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UPGRADING AND IMPROVEMENT OF AIRPORT VISUAL AIDS FOR SAFETY AND SECURITY

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SAŽETAK

Safety & Security su pojmovi u zračnom prometu koji povezuju ljude i inteligentne sustave. Pitanje je do koje su razine i u kojim situacijama uključeni ljudi ili inteligentni sustavi. U radu je obrađen primjer multilateracijskog sustava (tehnologija, ljudi i organizacija), na primjeru vođenja i kontrole kretanja zrakoplova na aerodromu. Obrada je provedena kroz istraživanje primjenom Promethee metode. Parametri su razvoj tehnologije koja zamjenjuje čovjeka kao donositelja odluka o sigurnosti zračnog prometa na aerodromu. U frazeologiji zrakoplovstva, "Safety" opisuje tehniku i inteligentne tehnologije, dok je "Security" usmjeren na ljude. Primjenom na zračne luke, njihove veze se razmatraju kroz sučelje čovjek-računalo. Međutim, razvoj tehnologija u funkciji sigurnosti zračnog prometa pokazuje transformaciju sučelja od interakcije, preko integracije do eliminacije. Eliminacija je zamjena, zapravo zaštita čovjeka isključivanjem iz procesa odlučivanja kao rezultat učinkovitosti novih inteligentnih sustava u kojima nema sučelja. Takvi sustavi, budući da su samo prilagodljivi, izravno su uključeni u procese u kojima je zajamčena viša razina sigurnosti bez grešaka. U radu se dokazuje hipoteza da je novotvorenica "Safecurity" u rješavanju problematike zračnog prometa na zračnim lukama nova pozitivna dimenzija umjetne inteligencije koja integrira Safety & Security, za razliku od kaptologije koja je prepoznata kao negativno svojstvo umjetne inteligencije.

Ključne riječi: *sigurnost, zaštita, čovjek, računalo, sučelje*

ABSTRACT

Safety & Security are terms in air traffic that connect humans and intelligent systems. The question is to what level and in what situations are humans or intelligent systems involved. The paper deals with an example of multilateration (technology, people and organization), through a system of guidance and control of aircraft movement using visual aids. The example is related to the research conducted using the Promethee method. The development of technology that replaces humans as a decision-maker on air traffic safety at the airport is being researched. In aviation phraseology, Safety is focused on technique and intelligent technologies, while Security is focused on people. In the current airport application, their connections are considered through the Human-Computer Interface. However, the development of technologies in the function of air traffic safety shows the transformation of Computer-Human, from interaction, through integration to elimination. The replacement is in fact the protection of humans by excluding them from the decision-making process as the outcome of the efficiency of new intelligent systems in which there is no interface. Such systems, being only adaptive, are directly involved in processes in which a higher level of error-free safety is guaranteed. The paper proves the hypothesis that the newly created "Safecurity" in the airport problem is a new positive dimension of artificial intelligence that integrates Safety & Security, in contrast to captology, which is recognized as a negative property of artificial intelligence.

Keywords: *Safety, Security, Human, Computer, Interface*

1. UVOD
1. INTRODUCTION

In the segment of analysis of technical activities and human intelligence using certain methods, (such as the Promethee method), human-computer connections are recognized through communication, interaction or integration. When a person and a computer are subjects in certain circumstances where safety and security are the most important, the question of responsibility arises. The paper presents an overview of research into the operability of new airport visual aids (ten of them are in the legislative procedure), through applied multi-lateral cooperative systems, which in the "preventive mode of operation" provide relevant information essential for safety, and in the "conflict prevention mode" assume a concrete reaction and fully replace humans. An example of potential incident events such as the intrusion of aircraft on the Runway (RWY), of which there were 30 last year at the airport, Aéroport de Paris-*Charles de Gaulle* (CDG), the challenge consisted of determining the responsibilities of the participants in such situations. Therefore, a hypothesis was put forward about the need to differentiate the Safety & Security components in the aviation legislation.

2. ISTRAŽIVANJA SIGURNOSTI ZRAČNIH LUKA
2. AIRPORT SAFETY AND SECURITY RESARCHES

2.1. ZAKONODAVSTVO I PRAKSA
2.1. LEGISLATION AND PRACTICE

Airport security through continuous improvements by upgrading and improving visual aids is defined by guidelines and specifications in [1], which include "normative" language that indicates the requirements, which must be met in order to achieve compliance with legislation that does not stipulate the specification of Safety & Security conditions. In the aviation legislation, the requirements differ:

• MUST – indicates what is mandatory or necessary.

• SHOULD – indicates what is recommended.

• MAY – indicates what is not mandatory but allowed.

The above requirements are used for narrative purposes and are preceded by structured typed identifiers, for connecting documents and application tools. The upgrade and improvement based on the example of the practice of airport visual aids, [2-3] is based on technological development that goes through: Phase 1: interactive connections with intelligent technologies, (*Intelligent Human Systems* - IHS), *Human Intelligent Systems* - HIS, and *Human Intelligence Systems* - HIcS), as *Human-Computer Interaction* -HCIa, [4], Phase 2: integration of humans and intelligent technologies, (*Human Computer Integration* - HCIg) which is based on the use of algorithms with the principles of human thought and intelligence, and Phase 3: replacing humans with their exception in the decision-making process due to better efficiency of technique and technology. The exemption of humans, as an example of the multilateration process, is a positive effect of intelligent technology in contrast to its negative property of captology, [5-7].

The development of technique and technology for airport visual aids is used more and more in the design and creation of effective intelligent systems in the function of air traffic safety. For these reasons, this paper tries to point out the need for more precise specification of Safety & Security conditions for the "Must", "Should" and "May".

2.2. PROMETHEE METODA ZA OBRADU VIZUALNIH POMAGALA AERODROMA KROZ OPERABILNOST I SIGURNOST
2.2. PROMETHEE METHOD FOR PROCESSING AIRPORT VISUAL AIDS THROUGH OPERABILITY AND SAFETY

For paradigms of the effectiveness of airport visual aids, analyses and syntheses were carried out in the context of multi-criteria validation, using the Promethee method, [8]. These engineering, mathematical and statistical tools are used for research and graduation theses at the Electrical Engineering Department of the Zagreb

University of Applied Sciences and have been confirmed on the basis of empirical foundations in the scenarios of this work. The set weighting factors for processing: man - technology - Safety & Security, took into account:

• Similarity or difference of criteria,

• Criteria conflicting with each other,

• Strength of conflict situations essential for resolution and

• Influence of the weighting factors of individual criteria.

Multidimensional representations of conditions, in which visual aids were connected to their criteria, representatively, (50 processings) are a confirmation of the connection of the observed entities responsible for the safety of air traffic at the airport, namely:

- The pilot who controls the aircraft,
- The controller on the Tower (*Tower* -TWR) who coordinates air traffic, and
- The employee of the ground protection and maintenance service.

Since some criteria influence each other, they are directly related to features, which can be weak or strong, and depend on the location where the process takes place. Based on the aforementioned processing, the visual means were confirmed through operability and their function in decision-making and assessment of Safety & Security, (table 1).

***Tablica 1** Ljudi/Tehnika – Procjena/Obrada*

***Table 1** Human/Techniq – Assessment/Processing*

	CONDITIONS	FEATURES	LOCATIONS
HUMAN Security	AFFECTED	Assessment	RWY &TWY TWR
TECHNIQUE Safety	WITHOUT IMPACT	Processing	NO LIMITS

2.3. VIZUALNA POMAGALA AERODROMA U SUSTAVIMA MULTILATERACIJE

2.3. AIRPORT VISUAL AIDS IN MULTILATERATION SYSTEMS

In the context of airport visual aids, the application multilateration system, (*Advanced Surface Movement Guidance & Control System* – ASMGCS), was chosen. It is an operational service that enables directing, guiding, monitoring and controlling aircrafts and vehicles in order to maintain the declared speed of surface movement in all weather conditions within the operational visibility level of the airport. Multilateration system (*Multilateration* - MLat) is a cooperative system consisting of technologies, people and procedures. Application in aviation is a form of communication with the air traffic management system (*Air Traffic Management* - ATM).

This surveillance system reliably determines the position of the aircraft with its data that it processes and exchanges as identification without sending a query signal to the aircraft. The four levels of implementation for A-SMGCS are defined by legislation, [9-11]:

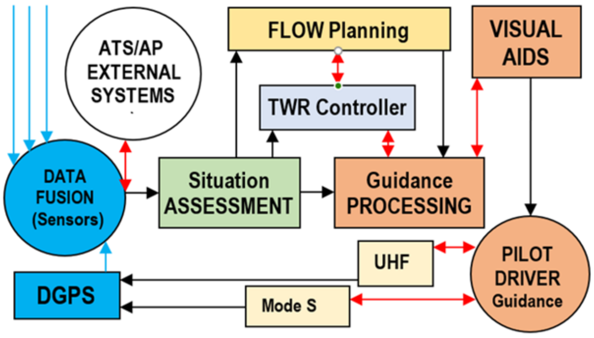
Level 1: Surveillance has been improved with procedures covering vehicles and the area of aircraft movement on manoeuvre surfaces where visual aids are located. Procedures are related to identification, providing information on position and identity with generation of instructions and approval to controllers at TWR.

Level 2: Surveillance is in addition to safety nets to supplement protection, (among other things, visual aids), on airport maneuvering areas. Procedures have been supplemented with the issuing of warnings to controllers in the event of any collisions between vehicles on the RWY, and *Aircraft* -AC, intrusion into restricted areas.

Level 3: Reveals conflicting situations in the field of movement. Procedures are better guided and planned by controllers using visual means of movement of aircraft and vehicles.

Level 4: The level resolves conflicts, automatically plans, directs and offers guidance solutions for all critical situations in which aircraft may find themselves.

The collected data is integrated with application algorithms for the detection of potentially dangerous collisions, and the alarm function provides visual and audible warnings to the controllers about potential conflicts, such as the intrusion of an AC onto the RWY. The architecture of the A-SMGCS Services example is shown in Figure 1.



Slika 1 *Arhitektura A-SMGCS usluge, (Napredni sustav za vođenje i kontrolu kretanja)*

Figure 1 *Architecture A-SMGCS Services, (Advanced Surface Movement Guidance & Control System)*

In the presented architecture of A-SMGCS Services, visual aids are in a one-way direct connection to the participants of a potentially conflicting situation (a pilot in an aircraft or an operator in a maintenance vehicle), which can be a threat to air traffic at the airport. For this reason, it was necessary to additionally consider the levels of operability based on the movement (guidance) parameters.

2.4. ANALIZA VIZUALNIH POMAGALA ZA OPERATIVNU SIGURNOST

2.4. ANALYSIS OF VISUAL AIDS FOR OPERATIONAL SAFETY

On the basis of the research carried out using the generic process developed in [12], the basic methodology for assessing and evaluating the need for visual aids has been set. Processing included:

a) Operational context,

b) Operational scenarios, and

c) Threat barriers,

in order to prevent or mitigate the potential effects of an unwanted event. Assessment and evaluation in examples of processing airport visual aids was carried out through projects for airports in Croatia, BiH and Montenegro, [13]. Factors of the operational context of visual aids by including a combination of parameters according to the publication in the aviation legislation, were expanded to: 1. flight controller training, 2. aircraft performance, 3. training and method of maintenance of visual aids, 4. behaviour in accident situations, 5. alarm and signalling warnings, 6. human-machine interfaces. The processing of operational scenarios included mechanisms: detection, interpretation, decision-making and execution. Analysis of specific operational situations was used to identify and review potential risks (examples of aircraft landing on an occupied RWY). Based on these processes, the differences between the potential events in which the aircraft can be found on the manoeuvre surfaces are systematized. Through the implementation of A-SMGCS, the activations of intelligent systems and the reactions of the participants were monitored, (table 2).

Tablica 2 *Operacije za smanjenje upada na pistu*

Table 2 *Runway Incursions Reduction Operations*

No	Operations – Participants, (Locations)	
	Operations on airport manoeuvre surfaces	**Visual notification**
1	Surveillance – IS[a]/AI[b], RWY[c], TXY[d]	INFORMATION
2	Guidance – AC[e]+Pilot IS→(TXY)	WARNING
3	Control – TWR[f] +Controller →(TXY)	CONFLICT
4	Routing - IS→AC→TWR (RWY,TXY)	CONFLICT
5	Monitoring - IS→ (RWY,TXY)	ALARM
6	Situation Assessment - IS→for ALL	SOLUTION
7	Conflict Handling- IS→ for ALL	EXECUTION

a. IS=Intelligent System; b. AI=Artificial Intelligence; c. RWY= RunWaY; d. TXY = TaXiwaY e. AC= AirCraft+Pilot; f. TWR= ToWeR+Controller;

For all processed situations from examples of airport projects, the need to review all newer visual aids resulting from the development of techniques and technology in the function of air traffic safety at airports was imposed, (Table 3).

Tablica 3 Operacije za smanjenje upada na pistu

Table 3 Runway Incursions Reduction Lights

No	Airport Lighting Systems (Additional) Visual Aids - Entity	Acronym
1	Runway Center Line Lights	RCLL
2	Taxiway Center Line Lights	TCLL
3	Stop Bar Lights	STBL
4	Runway Guard Lights	RGL
5	Runway End Identifier Lights	REIL
6	Runway Status Lights	RWSL
7	Extended Runway Status Lights	ERWSL
8	Runway Entrance Lights	REL
9	Final Approach Runway Occupancy Signal	FAROS
10	Take-off Hold Lights	THL
11	Runway Intersection Lights	RILs
12	Runway Holding Point Lighting	RHPL
13	Taxiway Lead-On Light Configuration	TXLOL
14	Short Term Conflict Alert	STCA
15	Autonomous Runway Incursion Warning System	ARIWS
16	Variable Message Sign	VMS

Seven categories of conditions in which an aircraft can be found on manoeuvring surfaces tend to a potential incident that can be a threat to safety. The action of subjects responsible for air traffic safety at the airport, Figure 1, is a two-way relationship subject to the process of superiority within a system that includes people, technology, and infrastructure.

In the modelled processing of the Promethee method, the entities of the example of the processed cooperative system at the airport in traffic are vehicles on maintenance of visual aids and aircraft that can be found on manoeuvring surfaces. Wireless communication, monitoring and management takes place between them through multiple sensor networks on the infrastructure on which they are located. For the creation and function of their cooperation through computer applications, common properties are taken into account, which include: a) more than one entity, b) the entity is required to make decisions, c) the entities share at least one common goal, and d) the entities can share information "active or passive". All potential "visual aids" entities were synthesized on these bases, as in the example of the A-SMGCS architecture. The test development analysis and the introduction into operable condition with legislative requirements, of certain visual aids as part of the safety system, is based on research experiences conducted by the US *Federal Aviation Administration* - FAA, [14]. Since 1997, multi-year tests on the *Runway Guard Lights* - RGL system at American airports began. RGL as a visual aid, although not automatic, soon became mandatory for all airports. Based on the confirmed empirical basis of the application of the RGL system, further research was conducted and other possibilities of application of certain improved light aids, better than the initial ones, were analysed, (table 4).

Tablica 4 Učinkovitost zaštitnih svjetala upada na pistu

Table 4 Efficiency Runway Guard Lights

Visual Aids RGL Research	Signs with lighting	Runway guard lights - elevated	Runway guard lights - inset	Lights Caution zone „T“- RGL
Efficiency (%)	26	70	2	2

For its legislative imperative application, the implemented empirical methodology was authoritative, which was confirmed by the final research in a continuous monitoring during 9 months at two American airports with very intensive traffic.

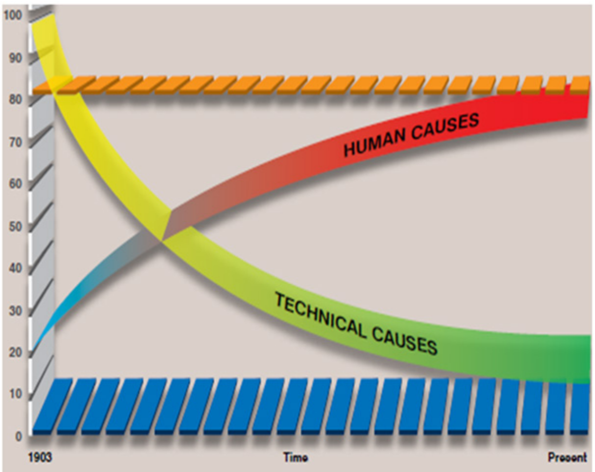
The average of the results obtained from 42 independent subjects directly involved in the procedures was confirmed with 97%. The development of the RGL system was based on the monitoring of its four configurations, which were intended to warn participants on the manoeuvring surfaces of the approach to the runway in different external visibility conditions, day, night, dawn and sunset.

Improvements are based on the introduction of automatic functioning and monitoring of operability through maintenance. The reliability of certain lighting system is modelled by set formulas with maintenance parameters of each unit light source. The legislative requirement of the light intensity of each unit source was confirmed by the original work, [15-16].

3. PRIMJERI NOVIH SUSTAVA SIGURNOSNIH SUSTAVA RASVJETE AERODROMA

3. PARADIGMS OF NEW AERODROME SAFETY LIGHTING SYSTEMS

The research carried out in the application of the mentioned entity "visual aids" obtained confirmatory results because the reliability and technical aspect of the equipment today with less than 10% of failures is different from incident situations in which a human is to blame for 80% of cases, [17-18] (Figure 2).



Slika 2 *Postotak tehničkih kvarova i ljudskih pogrešaka u sustavima sigurnosti zračnog prometa, [18]*

Figure 2 *Percentage of technical failures and human errors in air traffic safety systems, [18]*

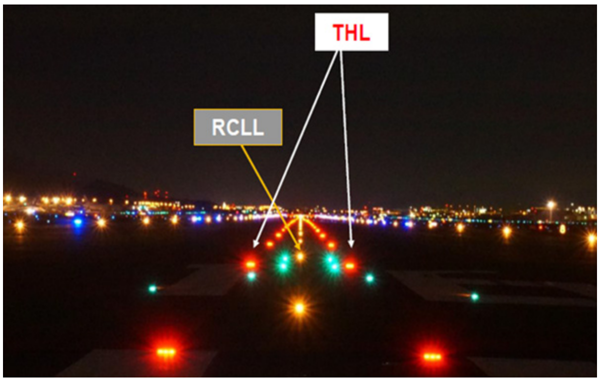
It was these realizations that were crucial for air traffic safety at airports to start relying on technology and intelligent systems. Three paradigms of fully autonomous automatic light aids are listed.

The first paradigm, the Runaway status lights system, (*Runway Status Lights* – RWSL), was confirmed. During running-in and exploitation, the system was improved and as "Extended" - ERWSL uses new light aids installed in the manoeuvring areas of the airport, (*Runway Entrance Lights* – REL) (figure 3), and (*Take-off Hold Lights* - THL) (figure 4).

The system is fully automatic and directly warns pilots and vehicle operators of danger if they continue moving towards the area where the system is installed.

Slika 3 *Nova ulazna svjetla na pistu – REL, Zračna luka Osaka, (2016.), [19]*

Figure 3 *New Runway Entrance Lights – REL, at Osaka Int. Airport, (2016), [19]*



Slika 4 *Nova svjetla čekanja za polijetanje - THL u Zračna luka Fukuoka, (2015.), [19]*

Figure 4 *New Take-off Hold Lights - THL at Airport Fukuoka, (2015), [19]*

ERWSL systems fully automatically include warnings to the pilot of the aircraft in several stages: 1. entry to the runway, 2. start of take-off and 3. taxiing on manoeuvre surfaces. The applied set of technologies automatically processes data obtained in real time from a multi-sensor monitoring network and substitutes multilateration. The systems have been installed and are in operation at several airports in America and Japan. According to the recommendations of the FAA, the precondition for releasing into traffic is that certain pilot and controller training criteria are met.

The introduction of the system initially from 2011 lasted 5-8 years. Today, such systems are put into full operation within a year. The efficiency results were confirmed by a survey conducted among American controllers who only supervise the operation of the operational RWSL. 86% of them confirmed that the system improved safety at the airport where it was installed, [19].

The second paradigm is the improved system, (*Precision Approach Path Indicator* – PAPI), [20]. The system is represented by four units of flight path indicators for precision approach of the aircraft, which are installed on the left side of the RWY and serve the pilots for a safe visual landing. The upgrade of this system to the FAROS system is intended to warn pilots who are in the process of landing at the airport of potential danger. The FAROS system confirms to the pilot the correct glide angle with the continuous, (permanent) light intensity of its lights. The added automation activates the flashing intensity because the system evaluates the situations of an unwanted event when the RWY on which the aircraft is to land in the approach is occupied. This system is also activated fully automatically for aircraft approaching the RWY and at a distance of 1.5 nm. Their blinking is a signal to the pilots to abort the landing, (Figure 5).

Slika 5 *Sustav FAROS = bljeskajući PAPI, [20]*

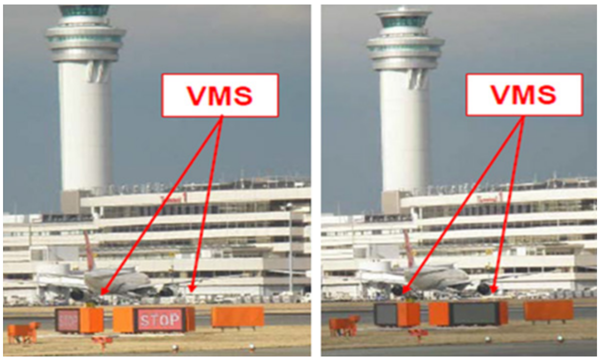
Figure 5 *FAROS System = Flashing PAPI, [20]*

The third paradigm is the latest LED technology of variable information signs that are placed along the taxiways, called the VMS - (Variable Message Sign) system, (Figure 6).

Slika 6 *Promjenjivi znak poruke LED tehnologije, [19]*

Figure 6 *LED Technology Variable Message Sign, [19]*

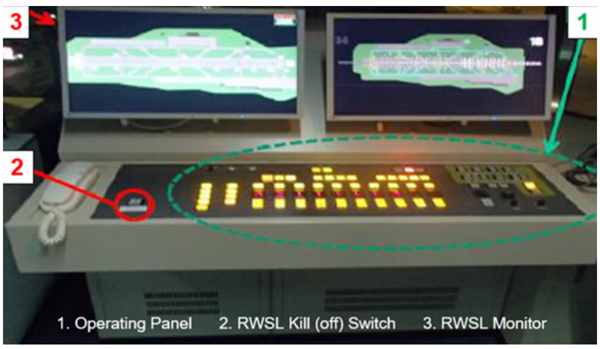
According to the described architecture of A-SMGCS Services, it is a part of the "Visual Aids" equipment for which the unified data of the sensors of the surrounding structure is obtained and forwarded. The movement and guidance of an aircraft or a vehicle on the surrounding manoeuvring surfaces is managed completely automatically without the possibility of influence by the controller on the tower. For the pilot in the aircraft, this operation is a clear one-way command of the visual aid, which in case of danger displays an unmistakable command to stop. When the RWY is free, the aircraft taxis towards it without stopping because there is no more stop command "STOP" on the display sign, (figure 7).



Slika 7 *Znak s promjenjivom porukom u međunarodnoj zračnoj luci Tokio, (lijevo – osvijetljen, desno – ugašen), 2012., [19]*

Figure 7 *Variable Message Sign at Tokyio International Airport, (Left – illuminated, Right - extinguished), 2012, [19]*

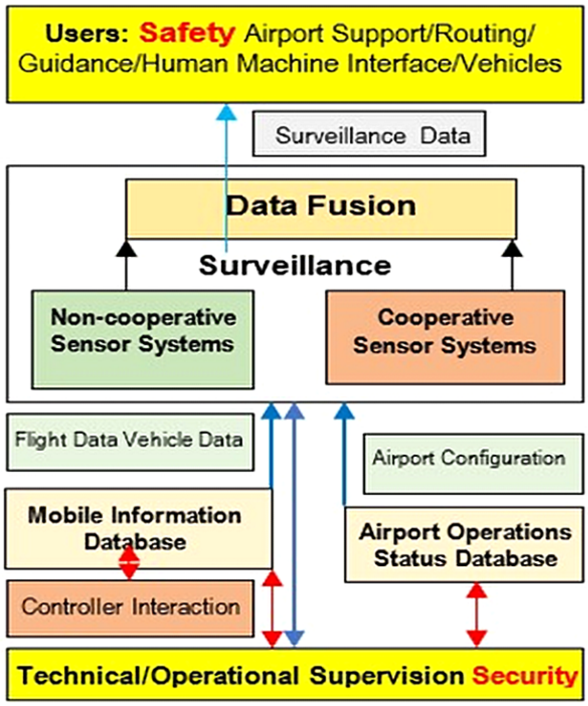
The continued movement of the aircraft to the very entrance onto RWY is enabled by the green TCLL lights, and according to this the decision to exit is confirmed by the extinguished THL lights. The controller on the tower has an insight into the operability of the system through the operation panel, (figure 8).



Slika 8 *ATC toranj u zračnoj luci Fukuoka, 2015., [19]*

Figure 8 *ATC Tower at Airport Fukuoka, 2015, [19]*

The only operation allowed to the controller is to turn off the entire system, for which he has the RWSL, Kill (off) switch at his disposal. It is not possible to restart the system from the TWR. The displays on the screen are only information about lights that can be turned on or off. The system does not have the possibility or the need to display malfunctions because it fulfils the technical safety component - "*safety*" by itself. From the aspect of maintenance, each light unit is monitored in the airport maintenance service centre, where its condition parameters are displayed (place of installation, light intensity and hours of operation). The communication between the controller on the tower and the pilot in the aircraft that is preparing for take-off is supervised by a multi-lateration system that proves the "*security*" property. The approval or prohibition so issued is an order for the controller. If the pilot requests confirmation of the free exit status, the controller will cancel the previous approval based on the system prohibition and confirm the actual status.
The entire scenario is developed according to aviation legislation based on the (*Operating Procedure* - OP), [21-22]. It is a basic operating procedure that is carried out with the aim of avoiding the risk of human error and in it the "*security*" component is confirmed due to the unification of data used to make decisions. For example, when the controller issues a clearance and the RWSL system is engaged, appropriate communication must be established between the controller and the pilot or vehicle operator who may also be on the manoeuvre surface. Solving the mismatch between the permissions issued by the controller and the RWSL system rests on the "*safety*" component. This property manifests itself as multilateration through a system that is completely reliable and secure and superior to the operator with the "*security*" property. The exchange of unified data from the movement surface and from databases on the status of operations according to the airport configuration are the key elements of the movement monitoring architecture on manoeuvring surfaces, for the purpose of integration into the airport environment (Figure 9). This example can confirm the hypothesis set about the integration of components "safety" and "security".



Slika 9 *Arhitektura usluge nadzora, [11]*

Figure 9 *Surveillance Service Architecture, [11]*

5. ZAKLJUČAK
5. CONCLUSION

Conducted research in the context of aviation terminology *Safety* and *Security* through the improvement of technical solutions in concrete examples of visual airport aids, proves the evaluation of the *Human/Computer* relationship. Using intelligent technologies, man has very quickly moved from the initial one-way, a) information communication to, b) interactivity. The value of databases that were created using intelligent systems as an opportunity to generate knowledge has raised the level to, c) integration. The integration of man and technology with the development of computers and the availability of the Internet is evolving in two directions. In one direction, the dominance of captology can be recognized as a phase in which technology enticingly binds man to itself, and in the other direction, technology without failure replaces the intellectual actions of man. In specific examples regarding air traffic safety, the terminology *Safety* and *Security* is used. In the conducted modelling, it is concluded on the positive effect of *Computer-Human* in the sense of human saving, which is confirmed by the fact that in risky situations, an intelligent system makes a decision instead of a human. In the conducted research and analysis using the Promethee method, it was confirmed that instead of a human who evaluates in the context of air traffic safety at the airport, taking into account conditions and location, the system for such cases undoubtedly makes a decision on action. Therefore, it is proposed that in such automatic procedures the previous aviation terminology *Safety* and *Security* be integrated and used as "*SafeCurity*".

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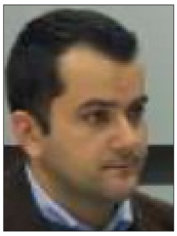

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