Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

Executive summary

An on-board security system and the interaction with cabin crew

Problem area
When does a passenger become a security threat or a hijacker? What signs can the cabin crew pick up to unmask a hijacker? How can the cabin crew nip a hijack in the bud?
Aviation security has become a key concern in the wake of the attacks of 11 September 2001. Subsequent investigations have highlighted the need to better equip flight deck and cabin personnel. Better security procedures and systems could have helped the crew to handle these situations. The current international political situation suggests that new threats can crop up in the near future. Air transport appears to be a very sensitive target for hijackers and terrorists. New incidents and increasing threats may lead to a large-scale rejection of air transport. This will immediately lead to a new erosion of public confidence with a major effect on travel and aerospace industry world-wide.

Description of work
The leading European companies and institutes joined forces in the innovative project SAFEE (Security of Aircraft in the Future European Environment). SAFEE envisages constructing advanced aircraft security systems designed to assess to on-board threats and to provide a response advice to the flight crew. These systems will improve the security level inside an aircraft by reducing the vulnerability, limiting the impact of hostile actions and enabling the aircraft to return safely to the ground.
The Threat Assessment and Response Management System (TARMS) gathers information from on-board sensors and databases. It determines the on-board threat level and can ask the cabin crew to confirm its assumptions. In case of a suspected on-board security threat the cabin crew members receive an alert AND a recommended response. Such a response could consist of e.g. putting a trolley in the aisle.

Results and conclusions
TARMS is designed to increase on-board security and assist the on-board personnel. Human Machine Interfaces have been designed for the provision of threat information to the crew.
However, in our ongoing activities there is still a lot to learn. How do users combine this task with their current duties? Is it acceptable for the cabin crew to report a threat or unruly passenger to a system instead of a human being? Who is the most effective and reliable in security task: the technology or the human?
Regarding detection of threats, how reliable will the system detect threats in comparison to the user? Is the false alarm rate acceptable low? Are the system-suggested responses practical, and dedicated to the situation or is this a task that humans are much better at?
In the next stage of the project TARMS and its surrounding systems will be validated. The validation of TARMS itself will take place in human in the loop experiments in NLR's research flight simulator GRACE to answer part of the above questions.

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This report is based on a presentation held at the European Aircraft Cabin Safety Symposium, Prague, 7-9 June 2006.

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Summary

When does a passenger become a security threat or a hijacker? What signs can the cabin crew pick up to unmask a hijacker? How can the cabin crew nip a hijack in the bud?

The leading European companies and institutes joined forces in the innovative project SAFEE (Security of Aircraft in the Future European Environment). SAFEE envisages constructing advanced aircraft security systems designed to respond to on-board threats. SAFEE is focussed on implementation of a set of innovative aircraft security systems that will make a significant contribution towards assessment of on-board threats and response to an in-flight terrorist attack. These systems will improve the security and safety level inside an aircraft by reducing the vulnerability, limiting the impact of hostile actions and enabling the aircraft to return safely to the ground.

The security system gathers information from on-board sensors and databases. It determines the on-board threat level and can ask the cabin crew to confirm its assumptions. In case of a suspected on-board security threat the cabin crew members receive an alert AND a recommended response. Such a response could consist of e.g. putting a trolley in the aisle.

During the development of the concept it became clear that the cabin crew should play an important role in the detection of potential security threats in an early stage. It was decided that both detection by technology and by the observation of the cabin crew provide important input to the system.

Contents

Introduction

Air security has become a key concern in the wake of the attacks of 11 September 2001. Subsequent investigations have highlighted the need to better equip flight deck and cabin personnel. Better security procedures and systems could have helped the crew to handle these situations. The current international political situation suggests that new threats can crop up in the near future. Air transport appears to be a very sensitive target for hijackers and terrorists. New incidents and increasing threats may lead to a large-scale rejection of air transport. This will immediately lead to a new erosion of public confidence with a major effect on travel and aerospace industry world-wide.

National and international authorities (including JAA, FAA and European Commission) have taken a set of urgency matters to increase security, both in airports and on-board aircraft. An example of an on-board measure is the cockpit door reinforcement [FAA, 2002]. The on-board measures are useful, but these are still isolated measures. The challenge is now to come to an integrally integrated security system on-board aircraft that creates a safe, convenient, non-intrusive and economical aircraft environment.

The leading European companies and institutes joined forces in the innovative project SAFEE (Security of Aircraft in the Future European Environment)*[1]. Past experience has demonstrated that hostile persons may go through the different airport controls and access an aircraft. SAFEE envisages constructing advanced aircraft security systems designed to respond to on-board threats. Therefore SAFEE investigates and develops technologies and operational concepts aimed at improving security for commercial air travellers, focusing on on-board aircraft systems [Einav & Laviv, 2005].

Protecting an aircraft against hijacking means building up several layers of defence (Figure 1). The first level of defence involves security procedures on the ground – to prevent a dangerous individual to get on the plane in the first place. If that level fails, on-board systems come into play.

[1] EU FP6 Aeronautics Project funded under Directorate H/Transport

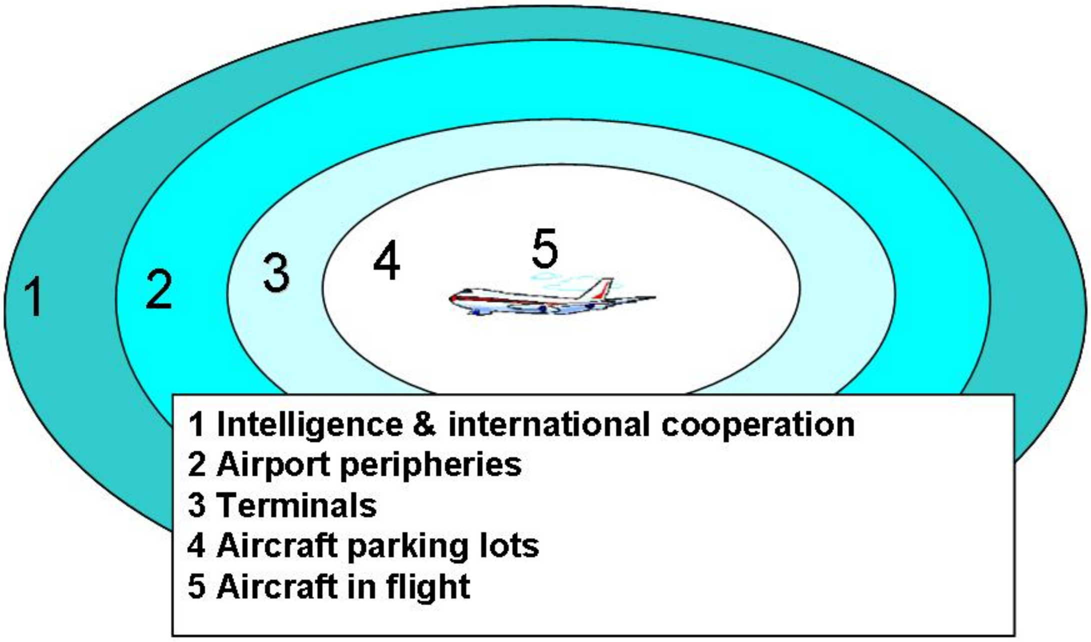

Figure 1: Levels of air transport security

This paper will zoom in on on-board threat assessment and response management. It will present the design of the Threat Assessment and Response Management System (TARMS) with special attention to the user interfaces for the cockpit and cabin crew. The paper will conclude with an approach for the validation and a list of questions we try to answer.

SAFEE approach

Past experience has demonstrated that hostile persons may pass the aircraft security checks and procedures and get access to an aircraft. Therefore there is a need to **secure the aircraft itself** as the last barrier to attacks. The general goal of SAFEE is to develop a set of advanced systems that will make a significant contribution towards the construction of an advanced aircraft security system designed to operate during on-board terrorist threat scenarios. The project is focused on implementation of on-board threat mitigating systems and the provision of reliable threat information to the cockpit crew.

The operational concept of the security system is based on the following principles for the different on-board users:

- **Cockpit Crew -** has a SAFEE modified cockpit and equipment available, communications to ground in normal mode shall be secured, after an attack all the emergency procedures must be applied and be functional,

- **Cabin Crew -** might be the first to detect on-board threats, deals with acts of unlawful interference and to initiate actions,
- **Sky Marshal -** is trained to respond to and handle on-board threats, and to decide how to react in the first minutes of an attack.

Important features of the system under development are described next.
First of all, in case of an on-board threat, there is a need for fast decision making, based on available information. It was decided that TARMS should be a decision support system, meaning that it should help the pilot in making a decision and should not operate autonomously (except under the condition that the pilot is not responding).[2]

Secondly, with the introduction of the security procedures for locking the cockpit door during flight, the cockpit crew can not look into to the cabin to assess the situation themselves.[3] Currently the cockpit crew relies completely on the voice communication with the cabin crew. To the cockpit crew, TARMS should provide a visual information channel with the cabin. With the current state of technology, sensors, cameras and image recognition provide the opportunity to detect potential threats and warn the users.

All threat indications are passed to a central information management system. This system assesses all incoming threat indicators from multiple sources and defines a matching threat level. Apart from this threat level, it generates a list of courses of actions that are feasible, safe and in conformity with the relevant company security policy.

Amongst the counter measures, a function is developed that aims at ensuring a safe flight path in terms of avoiding ground or manmade structure collision. When the cockpit crew is no longer in charge of the aircraft, this autonomous function is activated and commanded by TARMS. When activated it will use information received from the flight systems to calculate the aircraft position and detect potential collision situations. In case of detection of a potential collision this function will automatically initiate a manoeuvre and will control the aircraft to fly to a secure altitude.

A system, as an information carrier of such sensitive information needs to be secured against inadvertent use. As a means to secure the system against unintended users, biometrical authentication is implemented as a side-system of TARMS.

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[2] According to the JAR-OPS the captain is in command. TARMS as a decision ***support*** system keeps the pilot in command.
[3] Some major airlines currently install video systems on-board. These systems provide the cockpit crew with some video pictures of the situation in the cabin.

Dealing with unruly passengers is closely related to cabin security. An unruly passenger may not have intentions of terrorist action but may nevertheless be a threat to safety of the flight or other passengers. In the detection of threats the system will analyse behaviour of passengers and as such may also be able to detect unruly behaviour in an early stage. It was therefore decided that TARMS also facilitates information provision, decision making and reporting of unruly passengers.

One important characteristic of the SAFEE system is its modularity. This allows phased implementation, i.e. some SAFEE subsystems could be installed in the short term while others will be installed in the medium and long term, depending of the acceptability by the stakeholders.

Threat Assessment and Response Management System - TARMS

TARMS aims at providing an adequate analysis of a possible threat scenario and a clear response advice to its users. The users can be airborne or ground staff, depending of the scope of its operational capabilities. Identified users are cockpit and cabin crew. Potentially, sky marshals could also execute their work more efficiently if access to the system would be provided. TARMS was developed without relying on sky marshals and neither is their role in on-board security fully utilised by TARMS.

TARMS plays a central role in the analysis of threat identification since it is of direct influence to the user response. Three successive stages can be distinguished in the information processing by TARMS: information analysis, scenario analysis and response management. All these steps require external knowledge from databases and sensors (Figure 2). The outcome of these stages is communicated to relevant connected systems, to on-board users and in some cases to external actors (e.g. Air Traffic Control or Airline Operations Centre). TARMS can thus be considered as the coordinating component for the interaction between the sensors, the acting systems, the primary users and the external actors.

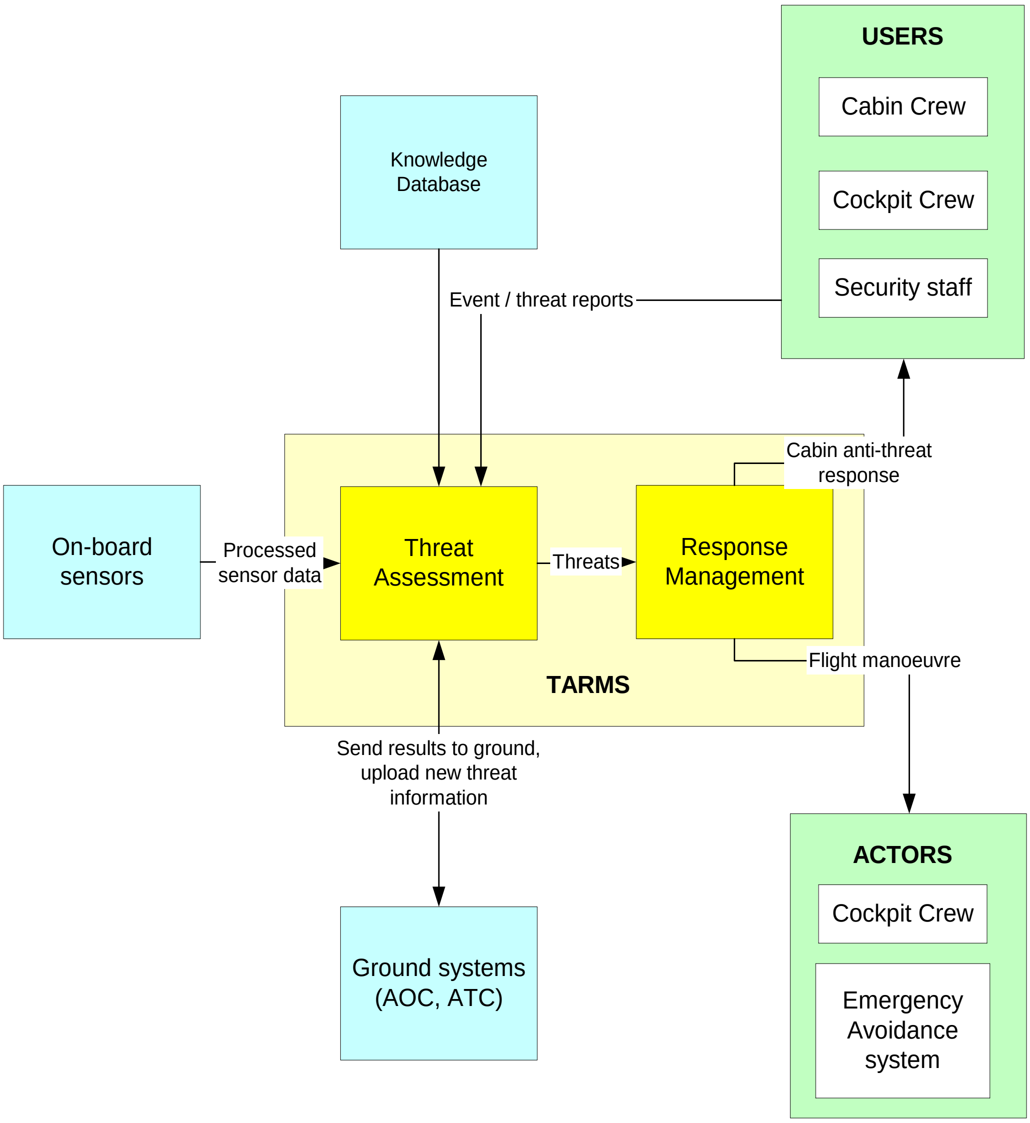

Figure 2: TARMS modules, actors and users

TARMS also receives information and alerts from cockpit crew, cabin crew and on-board security staff. During the development of TARMS, the analysis of hijack scenarios made evident that the cabin crew should play an important role in the detection of potential security threats in an early stage. Cabin crew members may be sensitive to other signals than the technology under development. It was decided that both detection by technology and by the observation of the cabin crew provide input to the system.

Based on this information TARMS will assess the situation and try to discover hidden relationships between the inputs. Therefore it makes use of probabilistic models in the form of Bayesian graph networks derived from static knowledge bases. The flexibility of the Bayesian approach enables models to be built using expert input or learned entirely from data, or from a combination of these methods. The Threat Assessment system is able to accept incoming observations. Based on these observations it provides a statement on the current situation by means of a threat level (i.e. low, medium, high, extreme).

Design of TARMS Human Machine Interface

A human machine interface (HMI) was developed for cockpit crew and cabin crew. The cockpit crew is provided with an electronic system called the electronic flight bag, which will provide them access to TARMS. The cockpit crew HMI is visualised in Figure 3.

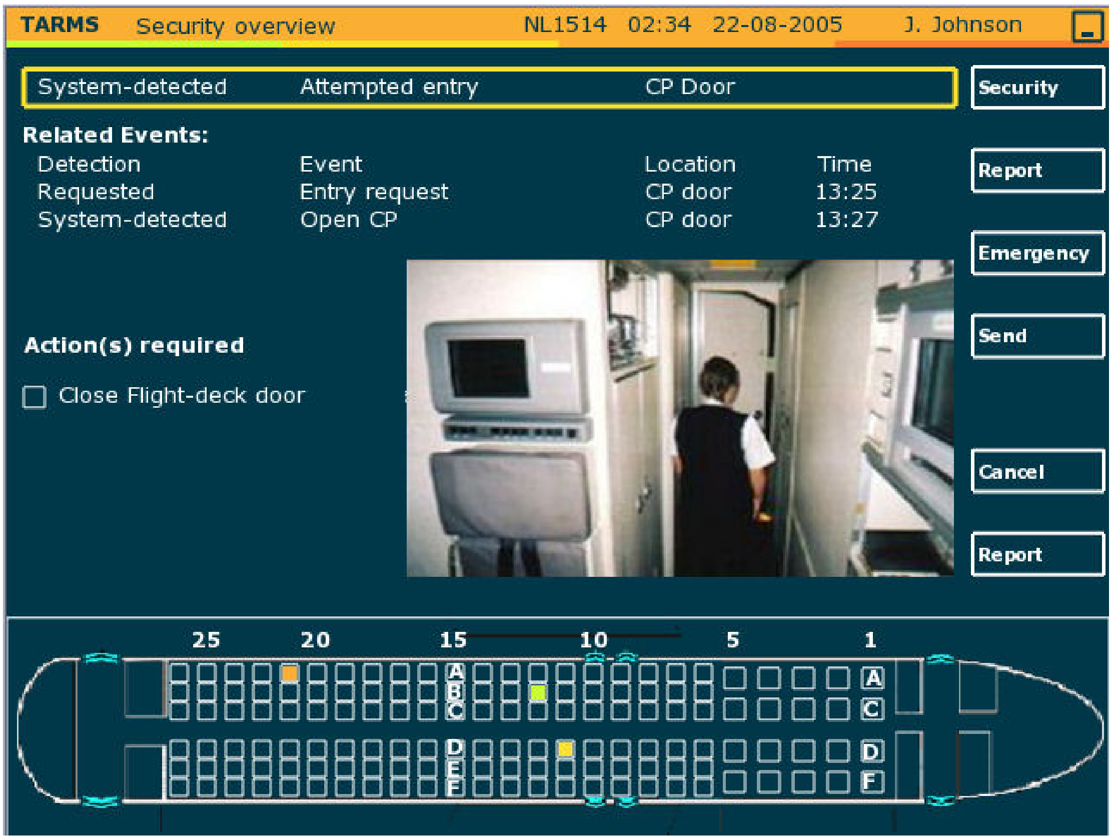

Figure 3: Cockpit crew HMI

The central control panel, which is also used for e.g. climate control, will provide access to the TARMS for cabin crew members. In the galleys of most modern airliner cabins a touch input display is available that contains information and functionality concerning the cabin crew tasks. This was identified as a suitable means for providing the cabin crew access to TARMS. Next to the central control panel the biometrical identification device will be implemented, to avoid inadvertent use. In addition, a small wearable alerting device is suggested. The alerting device is a simple device to alert individual cabin crew members to take action.

The system HMI was designed with three main principles in mind:

1. It is a decision support tool
2. The system displays information to the user adapted to the situation
3. It is a visual support to voice communication

As a decision support tool the system provides suggestions to the user but the user is in control. Only in the unfortunate case that the cockpit crew is not responding the system will activate a function that will autonomously fly the aircraft to a safe altitude, but otherwise the user decides.

When a cabin crew member walks up to the system without prior alert, and wants to access TARMS, he or she will be requested to authenticate. After user authentication the system will display an overview page called ‘security’. The overview page shows ‘Currently there are no threats detected’ when there are no events or threats reported or detected. If a single potential threat is detected, it will display the threat information, a page containing all relevant information and recommended actions to the threat. In case more threats have been detected an overview of threats is displayed. The individual threats can be clicked to review the details of the threat.

Different levels of threats are determined. For categorisation a small number of threat levels are defined in order to ensure that responses will be clearly defined for its users. The threats are colour coded to indicate their level. This threat level is determined by the system, and indicates to the user what is the severity and urgency of the threats. In this respect, it is important to note that the ICAO uses the following categories:

Level 1. Disruptive behaviour
Level 2. Physically abusive behaviour
Level 3. Life threatening behaviour
Level 4. Attempted breach or actual breach of the cockpit crew compartment

Furthermore, the means of detection of a threat (system-detected, user-reported) is displayed in the overview to indicate the certainty of the threat.

When the attendant walks up to the system after receiving an alert the system will show a warning screen with the request to authenticate, after which the relevant threat will be displayed immediately, with links to related information, and recommended actions. TARMS displays the relevant information and options on the basis of the system's interpretation of the information, such as the type of threat and the estimated reliability.

To provide visual support to the user instead of just naming bear facts, the system displays a map of the cabin for the users to be able to indicate and assess where a reported threat is initiated and or passenger seat. Furthermore photographs and video can be displayed as background information to a threat.

Users can report different types of situations: emergencies; unruly and suspicious passenger behaviour; or events. It was decided to include a dedicated button for emergencies, as these inputs are made under time pressure. It should not be the case that an emergency is reported inadvertently, however. Therefore the user is requested to confirm the report of an emergency.[4] After the confirmation the user is able to indicate the type of threat. This step is however not mandatory.

For reporting suspicious and unruly passenger behaviour and events the 'report' function was included (Figure 4). Here all options are displayed on one page, grouped in different categories. The user is also able to indicate where the event is taking place on the cabin map at the bottom of the screen.

A status bar at the top of the screen indicates to the user the navigation path, which is the virtual place in the system where the information displayed is located. The flight number, time, date are displayed and the user that is logged on. This should give the user the awareness that the system is functioning and that it logs information exchange.

[4] Following the JAR-OPS the captain is responsible for declaring an emergency. The emergency reported to the system is not taking this responsibility from the captain. It is still the role of the captain to declare an emergency. The TARMS is providing the captain more information to make a better assessment of the situation on-board.

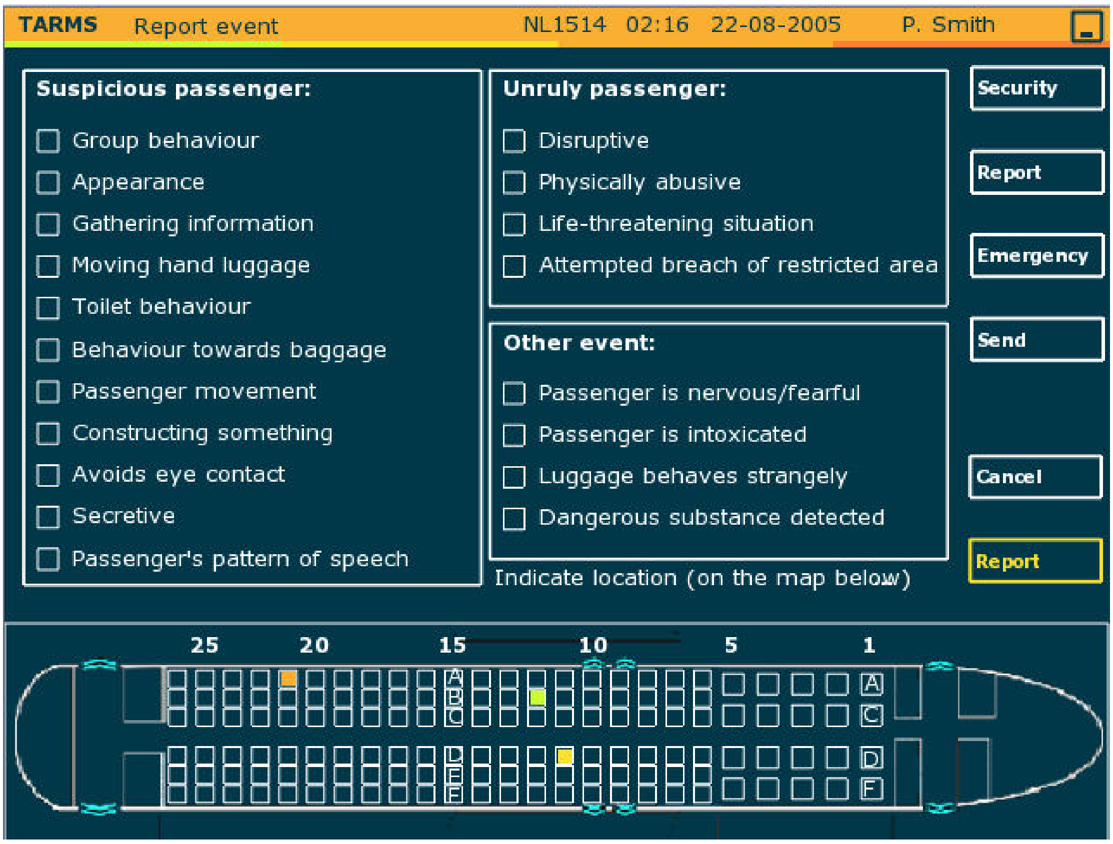

Figure 4: Report event page of TARMS HMI

Future work

TARMS was developed to increase on-board security and assist the on-board personnel. However in our future work -as part of the development project- there is still a lot to learn. Firstly, how do users combine this task with their current duties? Secondly, is it acceptable for the cabin crew to report a threat or unruly passenger to a system instead of a human being? Thirdly, how is the terminal optimally secured against unintended use and still efficient in use? And fourthly, concerning those tasks that can be fulfilled by the technology as well as by the human it will be interesting to see which of the two is most effective.

In its initial use, TARMS may raise false alerts. These will demand cabin crew input into the system to indicate that there is no real threat. This will demand the cabin crew’s attention, which would normally be devoted to normal cabin crew activities. Furthermore, the use of TARMS should be mapped onto the current (security) procedures. If in the current situation a crew member is dealing with an unruly passenger by trying to calm down the person, while a colleague may take up communication with the cockpit crew about this. With TARMS on-board, all relevant users can be informed at once. Each airline has their own security procedures and needs to map TARMS onto them in order to make sure that the use of the system actually aids the user instead of slowing him down. Concerning unruly passenger, is TARMS more efficient than existing reporting systems?

TARMS is secured for usage by unauthorised persons and for unintended use of information. An authentication procedure and cameras are put incorporated in the concept to ensure that only authorised crew members have access to the system. Furthermore, detailed passenger data may be interesting to some cabin crew members for completely different reasons than in case of a threat or unruly behaviour. In TARMS these details can only be accessed when unusual behaviour of the passenger is known to the system. These security measures involve some inefficiency in use. It will have to be evaluated whether these thresholds are acceptable for the users and effective in the meantime. Furthermore, passengers may be able to see the information displayed when the cabin crew member is accessing TARMS. The consequences of this point need to be evaluated whether it is acceptable. A generic economic analysis model of the security systems and measures is set up in support of an economically balanced exploitation.

Regarding detection of threats, how reliable will the system detect threats in comparison to the user? Are the system-suggested responses practical, and dedicated to the situation or is this a task that humans are much better at?

In the next stage of the project TARMS and its surrounding systems will be validated. The validation of TARMS itself will take place in human in the loop experiments in NLR's research flight simulator GRACE to answer part of the above questions.
In parallel to this, the costs of implementation of TARMS need to be evaluated in order to evaluate the feasibility.

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