cases) for all aircraft is not less than the red threshold *global.cases.red.Nconflict*.
	[too many CL cases for all AC]: In the time window *W* the number of cases of clearance alerts (type: alert_CL cases) for all aircraft is not less than the red threshold *global.cases.red.Nallclalerts*.
Medium severity/yellow	**[many very low score speakers]:** In the time window *W* the number of speaker verification alerts (type: alert_SP) indicating a very low score (i.e. a score below the threshold *spv.score.yellow* but above *spv.score.red*) is lower than the red threshold *global.alerts.red.Nspverificationlowprob* but is not less than the yellow threshold *global.alerts.yellow.Nspverificationlowprob*.
	[many CD alerts per AC]: In the time window *W* the number of conflict detection alerts (type: alert_CD) for one particular aircraft is lower than the red threshold *perAC.alerts.red.Nconflict* but is not less than the yellow threshold *perAC.alerts.yellow.Nconflict*.

State	Conditions
	[many CD cases per AC]: In the time window *W* the number of cases of conflict detection alerts (type: alert_CD cases) for one particular aircraft is lower than the red threshold *perAC.cases.red.Nconflict* but is not less than the yellow threshold *perAC.cases.yellow.Nconflict*.
	[many CM alerts per AC]: In the time window *W* the number of conformance monitoring alerts (type: alert_CM) for one particular aircraft is lower than the red threshold *perAC.alerts.red.Nallcmalerts* but is not less than the yellow threshold *perAC.alerts.yellow.Nallcmalerts*.
	[many CM cases per AC]: In the time window *W* the number of cases of conformance monitoring alerts (type: alert_CM cases) for one particular aircraft is lower than the red threshold *perAC.cases.red.Nallcmalerts* but is not less than the yellow threshold *perAC.cases.yellow.Nallcmalerts*.
	[many CL cases per AC]: In the time window *W* the number of cases of clearance alerts (type: alert_CL cases) for one particular aircraft is lower than the yellow threshold *perAC.cases.yellow.Nallclalerts* but is not less than the red threshold *perAC.cases.red.Nallclalerts*.
	[many CM alerts for all AC]: In the time window *W* the number of conformance monitoring alerts (type: alert_CM) for all aircraft is lower than the red threshold *global.alerts.red.Nallcmalerts* but is not less than the yellow threshold *global.alerts.yellow.Nallcmalerts*.
	[many CM cases for all AC]: In the time window *W* the number of cases of conformance monitoring alerts (type: alert_CM cases) for all aircraft is lower than the red threshold *global.cases.red.Nallcmalerts* but is not less than the yellow threshold *global.cases.yellow.Nallcmalerts*.
	[many CD alerts for all AC]: In the time window *W* the number of conflict detection alerts (type: alert_CD) for all aircraft is lower than the red threshold *global.alerts.red.Nconflict* but is not less than the yellow threshold *global.alerts.yellow.Nconflict*.
	[many CD cases for all AC]: In the time window *W* the number of cases of conflict detection alerts (type: alert_CD cases) for all aircraft is lower than the red threshold *global.cases.red.Nconflict* but is not less than the yellow threshold *global.cases.yellow.Nconflict*.
	[many CL cases for all AC]: In the time window *W* the number of cases of clearance alerts (type: alert_CL cases) for all aircraft is lower than the red threshold *global.cases.red.Nallclalerts* but is not less than the yellow threshold *global.cases.yellow.Nallclalerts*.
Low severity/green ●	**[no or some very low score speakers]:** In the time window *W* the number of speaker verification alerts (type: alert_SP), indicating a very low score (i.e. a score below the threshold *spv.score.yellow* but above *spv.score.red*) is lower than the yellow threshold *global.alerts.yellow.Nspverificationlowprob*.
	[no or some CD alerts per AC]: In the time window *W* the number of conflict detection alerts (type: alert_CD) for one particular aircraft is lower than the yellow threshold *perAC.alerts.yellow.Nconflict*.

State	Conditions
	[no or some CD cases per AC]: In the time window *W* the number of cases of conflict detection alerts (type: alert_CD cases) for one particular aircraft is lower than the yellow threshold *perAC.cases.yellow.Nconflict*.
	[no or some CM alerts per AC]: In the time window *W* the number of conformance monitoring alerts (type: alert_CM) for one particular aircraft is lower than the yellow threshold *perAC.alerts.yellow.Nallcmalerts*.
	[no or some CM cases per AC]: In the time window *W* the number of cases of conformance monitoring alerts (type: alert_CM cases) for one particular aircraft is lower than the yellow threshold *perAC.cases.yellow.Nconflict*.
	[no or some CL cases per AC]: In the time window *W* the number of cases of clearance alerts (type: alert_CL cases) for one particular aircraft is lower than the yellow threshold *perAC.cases.yellow.Nallclalerts*.
	[no or some CM alerts for all AC]: In the time window *W* the number of conformance monitoring alerts (type: alert_CM) for all aircraft is lower than the yellow threshold *global.alerts.yellow.Nallcmalerts*.
	[no or some CM cases for all AC]: In the time window *W* the number of cases of conformance monitoring alerts (type: alert_CM cases) for all aircraft is lower than the yellow threshold *global.cases.yellow.Nallcmalerts*.
	[no or some CD alerts for all AC]: In the time window *W* the number of conflict detection alerts (type: alert_CD) for all aircraft is lower than the yellow threshold *global.alerts.yellow.Nconflict*.
	[no or some CD cases for all AC]: In the time window *W* the number of cases of conflict detection alerts (type: alert_CD cases) for all aircraft is lower than the yellow threshold *global.cases.yellow.Nconflict*.
	[no or some CL cases for all AC]: In the time window *W* the number of cases of clearance alerts (type: alert_CL cases) for all aircraft is lower than the yellow threshold *global.cases.yellow.Nallclalerts*.

The thresholds, as well as *W*, *P*, and *T* are configurable and are also partially dependent on the rate the position data updates are received. For the TraMICS verification in the verification environment, the values listed in Table 2.8 have been configured and used.

Table 2.8: Initial values used to verify the CORE module

Name	Initial value	Description
W	5 [min]	Time window that is used for calculating the security situation indicator. All alerts and cases that happened within the time window are considered. All alerts and cases that occurred before the time window are not considered.
P	1 [min]	Period for updating the security situation indicator.

Name	Initial value	Description
T	15 [s]	Time interval between different cases. If there are no alerts of the same type raised for *T* seconds, the previous alert case is considered to be over and a new case is created, when the same alert type appears again.
perAC.alerts.red.Nallcmalerts	180	Red threshold for alert_CM alerts per aircraft.
perAC.alerts.red.Nconflict	120	Red threshold for alert_CD alerts per aircraft.
perAC.cases.red.Nallcmalerts	3	Red threshold for alert_CM cases per aircraft.
perAC.cases.red.Nallclalerts	3	Red threshold for alert_CL cases per aircraft.
perAC.cases.red.Nconflict	4	Red threshold for alert_CD cases per aircraft.
global.alert.red. Nspeakerunauthorized	1	Red threshold for speaker verification alerts that indicated an unauthorized speaker or a too low score.
global.alerts.red. Nspverificationlowprob	20	Red threshold for speaker verification alerts that indicated a very low score.
global.alerts.red.Nallcmalerts	300	Red threshold for alert_CM alerts for all aircraft.
global.alerts.red.Nconflict	240	Red threshold for alert_CD alerts for all aircraft.
global.cases.red.Nallcmalerts	4	Red threshold for alert_CM cases for all aircraft.
global.cases.red.Nallclalerts	8	Red threshold for alert_CL cases for all aircraft.
global.cases.red.Nconflict	4	Red threshold for alert_CD cases for all aircraft.
perAC.alerts.yellow.Nallcmalerts	120	Yellow threshold for alert_CM alerts per aircraft.
perAC.alerts.yellow.Nconflict	60	Yellow threshold for alert_CD alerts per aircraft.
perAC.cases.yellow.Nallcmalerts	2	Yellow threshold for alert_CM cases per aircraft.
perAC.cases.yellow.Nallclalerts	2	Yellow threshold for alert_CL cases per aircraft.
perAC.cases.yellow.Nconflict	2	Yellow threshold for alert_CD cases per aircraft.
global.alerts.yellow. Nspverificationlowprob	10	Yellow threshold for speaker verification alerts that indicated a very low score.
global.alerts.yellow.Nallcmalerts	225	Yellow threshold for alert_CM alerts for all aircraft.
global.alerts.yellow.Nconflict	120	Yellow threshold for alert_CD alerts for all aircraft.
global.cases.yellow.Nallcmalerts	3	Yellow threshold for alert_CM cases for all aircraft.
global.cases.yellow.Nallclalerts	4	Yellow threshold for alert_CL cases for all aircraft.
global.cases.yellow.Nconflict	2	Yellow threshold for alert_CD cases for all aircraft.
spv.yellow.score	18	Yellow threshold for speaker verification score.
spv.red.score	7	Red threshold for speaker verification score.

After the security situation indicator is determined, the CORE module sends a Syslog message with the updated security situation indicator to the Correlation Engine (see Table 4.3, chapter 4 “Brief user manual”) as well as a message via the Traffic View interface to the CWP. A description of the provoking condition is added with its value and threshold (see Table 4.2).

2.8 Traffic View Message Interface

The alerts raised by the CMCD, CL, SpV, and CORE modules are visualised in the Traffic View HMI for the ATCO. The Traffic View Message Interface receives the alerts and creates corresponding alert messages that can be received and visualised by the Traffic View. These messages are sent via the Central Simulation Data Queue to the CWP where the ATCO is working.

2.9 Integration of the modules

Both TraMICS parts (from DLR and SAV) were integrated with each other and also with the verification environment. During the verification of the CORE test cases, the TraMICS was used as shown in Figure 1.2 on page 18.

3 TraMICS' verification environment

Not all TraMICS' modules were integrated, due to ethical concerns (29; 30). This led to the fact, that the Stress Detection Module could only be used and verified at SAV's premises and not at DLR's premises. The fact that the participants in the experiments cannot be exposed to real high-stress levels prevents the verification of the SD within TraMICS, but the SD module has been fully developed, it is ready for integration into TraMICS, and the functionality of the module is verified in the laboratory. When deployed in practice, the future users can verify its functionality on their recordings of communication from real emergency situations (which are not public).

Therefore, the following sections will describe the different simulation/test environments at SAV and DLR.

3.1 Verification environment at SAV

The laboratory of the Department of Speech Analysis and Synthesis consists of offices of the employees with their personal computers, servers, and hard disk data storages, connected via local area network, and a recording studio. The training of models based on deep neural networks requires a relatively huge computing power, large memory capacity, and graphical processing units. Most of the experimental software works in the Linux environment and the Kaldi toolbox is used for the development of recognizers. The standard testing procedure is used to test the SpV and SD modules in various settings. The training and testing databases are split into non-overlapping training and testing parts and the test utterances are sent to the tested module, the particular scores are collected and Equal Error Rate (for SpV) and Accuracy (for SD) are computed.

For development and testing purposes, SAV uses a pool of speech databases, some of them were designed by SAV, the others are publicly available. Some of them were used for training the final versions of SpV and SD modules and their testing in the verification process. Others were only used in the experiments during development and fine-tuning phase that will be described in future publications. As both speaker verification and stress detection from voice can be considered (at a certain level of simplification) as language-independent tasks, the pool contains and combines databases in several languages (English, German, Slovak, Italian). The list of the databases used for research and development of the TraMICS SpV and SD modules can be found in Table 3.1.

Table 3.1: Databases used for research and development of the TraMICS SpV and SD modules

Databases developed at SAV used for SpV	Publicly available databases used for SpV	Databases developed at SAV used for SD	Publicly available databases used for SD
APD (31)	VoxCeleb1 (9)	CRISIS (24)	EmoDB (32)
SpeechDat-E (33)	VoxCeleb2 (10)	StressDat (see subsection 0)	EMOVO (34)
MobilDat-Sk (35)	VoxForge (36)		IEMOCAP (37)
RadioVoxCeleb (see subsection 5.1.3)	LibriSpeech (38)		CREMA-D (39)

Databases developed at SAV used for SpV	Publicly available databases used for SpV	Databases developed at SAV used for SD	Publicly available databases used for SD
RadioVoxForge (see subsection 5.1.3)			MSP-IMPROV (40)
			VESUS (41)
			MSP-IMPROV (40)
			EmoV-DB (42)
			Enterface (43)
			jl-corpus (44)
			SAVEE (45)
			RAVDESS (46)

In the initial part of the SATIE project, a cooperation was established by SAV with the Avionic Faculty of the Technical University in Košice. It was planned that the teachers and students of this faculty will take part in testing the SpV and SD modules in the environment of their Air Traffic Control simulator. Due to the COVID 19 pandemic, the school was closed sooner than the experiments could start and the education process was replaced by e-learning.

The tests in the simulator had to be replaced by laboratory tests using large speech databases, that provide results of much higher statistical relevance due to much higher number of speech samples, but on the other hand they do not provide the developers with personal opinion of the users/participants.

For the SD, a new speech-under-stress database, StressDat, had to be created. A novel method of database building was developed which made it possible not only to achieve the required speech-under-stress recordings and detailed annotation, but also to perform the entire recording and annotation in pandemic conditions.

StressDat - Acted Speech under Stress Database

Due to the lack of available corpora of naturalistic continuous speech containing stress level annotation, SAV decided to design and develop a dedicated database (StressDat) that would facilitate modelling speech under stress. As in many other emotional speech corpora, to maximize the control over the speech material and recording conditions and due to ethical limitations, acted speech was employed.

Preliminary observations confirmed that even when an actor plays the stressing scenario, he shows certain physiological symptoms of real stress, like increased skin conductivity and increased heart rate. These symptoms are of course weaker, than when actually exposed to a stressful situation. The actor was asked to read several sentences imitating low, then medium, and high level of stress. Figure 3.1 shows, that both, his skin conductivity, or Galvanic Skin Response (GSR), labelled as G, and his heart rate HR show courses typical of a step increase in stress and gradual coping with it, for each of the three acted levels of stress.

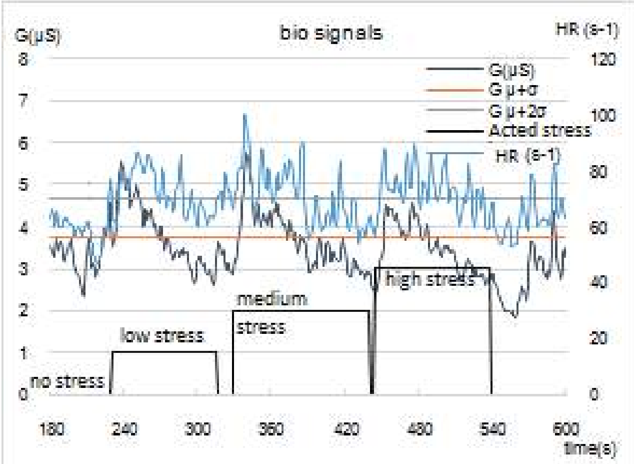


Figure 3.1: Skin conductivity G (dark blue) and heart rate HR (light blue) of the speaker acting three levels of increased stress. Black line presents the stress level intended by the speaker.

To maintain the naturalness of elicited speech in the new StressDat database, the actors recorded speech in their home environments using smartphones, and newly designed scenarios reflected real-life situations with detailed descriptions of the participants and the stressors influencing them.

Production point of view / Intended level of stress in speech. The stressors and situations were designed to induce three basic levels of stress: neutral (low stress), increased (medium stress), and extremely increased (high-stress). After a brief "getting into the character" based on the above descriptions, actors read multiple sentences related to a given scenario in a given stress level. Each actor played 12 stress-inducing scenarios in neutral, increased, and extremely increased level of stress and four "non-stressing" scenarios in neutral level only. Each recorded utterance therefore unequivocally belongs to one of the three levels of stress intended by the speaker during production.

Perception point of view / Perceived level of stress in speech. After speech elicitation and processing, the annotation of the perceived level of stress in the recorded sentences was organized. Multiple annotators listened to each sentence and rated it on a discrete ten-point scale how much under stress they think the speaker felt. Each utterance is annotated with the mean of the values of the perceived stress level designated by annotators. The evaluations of perceived stress can therefore reach real number values from the interval 0 to 100. This allows regression to be used in stress assessment instead of classification. A web-based speech stress assessment tool named "Stress Thermometer" was designed, which allows the annotator to listen to the utterance and to assign a perceived stress level according to the instructions (see Figure 3.2).

The sampling of both the actors and annotators provide richness and variability in that each utterance of the corpus is produced by multiple speakers and its stress level is assessed by multiple raters. Thus, the information about the intended level of stress in speech production and the associated perceived level of stress for each utterance of StressDat provide the basis for developing the statistical models predicting the level of stress in speech.

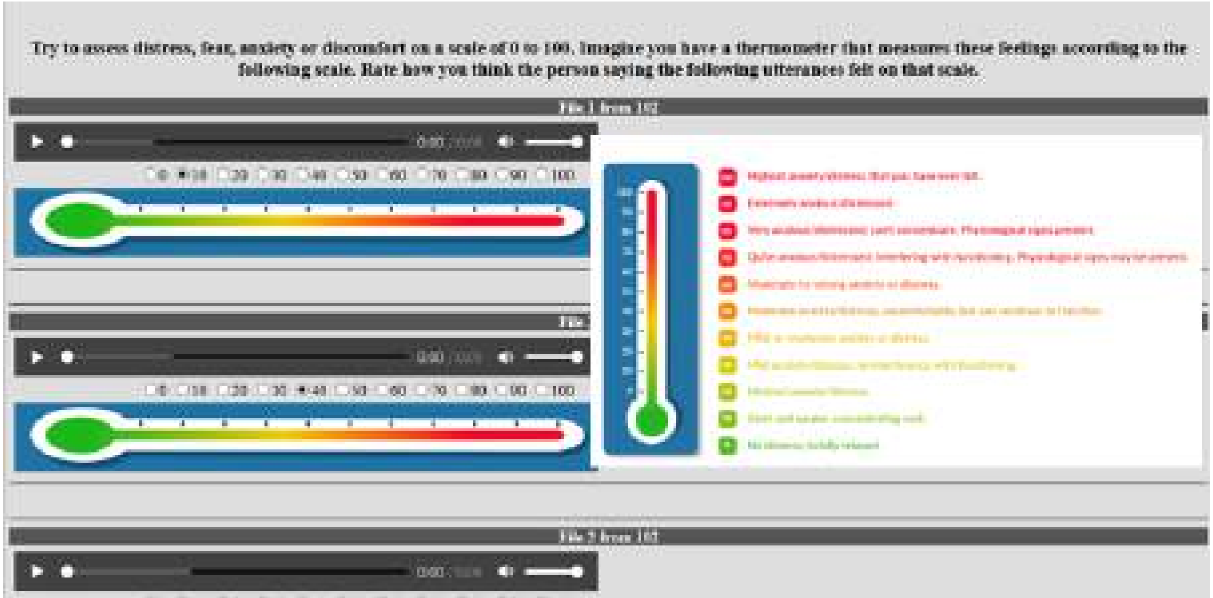


Figure 3.2: The graphical interface of the “Stress Thermometer” tool that allows the rater to listen to the utterance and to assign a perceived stress level according to the instructions in the right half of the screen.

3.2 Verification environment at DLR: Tower Simulator

Simulators, sensor systems, and flight-testing equipment together form the Air Traffic Validation Center of the DLR Institute of Flight Guidance (see Figure 3.3). The entire centre offers researchers the right tools for testing and evaluating new ideas, concepts, and technologies for all areas of air traffic management. It allows each development step to be continuously reviewed, from the initial idea down to the testing of prototypes and their implementation under realistic conditions.

The elements of the Validation Center can be used flexibly, depending on the research requirements, and both individually as well as grouped. Besides the facilities of the Institute itself, it is also possible to connect to further research facilities and verification or validation platforms of other DLR institutes or external partners (e.g. more simulation cockpits and air traffic control simulators).

TraMICS shall be integrated into a controller working position. In SATIE, it will be a ground/apron position in particular. DLR’s Air Traffic Validation Center is chosen as verification environment (47) because of its ability to simulate this. Specifically, TraMICS is integrated in the ATS360 tower simulator in order to accommodate to the foreseen real-life application. The applied simulation software supports development of traffic scenarios, simulation of aircraft movement, and the control of aircraft movement via pseudo-pilot and air traffic controller stations. Besides the human-in-the-loop simulations, it provides recording of the entire aircraft movement and subsequent replay functionalities, which supports the TraMICS verification.

TraMICS needs input data for a proper functioning. The necessary input data and their sources are listed in Table 3.2.

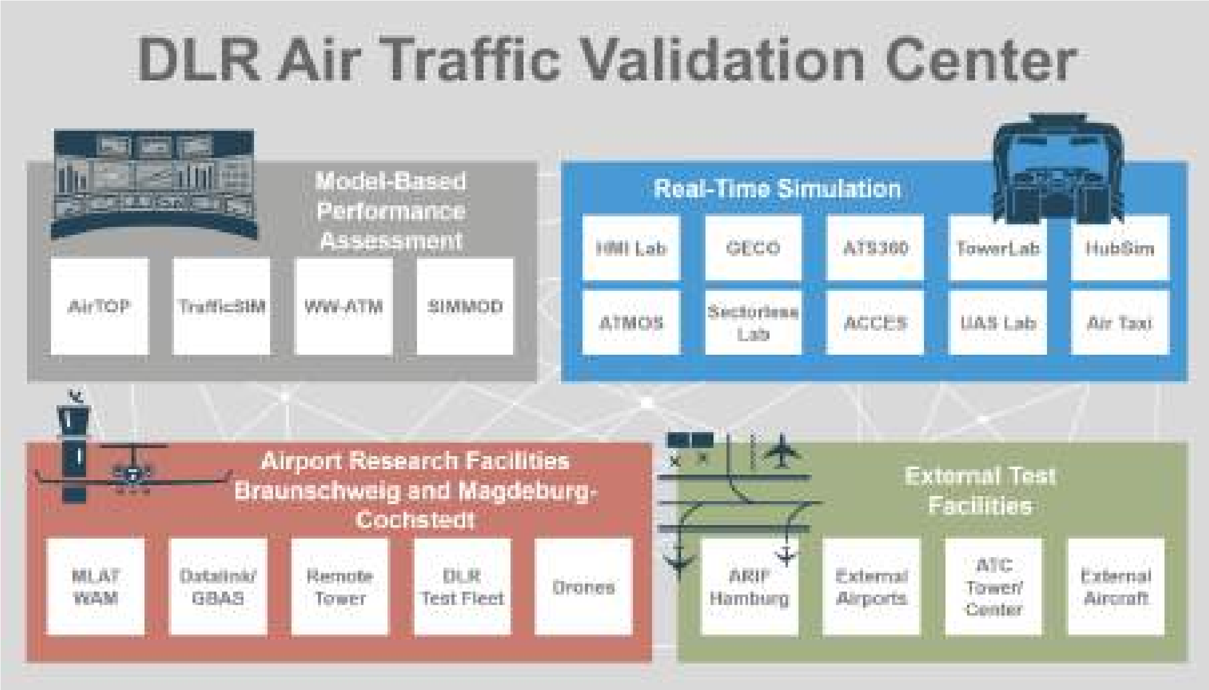


Figure 3.3: Set-up of the Air Traffic Validation Center[2]

Table 3.2: Needed data from the environment

Data	Source
Flight plans	NARSIM[3] (air traffic simulation software)
Ground movement data (i.e. updates of aircraft position data)	NARSIM
Air-ground voice communication.	Talk[4]
Clearances given by the ATCO	Electronic Flightstrips system in the CWP to be used by the ATCO.
Planned routes for each aircraft	If changed by the ATCO: input into the Traffic View which is part of the CWP.

[2] https://www.dlr.de/fl/en/desktopdefault.aspx/tabid-1140/
[3] https://www.nlr.org/capabilities/nlr-air-traffic-control-research-simulator-narsim-tower/.
[4] Talk is a proprietary radio communication emulation for ATC used within the Air Traffic Validation Center.

4 Brief user manual

TraMICS is intended to serve at least two users: the ATCO and the SOC operator. As D7.2 ("Training Handbook") (48) will focus on the SOC operator, this chapter provides an overview and the relation of TraMICS output for the two kinds of users.

The ATCOs working on CWPs equipped with TraMICS need to input all clearances they issue in-time into the electronic flight strips (or the label on the situation display, if this functionally is provided). They also have to check, if they want to use the proposed taxi routes and, if they do not agree, they shall change the route to their conception. Those two user inputs are not needed to enable TraMICS exclusively but are also required to enable higher levels of A-SMGCS (49).

4.1 TraMICS' visualisation for the ATCO

Figure 4.1 shows the situation display "Traffic View" for the ATCO with TraMICS results and descriptions.

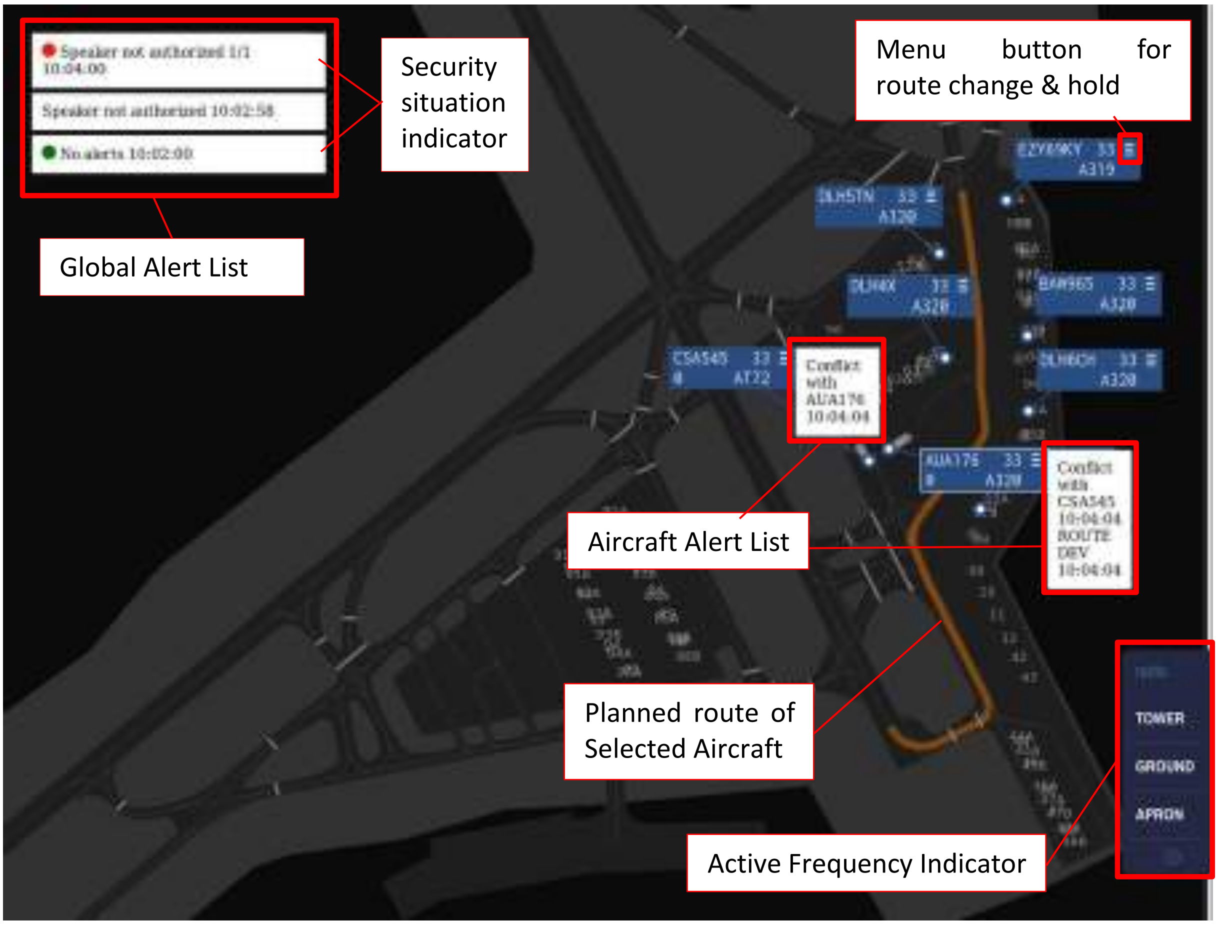


Figure 4.1: Description of the TraMICS results on the Traffic View HMI

All alerts, which belong to specific aircraft, are listed in the aircraft's Aircraft Alert List. If the same kind of alert is already in the list, only the time will be updated. The ATCO can dismiss the Aircraft Alert List by clicking on it. As soon as a new alert is found, it appears again in the Aircraft Alert List.

The Global Alert Lists contains the security situation indicator and all alerts which are not aircraft specific, like a speaker verification alert. The security situation indicator is identifiable easily by the green/yellow/red dots in the beginning of its list entry.

4.1.1 Flight specific alerts

If an alert raised by one of the TraMICS modules can be traced to an aircraft (AC), the label of the aircraft in the ATCO HMI is appended by an alert list (the Aircraft Alert List, see Figure 4.1) containing a short alert description with the corresponding timestamp indicating the time the alert occurred last. If an alert of the same type is already shown in the Aircraft Alert List of the dedicated AC, only the timestamp of the alert is updated. Alerts will not vanish automatically from the Aircraft Alert List; their timestamp is the indication if the alert is outdated. The alerts can be dismissed by the ATCO by clicking on the Aircraft Alert List.

Raised alerts are described with a short type name for space-saving. Table 4.1 gives an overview of the flight specific alerts with their corresponding meaning.

Table 4.1: Flight specific alert messages and their corresponding meaning

Short Name	Alert Meaning	Triggered by
No appropriate CLR	Pushback clearance is given for an AC at a rollout stand.	Clearance input
NO TAXI CLR	AC has not received taxi clearance but line-up clearance instead.	Clearance input
NO LND CLR	AC has not received landing clearance but taxi clearance instead.	Clearance input
NO PUSH CLR	AC has not received pushback clearance but taxi clearance instead.	Clearance input
TX instead of HLD	The AC has received a “hold immediately” command, but its speed is increasing (this may happen either without having stopped or the AC has stopped and starts moving again without clearance to do so).	Position data
Not stopping	AC is not stopping after a “hold immediately” is given and moves constant.	Position data
ROUTE DEV	AC is deviating from planned route.	Position data
NO ROUTE	AC is taxiing although no planned route is available.	Position data
ROUTE DEV [opposite heading]	AC is on planned route but with opposite heading.	Position data
NO CLR	AC is either pushing back or taxiing without the appropriate clearance.	Position data
Conflict with <callsign of another AC>	AC is conflicting with the other AC.	Position data

4.1.2 Global alerts

Alerts that are not linked to a specific flight are visualised on the top left corner of the HMI in the Global Alert List (see Figure 4.1). These alerts are either speaker verification alerts or security situation indicator updates.

Each time an unauthorized speaker or a speaker likely to be unauthorized (i.e. the speaker verification score that is below the defined threshold) is detected, an alert is raised and displayed.

The TraMICS uses a configurable time period to reassess the current security situation considering alerts detected in the last minutes. In SATIE, this reassessment period is set to one minute and alerts are considered which were detected in the last 5 minutes (cf. Table 2.8). The security situation indicator can be green (no security-related actions needed), yellow (something seems strange, be aware) or red (most properly there is a security incident). Details are described in section 2.7.

The security situation indicator is visualized as a message in the Global Alert List in top left of the HMI, showing the indicator colour, the cause of the colouring as short textual description of the highest value-threshold pair, and the time. If the security situation indicator colour remains the same after an update, the description is overwritten and the timestamp updated. However, when the colour changes, a new list entry is generated. This way, it is possible to see how the security situation indicator changes over time and has changed in the past.

If necessary, the messages in the Global Alert List can be cleared by the ATCO by clicking on the messages individually so that they disappear. Table 4.2 gives an overview of the messages that can appear in the Global Alert List.

Table 4.2: Global alert messages and their corresponding meaning

Global Alert List message	Alert meaning	Triggered by
Speaker not authorized	An unauthorized speaker has been detected.	Speaker verification alert
Speaker <speaker> low probability <value>/<threshold>	The <speaker> has been detected, but the score <value> is below the threshold for a certain identification.	Speaker verification alert
Speaker <speaker> extremely low probability <value>/<threshold>	The <speaker> has been detected, but the score <value> is below the lowest threshold for a certain identification, so it will be treated as an unauthorized speaker.	Speaker verification alert
[green] No alerts	There have been no relevant alerts in the previous correlation interval.	Security situation indicator
[green] #CM alerts/#CM cases <value>/<threshold>	The number of conformance monitoring alerts/conformance monitoring cases is below the yellow threshold.	Security situation indicator
[green] #CD alerts/#CD cases <value>/<threshold>	The number of conflict detection alerts/conflict detection cases is below the yellow threshold.	Security situation indicator

Global Alert List message	Alert meaning	Triggered by
[green] #CL alerts/#CL cases <value>/<threshold>	The number of clearance monitoring alerts/clearance monitoring cases is below the yellow threshold.	Security situation indicator
[green] Speaker <speaker> low probability <value>/<threshold>	The number of "speaker low probability" alerts is below the yellow threshold.	Security situation indicator
[yellow/red] #CM alerts/#CM cases <value>/<threshold>	The number of conformance monitoring alerts/ conformance monitoring cases is above the yellow/red threshold.	Security situation indicator
[yellow/red] #CD alerts/#CD cases <value>/<threshold>	The number of conflict detection alerts/conflict detection cases is above the yellow/red threshold.	Security situation indicator
[yellow/red] #CL alerts/#CL cases <value>/<threshold>	The number of clearance monitoring alerts/clearance monitoring cases is above the yellow/red threshold.	Security situation indicator
[red] Speaker not authorized <value>/<threshold>	The number of speaker verification alerts indicating an unauthorized speaker is above the red threshold	Security situation indicator
[yellow/red] Speaker <speaker> low probability <value>/<threshold>	The number of speaker verification alerts indicating a very low score is above the yellow/red threshold.	Security situation indicator
[red] Speaker <speaker> extremely low probability <value>/<threshold>	The number of speaker verification alerts indicating a too low score is above the red threshold.	Security situation indicator

4.1.3 A note on safety and security

TraMICS is a tool designed to determine the security situation indicator. As detailed in chapter 2, TraMICS detects also safety related issues and takes them into account for determining the security situation indicator. TraMICS is not intended to be a safety-enhancing tool primarily and to replace existing safety solutions (e.g. using A-SMGCS). TraMICS is conceptualized as add-on.

The **safety** related alerts detected by TraMICS are flight specific and will be shown in the labels of the flights as described above. All entries in the Global Alert List are **security** related. This means specifically, that e.g. the security situation indicator stays green even if there is a severe safety conflict (and no other alerts are found). On the other hand, the security situation indicator might be red even if there are no safety alerts shown in any label. This will happen when e.g. an unauthorized speaker is detected or the triggering safety alerts are already solved. Summing up, the actual security situation indicator should not be used to draw conclusions about the actual safety situation and vice versa.

4.2 TraMICS' message contents for the SOC operator

The TraMICS system is sending Syslog messages according to the data format specification described in D4.1 (50). Messages are either sent as a single indication directly after an alert is raised by the CMCD, CL, or SpV module (which could be each second), or periodically by the CORE module, whenever the security situation indicator is re-assessed (see column four in Table 4.3).

The "Description" field in the Syslog event message contains information for the SOC operation describing the alert in a human-readable format. The "affectedAssets" field contains either the callsigns of the affected aircraft or the name of the frequency channel in the case of a speaker verification alert.

As messages consist of Alert-parts and the details part (here: ConflictDetection), below the reference from the message format to the content described in Table 4.3 is shown:

```
[
Alert@32473
        ID="ID1"
        Description="conflict detection details"
        timestamp="2020-01-23T23:05:22+00:00"
        SeverityLevel="Low"                              Column 4 in Table 4.3
        severity=”short term” // one of “short term”, “mid term” or “long
term”
        triggeredBy=”Event1”
]
[
ConflictDetection@32473                                  Column 2 in Table 4.3
        Id="Event1"
        Type=”Cyber” // one of “Cyber” or “Physical”
        Description= "" // free human readable text     Column 3 in Table 4.3
        affectsAssets={"DLH32473", “DLH11111”} // list // sameAs Origin
        StartTime="2020-01-22T23:00:26+00:00"
        EndTime="2020-01-22T23:05:22+00:00"
        CWP = “Ground1”  // optional


]
```

Table 4.3: TraMICS' syslog messages meanings

No.	Syslog Message type	Syslog message type <1st row>: description	Syslog alert message: Severity Level	Single indication/security situation indicator	Meaning	Equivalent correlation/alert message description for ATCO in HMI
1	Correlation	No severe alerts	Low	Security situation indicator	There have been no relevant alerts in the previous correlation interval.	[green] <any descriptions listed in this column in No. 2-7 possible>
2	Correlation	Number of conformance monitoring alerts / conformance monitoring cases <value> exceeds <threshold>	Medium/High	Security situation indicator	The number of conformance monitoring alerts/conformance monitoring cases is above the yellow/red threshold.	[yellow/red] #CM alerts / #CM cases <value>/<threshold>
3	Correlation	Number of conflict detection alerts / conflict detection cases <value> exceeds <threshold>	Medium/High	Security situation indicator	The number of conflict detection alerts/conflict detection cases is above the yellow/red threshold.	[yellow/red] #CD alerts / #CD cases <value>/<threshold>
4	Correlation	Number of clearance monitoring alerts / clearance monitoring cases <value> exceeds <threshold>	Medium/High	Security situation indicator	The number of clearance monitoring alerts/clearance monitoring cases is above the yellow/red threshold.	[yellow/red] #CL alerts / #CL cases <value>/<threshold>
5	Correlation	Speaker not authorized	High	Security situation indicator	The number of "speaker not authorized" messages is above the red threshold.	[red] Speaker not authorized <value>/<threshold>

No.	Syslog Message type	Syslog message type <1st row>: description	Syslog alert message: Severity Level	Single indication/security situation indicator	Meaning	Equivalent correlation/alert message description for ATCO in HMI
6	Correlation	Speaker authorization low probability	Medium	Security situation indicator	The number of "speaker low probability" messages is above the yellow/red threshold.	[yellow/red] Speaker <speaker> low probability <value>/<threshold>
7	Correlation	Speaker authorization extremely low probability	High	Security situation indicator	The number of "speaker extremely low probability" messages is above the red threshold.	[red] Speaker <speaker> extremely low probability <value>/<threshold>
8	ConformanceMonitoring	Route deviation	Low	Single indication	Aircraft is deviating from planned route.	ROUTE DEV
9	ConformanceMonitoring	Taxi without clearance	Low	Single indication	Aircraft is taxiing without a taxi clearance being given in the electronic flight strip system.	NO CLR
10	ConformanceMonitoring	Pushback without clearance	Low	Single indication	Aircraft is pushing back without a pushback clearance being given in the electronic flight strip system.	NO CLR
11	ConformanceMonitoring	Route deviation: opposite heading	Low	Single indication	Aircraft is on route but heading is opposite to planned route heading.	ROUTE DEV [opposite heading]
12	ConformanceMonitoring	No route	Low	Single indication	Aircraft is taxiing but has no planned route.	NO ROUTE
13	ConformanceMonitoring	No pushback clearance	Low	Single indication	Aircraft has no pushback clearance but taxi clearance instead.	NO PUSH CLR
14	ConformanceMonitoring	No taxi clearance	Low	Single indication	Aircraft has no taxi clearance but line-up clearance instead.	NO TAXI CLR

No.	Syslog Message type	Syslog message type <1st row>: description	Syslog alert message: Severity Level	Single indication/security situation indicator	Meaning	Equivalent correlation/alert message description for ATCO in HMI
15	ConformanceMonitoring	No landing clearance	Low	Single indication	AC has not received landing clearance but taxi clearance instead.	NO LND CLR
16	ConformanceMonitoring	Hold given but aircraft continues taxiing	Low	Single indication	Aircraft has received a "hold immediately" command, but its speed is increasing. (This may happen either without having stopped or the aircraft has stopped and starts moving again without clearance to do so.)	TX instead of HLD
17	ConformanceMonitoring	Aircraft not stopping	Low	Single indication	ATCO has given a "hold immediately" order via the aircraft context menu, but the aircraft is continuing to move with constant speed instead of slowing down and stopping.	Not Stopping
18	ConformanceMonitoring	Pushback clearance given but aircraft is on rollout position	Low	Single indication	Aircraft has received a pushback clearance but its stand is categorized as rollout position with no pushback necessary.	No appropriate CLR
19	ConflictDetection	Possible conflict between <aircraft > and <other aircraft>: distance is <distance in m>	Medium	Single Indication	The aircraft and another aircraft are dangerously close and moving on a collision course (not standing still and/or taxiing behind each other on a taxiway).	Conflict with <other aircraft>
20	Speaker Verification	Speaker not authorized	High	Single Indication	An unauthorized speaker has been detected.	Speaker not authorized

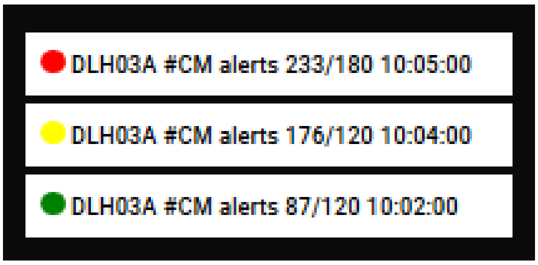
No.	Syslog Message type	Syslog message type <1st row>: description	Syslog alert message: Severity Level	Single indication/security situation indicator	Meaning	Equivalent correlation/alert message description for ATCO in HMI
21	Speaker Verification	Speaker authorization low probability <value>/<threshold>	Medium	Single Indication	The speaker verification score <value> is below the threshold for a certain identification.	Speaker <speaker> low probability <value>/<threshold>
22	Speaker Verification	Speaker authorization extremely low probability <value>/<threshold>	High	Single Indication	The speaker verification score <value> is below the lowest threshold for a certain identification, so it will be treated as an unauthorized speaker.	Speaker <speaker> extremely low probability <value>/<threshold>

4.3 Examples of alerts shown to the ATCO and sent to SOC operator

The following sub-sections contain examples for alerts and the corresponding visualisation on the ATCO HMI and as message description for the SOC operator/Correlation Engine. It is expected that the SOC operator will use mainly the security situation indicator update (4.3.1). If the security situation indicator triggers the operator's need for details, the other messages could be used to get more detailed information.

4.3.1 Security situation indicator update

Example for message type number 2 in Table 4.3.



Description for SOC Operator	Assets	General description
Number of conformance monitoring alerts <value> exceeds <threshold>	DLH03A	A number of conformance monitoring alerts have been raised for the aircraft DLH03A. Because of the number of alerts exceeding the corresponding thresholds in the specified time window (here: 5 minutes), the security situation indicator changed first from green to yellow, and then to red. This is represented by the Severity Level of the Syslog messages changing from low to medium and then to high.

4.3.2 Route Deviation

Example for message type number 8 in Table 4.3.

Description for SOC Operator	Assets	General description
Route Deviation	DLH01A	The aircraft DLH01A is deviating from its planned route (orange).

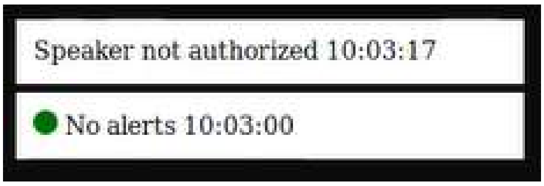
4.3.3 Conflict Detection Alert

Example for message type number 20 in Table 4.3.

Description for SOC Operator	Assets	General description
Possible conflict between DLH05A and DLH05B: distance is <distance in m>	DLH05A, DLH05B	The aircraft DLH05A and DLH05B are on a course that could lead to a conflict with the respective other aircraft.

4.3.4 Speaker not authorized

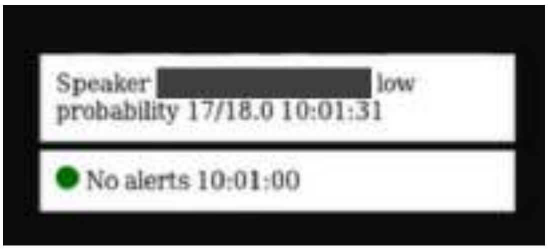
Example for message type number 5 in Table 4.3.



Description for SOC Operator	Assets	General description
Speaker not authorized	<radio frequency>	An unauthorized speaker has been detected on the frequency.

4.3.5 Speaker low probability

Example for message type number 6 in Table 4.3.



Description for SOC Operator	Assets	General description
Speaker <speaker> low probability <value>/<threshold>	<radio frequency>	The <speaker> has been identified, but the score is below the corresponding threshold.

5 Verification

The verification has been split into two different verification environments as described in chapter 3. The stress detection functionality as well as the speaker verification functionality were verified separately at SAV premises. The SpV module was integrated with CMCD, CL, and CORE modules to get the TraMICS tool and was functional during the verification experiments for CMCD, CL, and CORE in the DLR verification environment. The SD module was technically integrated in the TraMICS too, however due to ethical issues, the SD module could not be evaluated within the TraMICS, and its output was not received during TraMICS's verification.

The verification of the SpV and SD module was done in SAV premises. The automated tests were accomplished under laboratory conditions on large speech databases to obtain statistically representative results confirming functionality of the modules.

All main TraMICS modules use configuration data, on which the results of the functionalities depend as well. It is expected that the fine-tuning of this configuration data is a task on its own and might also vary from working position to working position. For test purposes, initial values have been set and described in the specific sections 2.3-2.7. For the validation within WP6, some specific questions were drafted to get a first impression about the acceptability of the initial values (1).

All test objectives, their test case ID and their status are listed in Table 5.1.

Table 5.1: Overview of TraMICS test objectives

TEST CASE ID	NAME	STATUS (OK, NOT)
SpV.1	Single-target speaker verification	OK
SpV.2	Speaker authorization (multitarget-group speaker verification)	OK
SpV.3	Radio channel speaker verification	OK
SD.1	Stress detection	OK
CMCD.1	Detection of deviation from assigned route	OK
CMCD.2	No route deviation alerts after being back on route	OK
CMCD.3	Detection of multiple deviations from a planned route	OK
CMCD.4	Opposite traffic	OK
CMCD.5	Opposite traffic at a crossing	OK
CMCD.6	Two AC merge into a taxiway without stopping	OK
CMCD.7	Two AC merge into a taxiway with stopping	OK
CMCD.8	Two AC merge into a taxiway with stopping behind a stop bar	OK
CMCD.9	Two AC at a crossing with disjoined routes	OK
CMCD.10	Two AC at a runway holding point	OK
CMCD.11	Two AC are moving on the same taxiway and the subsequent is faster	OK
CMCD.12	Two AC are moving on the same taxiway and the preceding stops	OK
CMCD.13	Route deviation with opposite heading	OK

TEST CASE ID	NAME	STATUS (OK, NOT)
CMCD.14	Hold clearance was given but AC does not stop	OK
CMCD.15	AC stopped, but continues taxi without continue taxi clearance	OK
UB.1	AC pushing without pushback clearance	OK
UB.2	AC taxiing without taxi clearance	OK
UB.3	Wrong clearance order	OK
UB.4	Pushback clearance at rollout position	OK
UB.5	Pushback with taxi clearance	OK
CORE.1	Message reception from SpV module	OK
CORE.2	Unauthorized speaker leads to a red security situation indicator	OK
CORE.3	Long lasting route deviation leads to a yellow/red security situation indicator	OK
CORE.4	Multiple route deviations of one AC lead to a yellow security situation indicator	OK
CORE.5	Route deviations of several AC lead to a red security situation indicator	OK
CORE.6	Conflict leads to a yellow security situation indicator	OK
CORE.7	Conflicts lead to a red security situation indicator	OK
CORE.8	Unauthorized speaker and route deviation	OK
CORE.9	Unauthorized speaker, route deviation and conflict	OK
CORE.10	Route deviation and conflict lead to a yellow security situation indicator	OK
CORE.11	Change from a yellow to a green security situation indicator	OK
CORE.12	Change from a red to a green security situation indicator	OK
CORE.13	Change from a red to a yellow to a green security situation indicator	OK
SYL.1	Verification of message creation and recording	OK
SYL.2	Verification of message reception at the Correlation Engine	OK

5.1 Speaker verification functionality

The off-line tests of the SpV module were focused on three test cases:

- The basic (single-target) speaker verification reliability test.
- Impact of whitelist cohort size on the error rate of the speaker authorization.
- Channel mismatch – Reliability of SpV on the radio channel.

5.1.1 Test case SpV.1: Single target speaker verification

In speaker verification, the claimed identity of the speaker is verified. There is only one target speaker in one comparison (in contrast with multiple target speakers in speaker authorization). The comparison of the X-vector of the test-utterance and X-vector of enrolment gives a similarity score. Binary decision of a match or mismatch is performed by comparing the score with a threshold. If the similarity score of the two samples exceeds the predefined threshold, the claimed identity of the speaker is considered as proven.

The test follows standard methodology used in the speaker verification. The first step is to define a testing database. In the second step, each particular test file (utterance) is compared with each enrolment – the similarity score is computed. Histograms of similarity score distributions of the target speaker and non-target speakers (Figure 5.1) are obtained. The specific threshold at which FRR is equal to FAR is found and the EER is determined.

Detailed results of the off-line tests are presented in Table 5.2. Very good results were obtained both on Librispeech database containing a big number of speakers and high-quality wide-range speech and on SpeechDat containing telephone-quality speech. A bit worse, but still acceptable results were obtained on VoxForge database, which is noisy here and there and also shows shortcomings in the labelling of speakers. The test summary is presented in Table 5.3.

Table 5.2: Detailed results of the off-line single-target speaker verification tests

DB name	No. of tested target speakers	No. of test files	No. of tests performed	EER
Librispeech	2444	24440	59731360	0.864%
SpeechDat	888	888	788544	0.906%
VoxForge	579	7215	3520920	1.634%

Table 5.3: SpV.1 - Single-target speaker verification - test summary

SpV.1	Single target speaker verification
Pre-requisites	Test is performed on the VoxForge database.
Expected Result	The maximum allowed EER shall not exceeded 1.70%.
Result	Passed. EER = 1.63%.
Remarks	This test case is automated.

5.1.2 Test case SpV.2: Speaker authorization / multitarget group speaker verification

In this test case, it is detected if the input speech is spoken by somebody from the currently-authorized-persons list (whitelist cohort).

In order to automatically determine whether there are only persons from the whitelist cohort communicating on the voice radio channel in the particular sector, the incoming speech signal has to be compared with the models (X-vectors) of all of the currently authorized speakers. If the similarity score exceeds the pre-defined decision level in at least one of these comparisons, it is decided that the actual speaker is authorized. The decision level is set by the user and is called threshold.

For each size of the whitelist cohort, the EER (i.e. equality of FRR and FAR) is reached at a different threshold. An adaptive-threshold test was performed, in which the threshold is changed so that the respective EER can be computed for each particular size of the whitelist cohort (see Table 5.4).

According to the fact that the maximum number of speakers that are authorized to take part in the radio voice-communication on the given frequency in the given moment and in the given sector is typically up to 20, it was decided to choose the size of the group S=30 for the group verification test.

The VoxForge database was used as a testing database for this evaluation.

The results of the tests of speaker authorization are presented in Figure 5.1 in a form of histograms of the score distribution of the target tests (enrolled, authorized) speakers and non-target speakers (impostors) for various sizes S of the whitelist cohort. The results of the tests of speaker authorization are presented in Figure 5.1 in a form of histograms of the similarity score distribution of the tests of the target (enrolled, authorized) speakers and non-target speakers (impostors) for various sizes S of the whitelist cohort. The score distribution of the target speakers' group is reasonably well separated from that of non-target groups even for the size of the whitelist cohort S=30, indicating that the speaker authorization works well.

Detailed results of the off-line tests are presented in Table 5.4. The test summary is presented in Table 5.5.

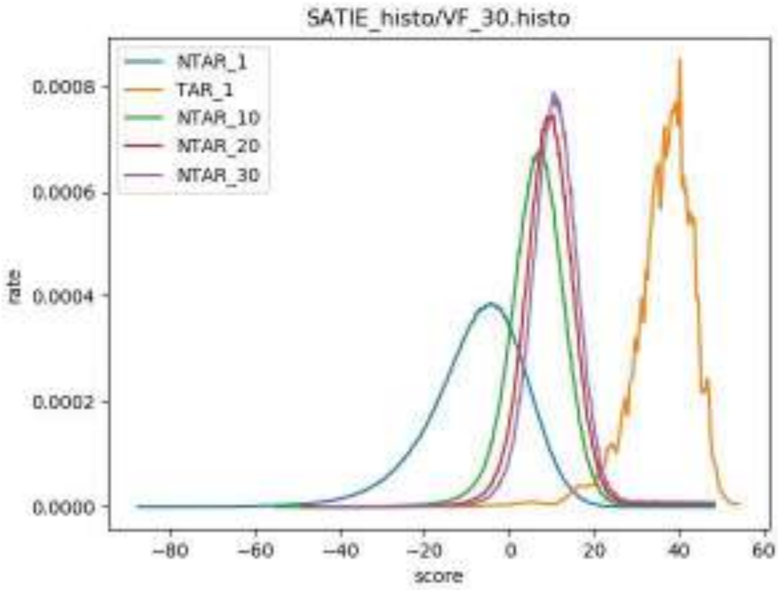


Figure 5.1: Histograms of score distributions of the target speaker (TAR_1, yellow) and non-target speakers at various whitelist cohort sizes S (S=1, 10, 20 and 30) depicted as NTAR_S.

Table 5.4: Detailed results of the off-line multitarget group speaker verification tests - dependence of the EER on the number of currently authorized speakers

GROUP SIZE (S)	1	2	3	4	5	10	15	20	25	30
Threshold	13.06	14.69	15.60	16.18	16.57	17.95	18.83	19.22	19.60	19.93
EER	1.63%	1.92%	2.10%	2.26%	2.45%	2.90%	3.17%	3.47%	3.72%	3.87%

As can be seen on Figure 5.1 with increasing S the histogram (i.e. the distribution of the probability scores) of non-target speakers is shifting closer to that of target speakers. The specific threshold at which FAR is equal to FRR has to be found for each S and corresponding EER can be quantified (Table 5.4). For the whitelist cohort size S=30 the EER is 3.87%, which indicates that the performance of the SpV module is good enough even when the number of actually authorized persons is 30.

Table 5.5: SpV.2 – Speaker authorization / multitarget group speaker verification - test summary

SpV.2	Speaker authorization / multitarget group speaker verification
Pre-requisites	Test is performed on the VoxForge database.
Expected result	For the number of actually authorized speakers (whitelist cohort size) S=30, EER shall not exceed 4.0%.
Result	Passed. EER = 3.87%.
Remarks	This test case is automated.

5.1.3 Test case SpV.3: Radio channel speaker verification

The original SpV module was designed for broadband clean speech signal, and was suitable for the DLR's Tower Simulator in Braunschweig that uses a VoIP channel for voice communication. However, in the real-life the system will be monitoring the voice-radio traffic with narrow frequency range, noises, distortions, and other effects caused by the transmission via radio channel. The difference in the signal quality between the training data and testing data is called channel mismatch. To confirm, that single speaker verification will work well on the radio channel, which is an inevitable condition for multitarget group verification to work well in this channel, the test case SpV.3: Radio channel speaker verification was defined.

No real-life radio communication database, that was large enough, and appropriately annotated for SpV testing was available to the authors. Therefore, it was decided to obtain radio recordings by "playing back" – transmitting speech database recordings via a radio channel. Baofeng UV5R hand-held radios were used as the transmitter and receiver. Due to local limitations, the transmission was performed on Private Mobile Radio frequencies of 446.0 and 446.1 MHz. These frequencies belong to the UHF band, but the distortion and noise caused by the channel are similar to the transmission on the VHF frequencies used in ATM and can be used to realistically simulate the VHF radio-channel influences.

A positive side effect of this approach is that a parallel database of corresponding broadband and radio speech recordings was created in a controlled manner with the annotation from the source database, with potential use in various types of analyses and experiments.

Both, the original VoxCeleb1 database and the radio channel RadioVoxCeleb1 databases were split in non-overlapping training and test sets. Detailed results of the off-line tests with various combinations of training and testing data are presented in Table 5.6. It can be seen that best results in the task of speaker verification on the radio signal (RadioVoxCeleb1_test) is achieved when the system is trained on the combination of original and radio training data (VoxCeleb1_train and RadioVoxCeleb1_train). A notable side effect is an increase in the reliability of the verification on the original clean speech, probably as a result of the training data augmentation by the radio-channel data. The summary of the SpV.3 test can be found in Table 5.7.

Table 5.6: Detailed results of the channel mismatch tests

Training data	Test data	EER
VoxCeleb1_train	VoxCeleb1_test	1.50%
RadioVoxCeleb1_train	RadioVoxCeleb1_test	2.80%
VoxCeleb1_train	RadioVoxCeleb1_test	5.90%
RadioVoxCeleb1_train	VoxCeleb1_test	3.00%

Training data	Test data	EER
VoxCeleb1_train + RadioVoxCeleb1_train	VoxCeleb1_test	1.20%
VoxCeleb1_train + RadioVoxCeleb1_train	RadioVoxCeleb1_test	2.60%

Table 5.7: SpV.3 - Radio channel speaker verification - test summary

SpV.3	Radio channel speaker verification
Pre-requisites	Test is performed on the Radio-VoxCeleb1 database test set.
Expected result	EER shall not exceed 3.00%.
Result	Passed. EER = 2.60%.
Remarks	This test case is automated. SpV module was trained on the mixture of VoxCeleb1_train and RadioVoxCeleb1_train sets.

Table 5.6 shows experiments in a process of adapting the system to work on radio data. Originally, the SpV module was trained on clean, full-range speech from VoxCeleb1 database, but when tested on radio speech from RadioVoxCeleb1 database with limited spectral range and radio-channel distortion, the performance decreased due to “channel mismatch” between training and testing data. The test SpV.3 (Table 5.7) is done on the adapted version of SpV module, trained on a combination of clean and radio data which gives best results both for clean and radio speech.

5.2 Stress detection functionality

The SD evaluates the stress level in the utterance in a form of “stress-level score”.

A straightforward way to design such a module would be using machine learning techniques and training the system on a speech-under-stress database covering all the types of stress manifestations of interest. However, there is no statistically representative database of speech under stress, balanced and annotated with continuous values of arousal, publicly available. Therefore, a new database StressDat was created in SATIE (see section 3.1) and used for training the stress regressor and testing the SD module of TraMICS in the test case SD.1. StressDat contains acted speech manifestations of stress occurring in twelve stress-inducing scenarios, some of them coming from everyday life, others from the air traffic control domain. However, it is assumed that the learned stress cues are generalizable to other, unseen situations and manifestations of stress. This assumption can be partially confirmed by testing the stress detector on emotional databases.

5.2.1 Stress regressor

The tests have confirmed that our stress regressor is able to detect an increased intensity of emotions, i.e. a deviation from the neutral affective state, which may be a manifestation of increased stress. The results of the tests on three emotional databases are presented in Table 5.8. Anger presents the highest stress, sadness the lowest. Valence is not annotated in the StressDat database, so the output score of the stress regressor is correlated mainly with arousal. Therefore, valence-positive emotions with high arousal (e.g. happiness) can reach high scores.

Table 5.8: Average stress-level values of emotions in EmoDB, IEMOCAP, and CREMA-D databases predicted by the stress regressor trained on StressDat. Values are presented along a continuum from 0 to +100.

Database	Emotion					
	anger	disgust	fear	happiness	neutral	sadness
EmoDB	49.1	26.1	35.7	43.4	16.1	11.4
IEMOCAP	38.7	23.4	30.3	25.5	21.9	19.5
CREMA-D	34.8	24.5	28.3	30.7	22.7	20.5

The emotions in EmoDB are highly prototypical, in a sense their realisations follow generally accepted and simplified concept of each particular emotion. Moreover, the emotions are full-blown, acted with high intensity.

IEMOCAP and CREMA-D contain speech manifestations that are closer to natural speech, they present emotions of lower range of intensities, which are more difficult to identify. Table 5.8 presents mean of the measured stress values for the particular emotion. Even if some of the utterances reach very high stress-levels the mean values do not exceed one half of the full range of the scale.

5.2.2 Valence regressor

The TraMICS stress detector is meant to use stress cues from speech as indicators of emergency situations, therefore it should be focused on high-arousal affective states with negative valence. In order to distinguish pleasant affective states from unpleasant ones, a valence measurement block was developed and integrated into the stress detector.

RAVDESS and CREMA-D databases present emotions at several levels of intensity. RAVDESS includes neutral speech and two levels of emotion intended by speaker, CREMA-D neutral speech and three levels of emotion. The perceived intensity of emotions was rated on a continuous scale by several raters. But each emotion has its own range of intensity. The point representing the 100% intensity of angry emotion in the arousal-valence space will be located further from the origin of the coordinate system than for instance 100% intensity for fear. Vector lengths in this Cartesian coordinate system corresponding to the maximum intensities of emotions will be different, which also means that the intensity scales used for different emotions will differ.

Ratings from the annotators (raters) therefore needed to be mapped to one intensity scale common for all emotions and then projected on the valence axis. Based on the position of emotions in the arousal-valence space in the Circumplex model (22), raters' perceived intensity value and developers' own listening evaluation of recordings, valence values were assigned to all the utterances in the databases. These values were used for training the valence regressor.

Mean valence measured on the emotional speech utterances in three testing emotional databases is presented in Table 5.9. The values are presented along a continuum from -100 to +100.

Table 5.9: Mean valence measured on the emotional speech utterances in three databases (CREMA-D and EmoDB does not contain excitement emotion)

DB/Emotion	anger	fear	disgust	sadness	neutral	excitement	happiness
CREMA-D	-63.4	-32.8	-25.7	-23.0	-0.4	-	+4.37
EmoDB	-48.5	-7.2	-36.3	-32.7	-9.6	-	+34.4
IEMOCAP	-22.3	-9.5	-20.0	-23.5	-6.4	+12.3	+7.8

Each database consists of a training set and a test set. The valence regressor was trained on the whole RAVDESS database and CREMA-D training set. It was tested on the CREMA-D test set and the whole EmoDB and IEMOCAP databases. This intuitive ad hoc approach of valence measurement gives only indicative results. Detailed analyses suggest that the average scores for each emotion are estimated quite well, but the variance is still too large. A substantial improvement can only be achieved after a new large and representative, application-oriented database of emotional speech with trustworthy annotated values of perceived valence is created.

However, it seems that the valence measurement performs well on all the three databases and can provide the stress detector with information on pleasure/displeasure of the affective state of the speaker.

5.2.3 Test case SD.1: Stress detection

The test case SD.1 tests the functionality of the TraMICS Stress Detection Module. Each of the utterances of the StressDat test-set is fed to the SD module and the resulting predicted stress-level value is compared to the respective reference value stated in the annotation. The stress-level values can range from 0 to 100. If the difference between measured and annotated value is $\Delta St<10$, the result is considered as correct, if $\Delta St\geq10$, the result is considered as incorrect. The results are collected and the Accuracy is computed. The summary of the SD.1 test can be found in Table 5.10.

Table 5.10: SD.1 - Stress detection - test summary

SD.1	Stress detection
Pre-requisites	Test is performed on the StressDat database test-set.
Expected result	At the stress-level tolerance $\Delta St<10$ the Accuracy shall be higher than 80%.
Result	Passed. The Accuracy was 84%.
Remarks	This test case is automated.

5.3 Conformance monitoring and conflict detection functionality

The following CMCD test cases focus on the conformance monitoring and conflict detection functionality only.

5.3.1 Test case CMCD.1: Detection of deviation from assigned route

This test case aims to detect the deviation of a taxiing aircraft from its assigned taxi route. Figure 5.2 shows the assigned route for aircraft DLH01A in purple. The pseudo pilot is briefed to taxi the aircraft via the blue-coloured route instead of taking the planned purple-coloured route. Table 5.11 summarizes the test and Figure 5.3 shows the result.

Figure 5.2: Schematic of the test situation for detection of route deviation. DLH01A has an assigned route, but will taxi differently.

Table 5.11: CMCD.1 - Detection of deviation from assigned route - test summary

CMCD.1	Detection of deviation from assigned route
Pre-requisites	DLH01A has the route assigned as shown in Figure 5.2 and the taxi clearance is given. The pseudo pilot taxis the aircraft on the blue-coloured route in Figure 5.2.
Expected result	The route deviation shall be detected.
Result	Passed. The expected route deviation is detected (Figure 5.3).
Remarks	The thresholds are configured as described in Table 2.1.

Figure 5.3: Route deviation alert is shown to the ATCO

5.3.2 Test case CMCD.2: No route deviation alerts after being back on route

The aircraft DLH03A is cleared to taxi with purple-coloured route in Figure 5.4. The pseudo pilot is briefed to taxi the aircraft on the blue-coloured route instead. The alert “ROUTE DEV” is raised and displayed in the HMI (see Figure 5.5). If DLH03A is on its route again, no new alerts are raised. (see Figure 5.6).

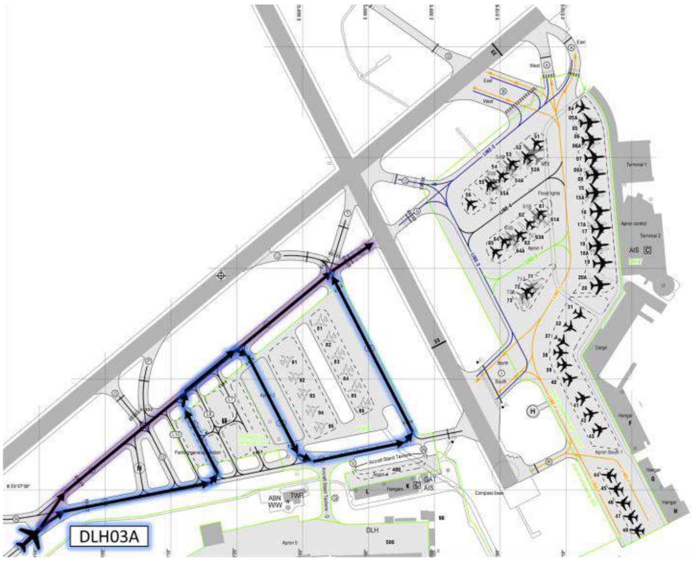


Figure 5.4: Schematic of the test situation to detect multiple route deviations of one aircraft. DLH03A has a planned route, but will taxi differently.

Table 5.12: CMCD.2 - No route deviation alerts after being back on route - test summary

CMCD.2	No route deviation alerts after being back on route
Pre-requisites	DLH03A is cleared to taxi the purple-coloured route as shown in Figure 5.4. The pseudo pilot taxis the aircraft on the blue-coloured route in Figure 5.4.
Expected result	When the AC is back in on its route, no alerts shall be sent.
Result	Passed. The alert “ROUTE DEV” has been displayed (Figure 5.5) and does not appear if DLH03A is on its route again (Figure 5.6).
Remarks	The thresholds are configured as described in Table 2.1.

Figure 5.5: Detected route deviation

Figure 5.6: Aircraft is on its cleared route again

5.3.3 Test case CMCD.3: Detection of multiple deviations from a planned route

This test case is the continuation of CMCD.2. The aircraft DLH03A is cleared to taxi with purple-coloured route in Figure 5.4. The pseudo pilot is briefed to taxi the aircraft on the blue-coloured route. The alert “ROUTE DEV” has been displayed (Figure 5.5). When DLH03A is on its route again the deviation alert will not re-occur (Figure 5.6). The second deviation is visible in Figure 5.7. Table 5.13 summarizes the test.

Table 5.13: CMCD.3 - Multiple deviations from planned route - test summary

CMCD.3	Multiple deviations from planned route
Pre-requisites	DLH03A is cleared to taxi the route as shown in Figure 5.4. The pseudo pilot taxis the aircraft on the blue-coloured route in Figure 5.4.
Expected result	The second deviation from the planned route shall also be detected.
Result	Passed. The alert “ROUTE DEV” is been displayed again at the second deviation (Figure 5.7).
Remarks	The thresholds are configured as described in Table 2.1.

Figure 5.7: The second route deviation detected

5.3.4 Test case CMCD.4: Opposite traffic

This test case aims to detect the conflict if one AC enters the route of another AC already taxiing in towards the other. Figure 5.8 shows the cleared routes for aircraft DLH04A in red and the aircraft DLH04B in blue. Table 5.14 summarizes the test and Figure 5.9 shows the result.

Figure 5.8: Schematic of the test situation to detect an opposite traffic

Table 5.14: CMCD.4 - Opposite traffic - test summary

CMCD.4	Opposite traffic
Pre-requisites	DLH04A has the red route assigned and DLH04B has the blue route assigned as shown in Figure 5.8. Both taxi clearances are given.
Expected result	The conflict arising from two aircrafts being opposite on a taxiway shall be detected.
Log output	"CD:samePoint: send CD-Alert Event for: DLH04B at: 10:00:33 with 122.31446252518148 distance to DLH04A"
Result	Passed. The alert "Conflict with" has been displayed (Figure 5.9).
Remarks	The thresholds are configured as described in Table 2.1.

Figure 5.9: Conflict alert is shown to the ATCO

5.3.5 Test case CMCD.5: Opposite traffic at a crossing

This test case aims to detect the conflict of two taxiing aircraft at a crossing, each aircraft following its assigned taxi route, but the routes lead to opposite traffic at a crossing. Figure 5.10 shows the cleared route for aircraft DLH05A in red and for DLH05B in blue. DLH05B is not advised to stop in front of the crossing and will comply with that. Table 5.15 summarizes the test and Figure 5.11 shows the result.

Figure 5.10: Schematic of the test situation to detect an opposite traffic at a crossing

Table 5.15: CMCD.5 - Opposite traffic at a crossing - test summary

CMCD.5	Opposite traffic at a crossing
Pre-requisites	DLH05A has the red route assigned and DLH05B has the blue route assigned as shown in Figure 5.10. Both taxi clearances are given. DLH05B is not advised to stop in front of the crossing and will turn left without stopping.
Expected result	The conflict arising from two aircrafts being opposite on a taxiway shall be detected.
Result	Passed. The alert “Conflict with” has been displayed (Figure 5.11).
Remarks	The thresholds are configured as described in Table 2.1.

Figure 5.11: The conflict alert resulting from opposite traffic at a crossing is shown to the ATCO

5.3.6 Test case CMCD.6: Two AC merge into a taxiway without stopping

This test case aims to detect the conflict of two taxiing aircraft following their assigned taxi routes which will merge in the same taxiway. Figure 5.12 shows the cleared routes for aircraft DLH05A in red and for DLH05B in blue. Table 5.16 summarizes the test and Figure 5.13 shows the result.

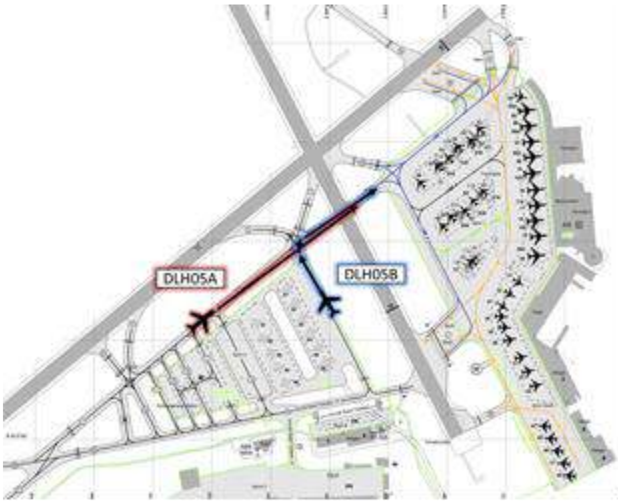


Figure 5.12: Schematic of the test situation for two AC at a crossing merging into the same taxiway, none waiting in front of the crossing.

Table 5.16: CMCD.6 - Two AC at a crossing merging into the same taxiway - test summary

CMCD.6	Two AC at a crossing merging into the same taxiway
Pre-requisites	DLH05A has the red-coloured route assigned and DLH05B has the blue-coloured route assigned as shown in Figure 5.12. Both taxi clearances are given. Both, DLH05A and DLH05B are **not waiting in front of the crossing**.
Expected result	The conflict caused by two aircraft having the same taxiway at the same time after the crossing without stopping shall be detected.
Result	Passed. The alert “Conflict with” has been displayed (Figure 5.13).
Remarks	The thresholds are configured as described in Table 2.1.

Figure 5.13: Two moving AC at a crossing with the same future route

5.3.7 Test case CMCD.7: Two AC merge into a taxiway with stopping

This test case aims to show that there is no conflict at a crossing if the AC stops correctly at the stop bar although both AC have the same future taxiway. Figure 5.14 shows the cleared route for test aircraft DLH02A and for DLH02B. DLH02A stops correctly at the stop bar. Table 5.17 summarizes the test and Figure 5.15 shows the result: no conflict.

Figure 5.14: Schematic of the test situation for two AC at a crossing merging into the same taxiway. DLH02A stops correctly at the stop bar.

Table 5.17: CMCD.7 - Two AC merge into a taxiway with stopping - test summary

CMCD.7	Two AC merge into a taxiway with stopping
Pre-requisites	DLH02B has the red-coloured route assigned and DLH02A has the blue-coloured route assigned as shown in Figure 5.14. Both taxi clearances are given. DLH02A **is waiting at the stop bar**.
Expected result	No conflict shall be detected.
Result	Passed. No alert is raised (Figure 5.15).
Remarks	The thresholds are configured as described in Table 2.1.

Figure 5.15: Two AC with merging routes. One AC (DLH02A) stopped at the stop bar

5.3.8 Test case CMCD.8: Two AC merge into a taxiway with stopping behind a stop bar

This test case aims to detect the conflict of two taxiing aircraft at a crossing with one incorrect stop at the stop bar, i.e. a stop behind the stop bar. Figure 5.16 shows the cleared route for aircraft DLH10B in red and for DLH10A in blue. DLH10A stops behind the stop bar. Table 5.18summarizes the test and Figure 5.17 shows the result.

Figure 5.16: Schematic of the test situation for two AC at a crossing with future same link. DLH10A stops behind the stop bar.

Table 5.18: CMCD.8 - Two AC merge into a taxiway with stopping behind a stop bar - test summary

CMCD.8	Two AC merge into a taxiway with stopping behind a stop bar
Pre-requisites	DLH10B has the red-coloured route assigned and DLH10A has the blue-coloured route assigned as shown in Figure 5.16. Both taxi clearances are given. DLH10A has **not stopped at the stop bar but behind**.
Expected result	A conflict alert shall be raised.
Result	Passed. The alert “Conflict with” has been displayed (Figure 5.17).
Remarks	The thresholds are configured as described in Table 2.1.

Figure 5.17: Two AC at a crossing merging into the same taxiway and DLH01A stopped behind the stop bar

5.3.9 Test case CMCD.9: Two AC at a crossing with disjoined routes

This test case aims to detect the conflict of two taxiing aircraft at a crossing without having the same taxiway as illustrated in Figure 5.18. Both arrive at the crossing at the same time and passing would lead to a safety incident. Figure 5.18 shows the cleared route for aircraft DLH03A in red and for DLH03B in blue. Table 5.19 summarizes the test and Figure 5.19 shows the result.

Figure 5.18: Schematic of the test situation for two AC at a crossing with disjoined routes

Table 5.19: CMCD.9 - Two AC at a crossing with disjoined routes - test summary

CMCD.9	Two AC at a crossing with disjoined routes
Pre-requisites	DLH03A has the route assigned as shown in Figure 5.18 in red and DLH03B has the route assigned as shown in Figure 5.18 in blue. Both taxi clearances are given.
Expected result	The conflict caused by two aircraft being at the same crossing at the same time shall be detected.
Result	Passed. The alert “Conflict with” has been displayed (Figure 5.19).
Remarks	The thresholds are configured as described in Table 2.1.

Figure 5.19: Conflict resulting from two AC at a crossing with disjoined routes shown to the ATCO

5.3.10 Test case CMCD.10: Two AC at a runway holding point

This test case aims to show that there is no conflict if two AC taxi subsequent to a runway-holding point. The first one stops, the second stops behind. Figure 5.20 shows the cleared route for aircraft CSA545 in green and for AUA176 in yellow. Table 5.20 summarizes the test and Figure 5.21 shows the result.

Figure 5.20: Schematic of the test situation leading to two AC taxiing to the runway-holding point

Table 5.20: CMCD.10 - Two AC at a runway holding point - test summary

CMCD.10	**Two AC at a runway holding point**
Pre-requisites	CSA545 has the green-coloured route assigned and AUA176 has the yellow-coloured route assigned as shown in Figure 5.20. AUA176 has pushed back with pushback clearance and both aircraft have started taxi with taxi clearance.
Expected result	No alert.
Result	Passed. No alert is raised (Figure 5.21).
Remarks	The thresholds are configured as described in Table 2.1.

Figure 5.21: Two AC at runway holding point raise no alert

5.3.11 Test case CMCD.11: Two AC are moving on the same taxiway and the subsequent is faster

This test case aims to detect the conflict of two consecutively taxiing aircraft on the same taxiway. The subsequent one (DLH05A) is faster than the predecessor (DLH05B). Figure 5.22 shows the cleared route for aircraft DLH05A in red and for DLH05B in blue. Table 5.21 summarizes the test and Figure 5.23 shows the result.

Figure 5.22: Schematic of the test situation with two subsequent AC on a taxiway

Table 5.21: CMCD.11 - Two AC are moving on the same taxiway and the subsequent is faster - test summary

CMCD.11	Two AC are moving on the same taxiway and the subsequent is faster
Pre-requisites	DLH05A and DLH05B have the same route assigned as shown in Figure 5.22. The subsequent DLH05A taxis faster.
Expected result	A conflict alert is raised.
Result	Passed. The alert “Conflict with” has been displayed (Figure 5.23).
Remarks	The thresholds are configured as described in Table 2.1.

Figure 5.23: Detected conflict as the subsequent AC moved faster than the predecessor

5.3.12 Test case CMCD.12: Two AC are moving on the same taxiway and the preceding stops

This test case aims to detect the conflict of two consecutive aircrafts, where the preceding stops and the subsequent not. Figure 5.24 shows the cleared route for aircraft DLH10B in blue and the holding aircraft DLH02A in red. Table 5.22 summarizes the test and Figure 5.25 shows the result.

Figure 5.24: Schematic of the test situation for two AC moving on the same taxiway and the preceding DLH02A stops

Table 5.22: CMCD.12 - Two AC are moving on the same taxiway and the preceding stops - test summary

CMCD.12	Two AC are moving on the same taxiway and the preceding stops
Pre-requisites	DLH02A and DLH10B have the same route assigned as shown in Figure 5.24 in red and blue colour. The preceding DLH02A stops.
Expected result	A conflict alert is raised.
Result	Passed. The alert “Conflict with” has been displayed (see Figure 5.25).
Remarks	The thresholds are configured as described in Table 2.1.

Figure 5.25: Conflict resulting of the preceding DLH02A stopping but the subsequent DLH10B not

5.3.13 Test case CMCD.13: Route deviation with opposite heading

This test case aims to detect a route deviation leading to the opposite heading as planned. Figure 5.26 shows the cleared route for aircraft DLH05B in purple. The pseudo pilot is briefed to taxi DLH05B via the blue-coloured route. Table 5.23 summarizes the test and Figure 5.27 shows the result.

Figure 5.26: Schematic of the test situation for an AC deviating its route by taxiing with opposite heading: DLH05B has the purple-coloured planned route with a right turn, but will taxi with a left turn (blue-coloured)

Table 5.23: CMCD.13 - Route deviation with opposite heading - test summary

CMCD.13	Route deviation with opposite heading
Pre-requisites	DLH05B has a planned route with a right turn, coloured in purple, but will taxi the blue-coloured route with a left turn (Figure 5.26).
Expected result	A route deviation alert is raised.
Result	Passed. The alert “ROUTE DEV” has been displayed (Figure 5.27).
Remarks	The thresholds are configured as described in Table 2.1.

Figure 5.27: Route deviation alert is shown as the AC is taxiing with opposite heading

5.3.14 Test case CMCD.14: Hold clearance was given but AC does not stop

This test case aims to detect the not-stopping of an aircraft if it should stop. Figure 5.28 shows the cleared route for aircraft DLH10A in blue. DLH10A received a HOLD clearance but will not stop and continues taxiing with constant speed. Table 5.24 summarizes the test and Figure 5.29 shows the result.

Figure 5.28: Schematic of the test situation for DLH10A, which is not stopping when it should.

Table 5.24: CMCD.14 - Hold clearance was given but AC does not stop - test summary

CMCD.14	Hold clearance was given but AC does not stop
Pre-requisites	DLH10A has the route assigned as shown in Figure 5.28 in blue. DLH10A has received a HOLD clearance but does not stop and moves with constant speed.
Expected result	A “no clearance” alert and “Not stopping” alerts shall be raised.
Result	Passed. The alerts “NO CLR” and “Not stopping” have appeared (Figure 5.29).
Remarks	The thresholds are configured as described in Table 2.3.

Figure 5.29: An alert is raised when DLH10A does not stop as it should and continues moving with constant speed

5.3.15 Test case CMCD.15: AC stopped, but continues taxi without continue taxi clearance

This test case aims to detect the un-cleared continuation of taxi after a directed and executed stop. Figure 5.30 shows the cleared route for aircraft DLH02A in blue. DLH02A has got a HOLD clearance and stopped. It continues taxi without the clearance to continue taxi. Table 5.25 summarizes the test and Figure 5.31 shows the result.

Figure 5.30: Schematic of the test situation for DLH02A which was holding as directed but starts taxi again without continue taxi clearance

Table 5.25: CMCD.15 - AC stopped, but continues taxi without continue taxi clearance - test summary

CMCD.15	AC stopped, but continues taxi without continue taxi clearance
Pre-requisites	DLH02A has the route assigned as shown in Figure 5.30 in blue. DLH02A has received a HOLD clearance and stopped (to let DLH02B pass by, see Figure 5.31), but starts continuing taxi without clearance.
Expected result	A “no clearance” alert and “TX instead of HLD” alerts shall be raised.
Result	Passed. The alert “NO CLR” and “TX instead of HLD” appeared (see Figure 5.31).
Remarks	The thresholds are configured as described in Table 2.3.

Figure 5.31: DLH02A with HOLD clearance is taxiing without continue clearance

5.4 Unusual behaviour detection functionality

The following UB test cases focus on the unusual behaviour detection functionality only.

5.4.1 Test case UB.1: AC pushing without pushback clearance

This test case aims to detect the clearance alert of an aircraft pushing without pushback clearance. Table 5.26 summarizes the test and Figure 5.32 shows the result.

Table 5.26: UB.1 - AC pushing without pushback clearance - test summary

UB.1	AC pushing without pushback clearance
Pre-requisites	AUA176 is in a pushback position, has the pushback route assigned but no pushback clearance yet and starts pushing back.
Expected result	The clearance alert “NO CLR” shall be raised.
Result	Passed. Alert “NO CLR” is raised (Figure 5.32).
Remarks	-

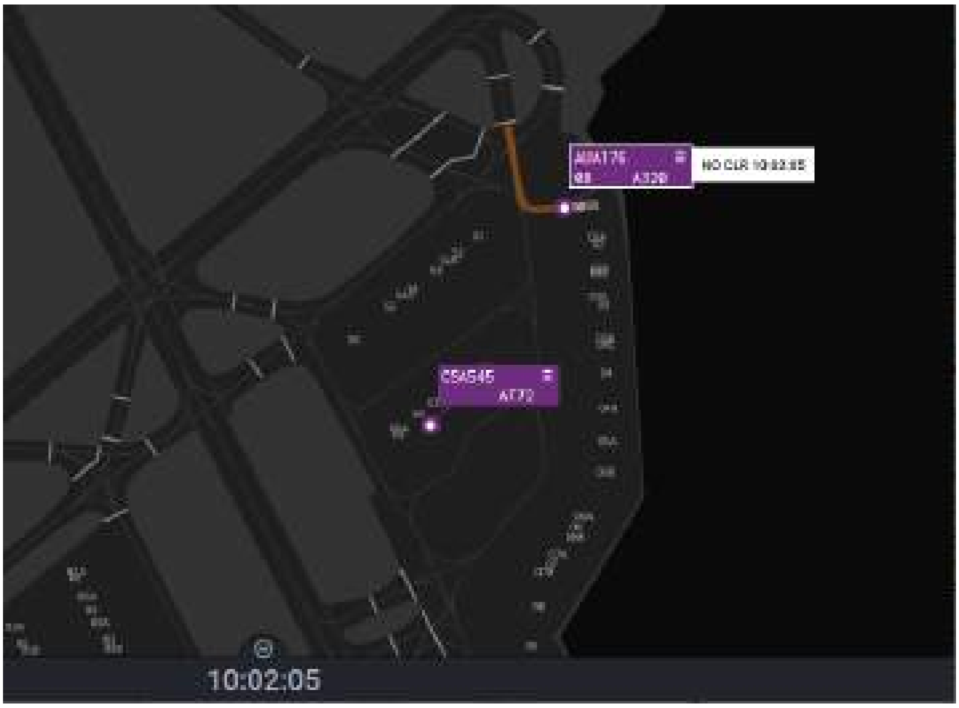


Figure 5.32: Alert showing that AUA176 is pushing without clearance

5.4.2 Test case UB.2: AC taxiing without taxi clearance

This test case aims to detect the clearance alert of an aircraft taxiing without taxi clearance. AUA176 has pushed with appropriate clearance and starts now taxiing without taxi clearance. Table 5.27 summarizes the test and Figure 5.33 shows the result.

Table 5.27: UB.2 - AC taxiing without taxi clearance - test summary

UB.2	AC taxiing without taxi clearance
Pre-requisites	AUA176 has finished pushback, a taxi route is assigned, but no taxi clearance is given. AUA176 starts taxiing anyway.
Expected result	The clearance alert “NO CLR” shall be raised.
Result	Passed. The alert “NO CLR” is raised (Figure 5.33).
Remarks	-

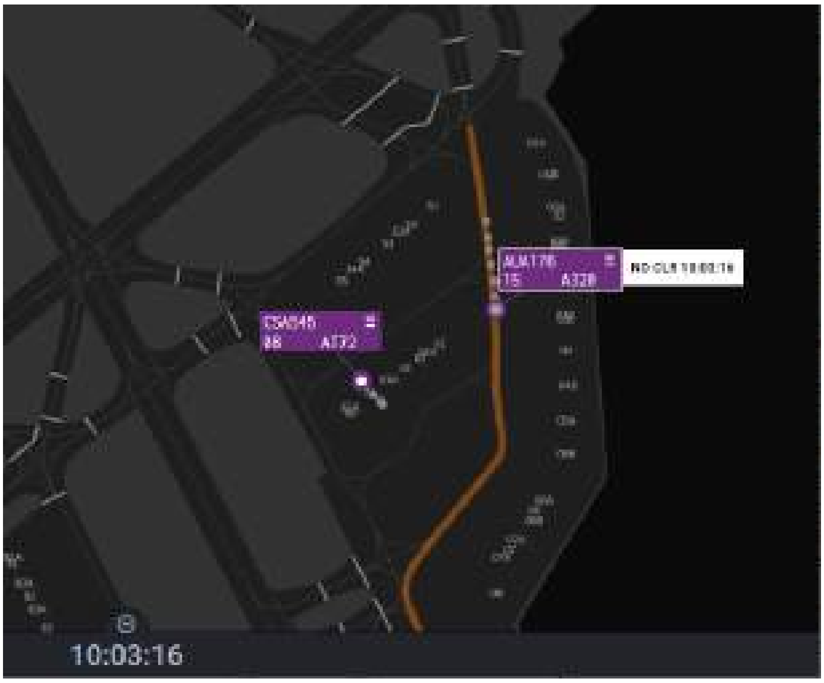


Figure 5.33: Alert showing that AUA176 is taxiing without clearance

5.4.3 Test case UB.3: Wrong clearance order

This test case aims to detect the clearance alert of an aircraft with wrong clearance order. DLH05A has received the pushback clearance, has pushed, and is now taxiing. It has received no taxi clearance, but a line-up clearance. Table 5.28 summarizes the test and Figure 5.34 shows the result.

Table 5.28: UB.3 - Wrong clearance order - test summary

UB.3	Wrong clearance order
Pre-requisites	DLH05A has pushed with pushback clearance, has received line up clearance, but no taxi clearance, and is taxiing.
Expected result	Two alerts shall be raised: “NO CLR” as it is taxiing without taxi clearance and “NO TAXI CLR” as it received the line-up clearance without preceding taxi clearance.
Result	Passed. Two different alerts are raised: “NO CLR” and “NO TAXI CLR” (Figure 5.34).
Remarks	The thresholds are configured as described in Table 2.3.

Figure 5.34: Two alerts are raised when an aircraft received line up clearance without taxi clearance

5.4.4 Test case UB.4: Pushback clearance at rollout position

This test case aims to detect the clearance alert of an aircraft starting taxi at a roll out position but with a pushback clearance. Table 5.29 summarizes the test and Figure 5.35 shows the result.

Table 5.29: UB.4 - Pushback clearance at rollout position - test summary

UB.4	**Pushback clearance at rollout position**
Pre-requisites	CSA545 is in a roll out position, has a route assigned, receives a pushback clearance, and starts taxiing.
Expected result	Two alerts shall be raised: “NO CLR” as it starts taxiing without taxi clearance and “No appropriate CLR” as it received a pushback clearance with does not fit to its parking position.
Result	Passed. Two types of alerts are raised: “NO CLR” and “No appropriate CLR” (Figure 5.35).
Remarks	The thresholds are configured as described in Table 2.3.

Figure 5.35: Alert for a not appropriate clearance

5.4.5 Test case UB.5: Pushback with taxi clearance

This test case aims to detect the clearance alert of an aircraft pushing back without pushback clearance but with a taxi clearance. Table 5.30 summarizes the test and Figure 5.36 shows the result.

Table 5.30: UB.5 - Pushback with taxi clearance - test summary

UB.5	Pushback with taxi clearance
Pre-requisites	AUA176 is at a pushback position, has the pushback route assigned, and no pushback clearance. It receives a taxi clearance and starts pushing back.
Expected result	Two types of alerts shall be raised: “NO CLR” as it starts pushing without pushback clearance and “NO PUSH CLR” as it has received the taxi clearance without the necessary pushback clearance before.
Result	Passed. Two types of alerts are raised: “NO CLR” and “NO PUSH CLR” (Figure 5.36).
Remarks	The thresholds are configured as described in Table 2.3.

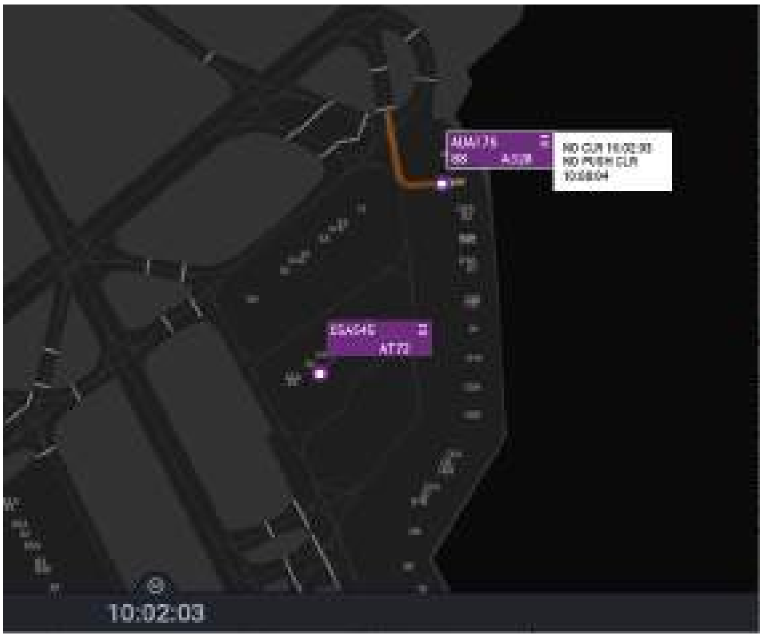


Figure 5.36: Two alerts are raised when AUA176 pushes back without pushback clearance but with taxi clearance

5.5 Security situation indicator determination

The tests of the CORE module to determine the security situation indicator require the other TaMICS modules to be integrated. The authorized speakers need to be enrolled. Figure 2.2 on page 24 shows the HMI, which enables enrolment as well as selection of current authorized speakers. This HMI can also be used to configure which threshold of the score value originated by SpV shall be used to categorize a speaker as unauthorized.

5.5.1 Test case CORE.1: Message reception from SpV module

This test case (Table 5.31) verifies the integration of the SpV with the CORE module.

Table 5.31: CORE.1 - Message reception from SpV module – test summary

CORE.1	Message reception from SpV module
Pre-requisites	TraMICS is running in its environment and an unauthorized speaker uses the (simulated) radio communication.
Expected result	An information about a received message from SpV module can be seen in the TraMICS log file.
Log output	common.core.controller.CoreController INFO: received a message from SAV module!** common.core.controller.CoreController INFO: 1603964573 sav_output NOT_AUTHORIZED 0 66 1603964573 1603964573
Result	Passed. The log output contains the expected information.
Remarks	-

5.5.2 Test case CORE.2: Unauthorized speaker leads to a red security situation indicator

An unauthorized speaker triggers the SpV module, which is expected to send an “unauthorised” message to the CORE module. The CORE module shall use this indication to determine a red/severe security situations indicator. The test case is summarized in Table 5.32.

Table 5.32: CORE.2 - Unauthorized speaker leads to red security situation indicator - test summary

CORE.2	Unauthorized speaker leads to red security situation indicator
Pre-requisites	The speaker is not registered as authorised in the SpV module.
Expected result	An unauthorized speaker shall be detected and the security situation indicator shall change to red.
Result	Passed. The “Speaker not authorized” alert and the red security situation indicator is shown in the Global Alert List on the HMI (Figure 5.37).
Remarks	The thresholds are configured as described in Table 2.8.

Figure 5.37: The Global Alert List contains the unauthorized speaker alert and the resulting red security situation indicator

5.5.3 Test case CORE.3: Long lasting route deviation leads to yellow/red security situation indicator

This test case aims to detect that a long-lasting route deviation from the assigned taxi route of one taxiing aircraft leads to a yellow and thereafter even red security situations indicator. Figure 5.2 in CMCD.1 shows the cleared route for test aircraft DLH01A in purple. The pseudo pilot is briefed to taxi the aircraft via the blue-coloured route. The planned route is not changed by the ATCO and the pilot continues on his chosen route like shown if the figure. The long lasting deviation from the cleared route shall first lead to a yellow security situation indicator, as the global threshold for the amount of route deviation alerts per aircraft (*perAC.alerts.yellow.Nallcmalerts*), which is set to 120, is exceeded. Thereafter, the security situation indicator changes to red, as the global threshold *perAC.alerts.red.Nallcmalerts* of 180 is exceeded. Table 5.33: summarizes the test, Figure 5.38 and Figure 5.39 show the result.

Table 5.33: CORE.3 - Long lasting route deviation leads to yellow/red security situation indicator - test summary

CORE.3	Long lasting route deviation leads to yellow/red security situation indicator
Pre-requisites	DLH01A has the route assigned as shown in Figure 5.2 in case CMCD.1 and the taxi clearance is given. The pseudo pilot taxis the aircraft on the blue-coloured route in Figure 5.2. No other alerts have been provoked before.
Expected result	A long-lasting deviation shall lead first to a yellow and later to a red security situations indicator, when the number of alerts exceed the thresholds.
Result	Passed. The expected results, first the yellow security situation indicator "DLH01A #CM alerts 154/120" (Figure 5.38) and later the red security situation indicator "DLH01A #CM alerts 190/180" (Figure 5.39) have been displayed.
Remarks	The thresholds are configured as described in Table 2.8.

Figure 5.38: A long lasting route deviation leads first to a yellow security situation indicator on the ATCO's HMI

Figure 5.39: An even longer lasting route deviation leads to a red security situation indicator on the ATCO's HMI

5.5.4 Test case CORE.4: Multiple route deviations of one AC lead to a yellow security situation indicator

The aircraft DLH03A is cleared to taxi with purple-coloured route in Figure 5.40. The pseudo pilot taxis the aircraft on the blue-coloured route. The second deviation from the cleared route shall lead to a yellow security situation indicator, as the yellow threshold for route deviation cases per aircraft (*perAC.cases.yellow.Nallcmalerts*), which is set to 2, is reached or exceeded. Table 5.34 summarizes the test and Figure 5.41 shows the result.

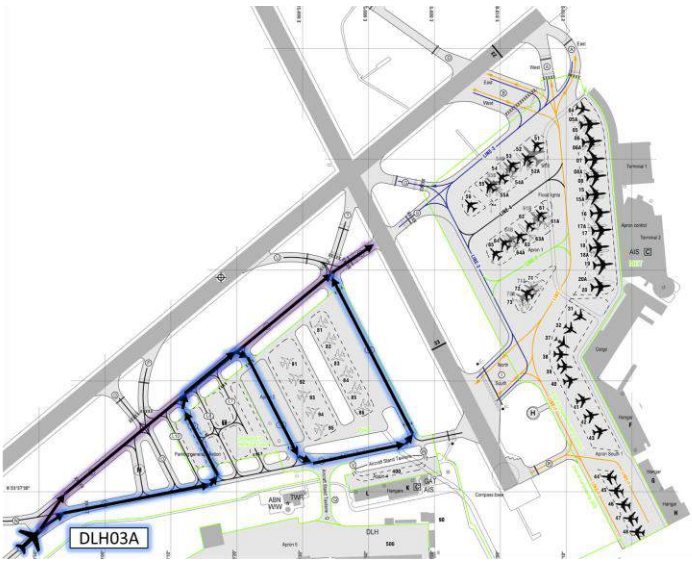


Figure 5.40: Schematic of test situation for multiple route deviations of one AC, which lead to yellow security situation indicator. DLH01A has a planned route, but will taxi differently

Table 5.34: CORE.4 - Multiple route deviations of one AC lead to a yellow security situation indicator - test summary

CORE.4	Multiple route deviations of one AC lead to a yellow security situation indicator
Pre-requisites	DLH03A has the route assigned as shown in Figure 5.40 and the taxi clearance is given. The pseudo pilot taxis the aircraft on the blue-coloured route in Figure 5.40. No other alerts have been provoked before.
Expected result	A yellow security situation indicator is expected at the second route deviation.
Result	Passed. The yellow security situation indication with “DLH03A #CM cases 2/2” is displayed (Figure 5.41).
Remarks	The thresholds are configured as described in Table 2.8.

Figure 5.41: A second route deviation for the same AC leads to a yellow security situation indicator

5.5.5 Test case CORE.5: Route deviations of several AC lead to a red security situation indicator

Four AC deviate for a short time from their routes. When the ATCO has detected the deviation, they will adjust the routes via the CWP HMI to the routes the AC are taxiing on. The aircraft DLH05A is cleared to taxi via the red-coloured route, DLH05B the blue, AUA176 the yellow, and CSA545 the green in Figure 5.42. The pseudo pilot taxis the four AC on the purple-coloured routes. The fourth deviation from the cleared route shall lead to a red security situation indicator, as the threshold for route deviation global cases (*global.cases.red.Nallcmalerts*), which is set to 4, is reached. Table 5.35 summarizes the test and Figure 5.43 shows the result.

Figure 5.42: Schematic of test situation for route deviations of four AC. The assigned routes are shown in red, blue, green and yellow, the taken ones in purple

Table 5.35: CORE.5 - Route deviations of several AC lead to a red security situation indicator - test summary

CORE.5	Route deviations of several AC lead to a red security situation indicator
Pre-requisites	DLH05A has the route assigned as shown in Figure 5.42 in red, DLH05B in blue, AUA176 in yellow, CSA545 in green and the taxi/pushback clearances are given. The pseudo pilot taxis all four AC on the purple-coloured routes in Figure 5.42. No other alerts have been provoked before.
Expected result	Route deviations of four AC shall lead to a red security situations indicator.
Result	Passed. The red security situation indicator is displayed “Global #CM cases 4/4” (Figure 5.43).
Remarks	The thresholds are configured as described in Table 2.8.

Figure 5.43: Route deviations of four AC lead to a red security situation indicator

The route deviations in this test case led also to a conflict, which is shown to the ATCO (Figure 5.45). The AUA176 and the CSA545 are already back on their cleared routes, the alert messages have not been dismissed by the ATCO. The timestamps show that they are outdated. The ROUTE DEV alerts of DLH05A and DLH05B are not updated as the flights do not move.

5.5.6 Test case CORE.6: Conflict leads to a yellow security situation indicator

This test case bases on CMCD.5 and aims to trigger a yellow security situation indicator because of two conflicting AC. The taken routes are shown in Figure 5.44. Table 5.36 summarizes the test and Figure 5.45 shows the result.

Figure 5.44: Schematic of test situation for two conflicting AC

Table 5.36: CORE.6 - Conflict leads to a yellow security situation indicator - test summary

CORE.6	Conflict leads to a yellow security situation indicator
Pre-requisites	The two AC have the routes assigned as shown in Figure 5.44 and the taxi clearances are given. No other alerts have been provoked before.
Expected result	The detected two conflicting aircraft shall lead to a yellow security situation indicator.
Result	Passed. The expected result, the yellow security situation indicator has been displayed “Global #CD cases 2/2” (Figure 5.45).
Remarks	The thresholds are configured as described in Table 2.8.

Figure 5.45: Two conflicting AC trigger a yellow security situation indicator

5.5.7 Test case CORE.7: Conflicts lead to a red security situation indicator

This test case aims to trigger a red security situation indicator due to too many conflicting AC. Table 5.37 summarizes the test and Figure 5.47 shows the result.

Figure 5.46 Schematic of the test situation for two conflicts involving each two AC to trigger a red security situation indicator

Table 5.37: CORE.7 - Conflicts lead to a red security situation indicator - test summary

CORE.7	Conflicts lead to a red security situation indicator
Pre-requisites	The four AC have the routes assigned as shown in Figure 5.46 and the taxi clearances are given. The pseudo pilot is advised to conflict CSA545 and AUA176 in the small red circle shown in the figure.
Expected result	Two conflicts with two aircraft each shall trigger a red security situation indicator.
Result	Passed. The red security situation indicator “Global #CD cases 4/4” is displayed (Figure 5.47).
Remarks	The thresholds are configured as described in Table 2.8.

Figure 5.47: Too many conflicts trigger a red security situation indicator

In Figure 5.47 test case the ATCO has already notified and dismissed the conflict alerts in the flight labels.

5.5.8 Test case CORE.8: Unauthorized speaker and route deviation

This test case aims to trigger a red security situation indicator with an unauthorized speaker and an additional route deviation. Figure 5.48 shows the cleared route for aircraft AUA176 in yellow. The unauthorized speaker redirects AUA176 via the blue-coloured route. This shall lead to a red security situation indicator. Table 5.38 summarizes the test and Figure 5.49 shows the result.

Figure 5.48: Schematic of the test situation with an unauthorized speaker and a route deviation

Table 5.38: CORE.8 - Unauthorized speaker and route deviation - test summary

CORE.8	Unauthorized speaker and route deviation
Pre-requisites	AUA176 planned on the yellow-coloured route but the pseudo pilot taxis the AC on the blue-coloured route (Figure 5.48), advised by an unauthorized speaker.
Expected result	An unauthorized speaker alert shall be shown in the Global Alert List and the security situation indicator shall change to red.

Result	Passed. The red security situation indicator appears in the Global Alert List, as well as the “Speaker not authorized” alert (Figure 5.49).
Remarks	The thresholds are configured as described in Table 2.8.

Figure 5.49: Red security situation indicator due to an unauthorized speaker and a route deviation

5.5.9 Test case CORE.9: Unauthorized speaker, route deviation and conflict

This test case aims to trigger a red security situation indicator due to an unauthorized speaker and an additional conflict. Figure 5.50 shows the cleared routes for aircraft CSA545 in green and for AUA176 in yellow. The unauthorized speaker redirects AUA176 via the blue-coloured route. This shall trigger the security situation indicator to change to red. Table 5.39 summarizes the test and Figure 5.51 shows the result.

Figure 5.50: Schematic of the test situation with an unauthorized speaker and a conflict

Table 5.39: CORE.9 - Unauthorized speaker, route deviation and conflict - test summary

CORE.9	Unauthorized speaker, route deviation and conflict
Pre-requisites	CSA545 is cleared to taxi the green route, AUA176 the yellow-coloured route. An unauthorized speaker redirects and the pseudo pilot taxis AUA176 via the blue-coloured route (Figure 5.50). The pseudo pilot is briefed to conflict CSA545 and AUA176 in the small red circle shown in the figure. No other alerts have been provoked before.
Expected result	An unauthorized speaker alert shall be shown in the Global Alert List and the security situation indicator shall change to red.
Result	Passed. The red security situation indicator appears in the Global Alert List, as well as the “Speaker not authorized” alert (Figure 5.51).
Remarks	The thresholds are configured as described in Table 2.8.

Figure 5.51: A conflict and an unauthorized speaker change the security situation indicator to red

5.5.10 Test case CORE.10: Route deviation and conflict lead to a yellow security situation indicator

This test case aims to trigger a yellow security situation indicator by provoking a conflict and a route deviation. Figure 5.52 shows the planned routes for aircraft DLH05A in red and for DLH05B in purple. The pseudo pilot taxis DLH05B on the blue-coloured route. Table 5.40 summarizes the test and Figure 5.53 shows the result.

Figure 5.52: Schematic of test situation to trigger a yellow security situation indicator via a route deviation and a conflict

Table 5.40: CORE.10 - Route deviation and conflict lead to a yellow security situation indicator - test summary

CORE.10	Route deviation and conflict lead to a yellow security situation indicator
Pre-requisites	DLH05A is taxiing on the red-coloured route in Figure 5.52. DLH05B is planned on the purple-coloured route, but the pseudo pilot taxis it on the blue-coloured route (Figure 5.52).
Expected result	The security situation indicator changes to yellow.
Result	Passed. The yellow security situation indicator is displayed with “Global #CD cases 2/2” (Figure 5.53).
Remarks	The thresholds are configured as described in Table 2.8.

Figure 5.53: Route deviation and a conflict trigger a yellow security situation indicator

5.5.11 Test case CORE.11: Change from a yellow to a green security situation indicator

The test case aims to show that a yellow security situation indicator changes back to green if no or few and not rated as serious types of alerts have been raised in a specific time. CORE.11 is based on CORE.4, where a second route deviation of one aircraft led to a yellow security situations indicator. Back on its route again, the aircraft taxis without any alerts to his stand. Table 5.41 summarizes the test and Figure 5.54 shows the result.

Table 5.41: CORE.11 - Change from a yellow to a green security situation indicator

CORE.11	Change from a yellow to a green security situation indicator
Pre-requisites	The test case CORE.4 is executed. No further alerts are provoked.
Expected result	The security situation indicator turns green again.
Result	Passed. The security situation indicator turned green again (Figure 5.41 and Figure 5.54).
Remarks	The thresholds are configured as described in Table 2.8.

Figure 5.54: The security situation indicator turns back to green

5.5.12 Test case CORE.12: Change from a red to a green security situation indicator

The test case aims to show that a red security situation indicator changes back to green if no or few and not rated as serious types of alerts have been raised in a specific time. It uses the same pre-requisites as CORE.8 and it continued without any further alerts provoked. Table 5.42 summarizes the test and Figure 5.55 shows the result.

Table 5.42: CORE.12 - Change from a red to a green security situation indicator - test summary

CORE.12	Change from a red to a green security situation indicator
Pre-requisites	The test case CORE.8 is executed. No further alerts are provoked.
Expected result	The security situation indicator turns green again.
Result	Passed. The security situation indicator turned green again (Figure 5.49 and Figure 5.55).
Remarks	The thresholds are configured as described in Table 2.8.

Figure 5.55: The security situation indicator turns back from red to green

5.5.13 Test case CORE.13: Change from a red to a yellow to a green security situation indicator

The test case aims to show that a red security situation indicator changes back to yellow or green if no or just a few types of alerts not rated as serious have been raised in a specific time. It uses the same pre-requisites as CORE.9. Table 5.43 summarizes the test and Figure 5.56 shows the result.

Table 5.43: CORE.13 - Change from a red to a yellow to a green security situation indicator - test summary

CORE.13	Change from a red to a yellow to a green security situation indicator
Pre-requisites	The test case CORE.9 is executed. No further conflicts or unauthorized speaker alerts are provoked.
Expected result	The security situation indicator turns first yellow, then green.
Result	Passed. The security situation indicator turned yellow and afterwards green (Figure 5.56).
Remarks	The thresholds are configured as described in Table 2.8.

Figure 5.56: The changes of the security situation indicator visualize a relaxation of the security situation

5.6 Messages to the Correlation Engine

For the validation within WP6, it was decided to use replayed TraMICS events to overcome potential synchronization problems which could appear when running a human-in-the-loop simulation with TraMICS in parallel to the activities of the other tools needed for Scenario #5. The two test cases verifying the recording and the sending to the Correlation Engine are described below.

5.6.1 Test case SYL.1: Verification of message creation and recording

This test aims to verify that the alerts raised in TraMICS are sent in the right format and are correctly recorded. Table 5.44 summarizes the test.

Table 5.44: SYL.1 - Verification of message creation and recording - test summary

SYL.1	Verification of message creation and recording
Pre-requisites	TraMICS is running in the verification environment. The Syslog message destination is set to a local host with a logger running on the configured port. Some alerts are raised in TraMICS.

Expected result	The recording file created by the logger contains the Syslog messages created during the TraMICS test run.
Result	Passed. Syslog messages have been successfully received on the destination host and the recording contains the correct format and description of the alerts raised in TraMICS.
Remarks	The destination of the Syslog messages has been changed to a local host to log the messages in a recording and check the correct format. If the destination host is configured to be the host of SATIE's Correlation Engine, the messages will be sent to the Correlation Engine in real time.

5.6.2 Test case SYL.2: Verification of message reception at the Correlation Engine

This test aims to verify that the recorded data is correctly sent to the Correlation Engine. Table 5.45 summarizes the test.

Table 5.45: SYL.2 - Verification of message reception at the Correlation Engine - test summary

SYL.2	**Verification of message reception at the Correlation Engine**
Pre-requisites	A recording of TraMICS Syslog messages was saved and is started as a replay.
Expected result	The Correlation Engine receives the messages sent out of the DLR premises.
Result	Passed. The messages in the recording have been successfully received at the Correlation Engine.
Remarks	-

5.7 KPI evaluation

The Table 5.46 summarizes the KPIs defined in section 1.4 and the results from the verification.

Table 5.46: Summary of expected and reached KPIs

KPI name	**Expected value**	**Measured value**	**Explanation**
$Time\_until\_security\_situation\_update_{TraMICS}$	1 minute	1 minute	The time was configured (see parameter *P* in Table 2.8).
$Equal\_Error\_Rate_{SpV}$	<4%	3.87%	Different test cases result in different EERs. As SpV.2 conditions are used in the overall TraMICS verification, those values are taken.
$Accuracy_{SD}$	>80%	84%	The stress-level tolerance was set to ΔSt<10.
Non_Compliance_Detection_Rate	95%	100%	The test cases were used to calculate this KPI. Since all tests have been passed, the rate is 100%.

6 Conclusions

Due to the COVID-19 pandemic impact, the partners' strong protection policies for their employees and national restrictions with regards to access to laboratories and facilities, the work needed to be performed differently than planned. SAV had to develop their own stress under speech database and replace the experiments with laboratory tests. Such tests were originally planned to take place physically in the Košice University ATC simulator. At DLR, the focus needed to be changed to a strict verification, using pre-recorded traffic situations as much as possible, as the access to the facilities was restricted, if not forbidden. This increased the testing effort, slowed down development, and prevented also asking ATCOs for their feedback. On the other hand, it showed the need to invent new approaches for achieving the goals by utilising different technologies (e.g. remote work places, VPN based simulation connections, enhanced virtualisation of formerly needed physical actions …). This allowed to phrase the validation questions sufficiently and add them to the validation questionnaires of WP6. The achieved outputs of T4.2 will be assessed in the course of the validations.

Despite those limiting facts, TraMICS is built and verified and reaches all its target values for the KPIs. A new speech-under-stress database was developed within the project and new methods for stress detection and speaker verification were proposed and tested. The TraMICS was enabled to be implemented at apron/ground control positions at airports, while a new method for determining an indicator for the security situation is described.

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