# Operationalization of Norms in the SKY-Scanner Decision Support System for Aircraft Approach and Departure*


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*The paper presents the SKY-Scanner DSS – a real-time decision support system for air traffic controllers. The system is based on the use of laser for aircraft tracking and assists the controllers in aircraft landing and takeoff. Decision support is based on the normative regulations that are currently applied to aircraft trajectories. The conformance alerting method is chosen. The SKY-Scanner DSS checks norm adherence and reports results in terms of violation risk. The focus of the paper is on representing norms in the system (operationalization). It is suggested to represent the norms for aircraft trajectories as risk definitions in the SKY-Scanner DSS. There are two types of norms – limit-based and deviation-based. A norm violation risk model tailored to the objectives of the SKY-Scanner DSS is defined. Norm violation risk is characterized by the risk factor (attribute of the aircraft trajectory), risk type, norm pattern, expected value and a set of thresholds. Risk evaluation maps the observed factor value into a discrete risk level. The presented examples use the traffic-light levels: green–yellow–red.*


## Introduction

In the paper, we present an ongoing work on the operationalization of norms and norm violation risk conceptualization in the prototype decision support system for aircraft approach and departure. The work is conducted within the EU FP6 SKY-Scanner project. This project aims at developing a novel laser-based system to detect and track aircraft up to at least six nautical miles (NM) from the aerodrome traffic zone (ATZ) barycentre (Salerno et al., 2008). The SKY-Scanner project is performed in line with the Single European Sky Air traffic management Research (SESAR) programme. The SKY-Scanner work on automation support for controllers, including conflict detection and resolution, supports the SESAR D3 Target Concept (Crispino, Greco, 2007).

Current air traffic control (ATC) systems based on primary radars hardly distinguish aircraft targets and background clutter at a low altitude. In most cases, in the ATZ, radars cannot determine the height to the needed accuracy. In the SKY-Scanner project, it has been proposed to use the lidar (laser radar, LIght Detection And Ranging) for the aircraft detection and tracking. Lidar is installed on ground and, unlike other surveillance systems (such as secondary surveillance radar or automatic dependent surveillance broadcast), does not require additional equipment to be installed on the aircraft. The lidar is more precise than the primary radar when directed to the target. An approximate position recei-

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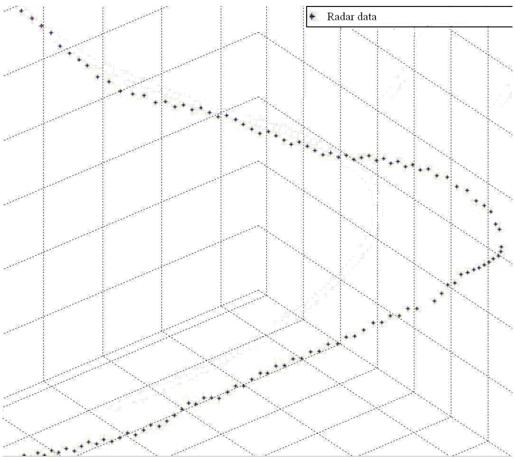
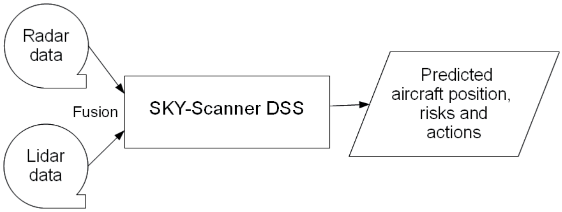
ved from the radar can help direct the lidar. When the target is found, the lidar switches to the tracking mode and provides the exact target position for the SKY-Scanner system (Lapin, 2010).

The work package of the Vilnius University encompasses the design and development of the decision support system (the SKY-Scanner DSS) for air traffic controllers. Air traffic control (ATC) is a service provided by the ground-based controllers for the purpose of preventing collisions and maintaining an orderly flow of traffic (Procedures – Air Traffic Management, 2007, Chapter 1). The overall aim of the SKY-Scanner DSS is to improve the controller's situational awareness by providing the adjusted aircraft position and evaluating risks for the aircraft. The requirement of the project is to render threatening classification in terms of accident potential risk for each tracked aircraft (SKY-Scanner D1…, 2007).

The SKY-Scanner DSS is based on lidar and radar data fusion. The system receives radar and lidar measurements in real time as a series of aircraft position coordinates (x, y, and z) and other parameters (e.g., speed) at a given moment (Fig. 1). Lidar and radar data are fused in order to evaluate the risk and to propose corrective actions to the controller (Fig. 2).

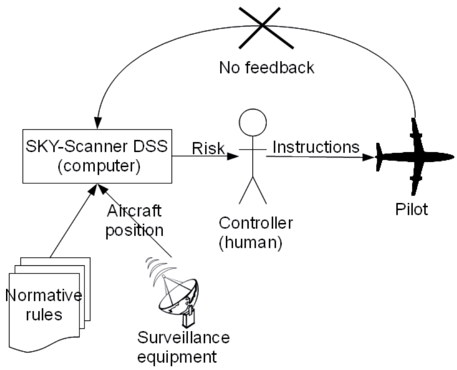



*F i g. 1.* ***Example of aircraft position coordinates received by the SKY-Scanner DSS***




*F i g. 2.* ***The SKY-Scanner DSS functions***

The movement of the aircraft in the ATZ is regulated by the normative rules defined in various flight rule documents and procedures (e.g., Procedures – Air Traffic Management, 2007). The air traffic controller has to ensure that aircraft follow these regulations. Thus, the SKY-Scanner DSS has to facilitate the controller in evaluating and resolving issues related to the norm adherence. Currently, three problem areas are addressed: (1) aircraft trajectories (collision risk, path violation), (2) wake turbulence avoidance, and (3) avoidance of dangerous substances in the atmosphere. Each of these areas has a respective set of normative rules. In the SKY-Scanner project, these norms are explored to determine the decision support opportunities created by the use of the lidar. If the precise aircraft position data from the lidar enable the SKY-Scanner DSS to check that the rule is followed, it should be checked and reported to the controller. As a result, a set of indicators is created. Each indicator shows the risk of violating an individual normative rule.




*F i g. 3.* ***The role of the SKY-Scanner DSS in the ATC context***

The SKY-Scanner DSS presents its results to the air traffic controller and not to the pilot. The controller then takes the final decision on what instructions to give to the pilot. There is no feedback loop from the pilot to the SKY-Scanner DSS (Fig. 3). This assumption accords with the SESAR ATM Concept, which states that humans should constitute the core of the future ATM operations (The ATM Target Concept, 2007). So, the main focus should be detecting possible violations and informing the controller.

This paper is focused on the operationalization of norms in the SKY-Scanner DSS. The goal is to transform the norms that are usually presented in human-readable form (such as maps, tables or textual descriptions) into the decision support system in such a way as to facilitate the evaluation of norm violation risk. The contribution of this paper is the suggested norm violation risk model tailored to the objectives of the approach and departure decision support. The novelty of this work is, first, the use of precise aircraft position data to check adherence to the fine-grained approach and departure norms. This is not possible using only radar data. Second, it treats the approach and departure norms comprehensively. The existing aviation-related decision support systems typically concentrate on an individual task and do not distinguish the applied norms from the other system parameters. The perspective we introduce in the SKY-Scanner DSS aims to explicitly represent a set of norms in the system.

The next section describes the selection of the decision support method. Then the norms for the aircraft trajectories in the approach and departure phases of flight are reviewed and norm patterns are defined. An overview of the relevant risk management terminology is presented. Finally, a risk definition model is suggested with respect to the different norm patterns.

## Decision Support Method

There are two decision-making models – analytical and naturalistic (Ogilvie, Fabian, 1998). The analytical model is objective but requires calculating the utility of each alternative, whereas the naturalistic model highlights the need to provide the human with relevant information. Avoiding unnecessary details facilitates the information encoding process. The naturalistic model is more suitable for real-time environments.

The objective of the SKY-Scanner DSS is to facilitate the controller in making a decision. The naturalistic model suggests that the system has to filter out the most important information, avoiding unnecessary details. Therefore, the emphasis is on helping to quickly detect problems by alerting about detected violation or violation risk. There are three fundamental methods for designing a system to predict and alert on the conflicts (conflicts in a broad sense – in this case it could be conflicts with the rules): termed conformance, nominal trajectory, and escape trajectory.

In the *conformance* method, alerts are considered justified when the aircraft does not follow the expected behaviour. More formally, a boundary of acceptable operating states is defined beforehand, and an alert is issued when the state of the aircraft exits this boundary. The boundary should enclose a large enough region to ensure that false alarms during a normal approach (due to typical dynamic oscillations) are unlikely; it should be also small enough so as not to lay too close to hazards. This method is relatively simple in that it relies only on the current state, so future trajectory predictions are not required. Conformance methods would be more appropriate for parallel approach problems in which normal aircraft positions can be readily identified, rather than for general free flight conflict detection systems in which the aircraft could be located anywhere and be going in any direction (Kuchar, 2001).

In the *nominal trajectory* method, the state of the process is projected into the future, using some form of the trajectory model. The projection is used to determine whether a hazard is explicitly expected to be encountered if the current control strategy continues. Should it become likely that a hazard will be encountered, an alert is then issued. This method is used in many collision-alerting systems. The alerts are issued only when they are necessary to avoid a hazard. If the future trajectory does not encounter a hazard, an alert is not issued. The accuracy of trajectory prediction generally degrades into the future, so some cut-off or maximum look-ahead time is typically required to avoid nuisance alarms (Kuchar, 2001).

The third design method is to issue an alert when the *expected escape path* is threatened by a hazard. This method extrapolates a trajectory from the current state into the future, but based on the assumption that an alert is issued and a corrective action is taken. Conditions for a safe escape need to be defined, and the escape path is examined to determine whether those escape conditions are reachable. If the escape conditions are not reachable at some level of confidence, then an alert is issued. It may be the case that the alert, although successful in avoiding the hazard, is not necessary. This is because there may be no hazard along the nominal trajectory, even though the escape path is threatened (Kuchar, 2001).

In a simulation experiment (Kuchar, 2001), the quality of decision-making for the conformance method was compared against the nominal trajectory method as a function of the predictability of the trajectory. Two types of trajectories were used – those of low uncertainty, i.e. predictable (called "high correlation"), and of high uncertainty (called "low correlation"). A total of 5000 simulations were performed at each combination of threshold setting, alerting method, and trajectory correlation level.

In the high correlation (predictable trajectories) case, the trajectory prediction method performs very well with respect to the rate of successful alerts versus the rate of unnecessary alerts. The conformance method is not able to reach the same level of performance and incurs a higher rate of unnecessary alerts (Kuchar, 2001).

In the low-correlation case (not predictable trajectories), the trajectory prediction method performs poorly; a high level of successful alert can only be attained while also incurring a high rate of unnecessary alert. The system is of little diagnostic benefit. The conformance method, however, is able to perform better than the nominal trajectory method in this case. Although the performance of both methods is poorer than in the high-correlation case, the point is that a better decision can be made based on the current state (via the conformance boundary) than when relying on inaccurate trajectory information (Kuchar, 2001).

Aircraft follow the predefined paths in the ATZ (SKY-Scanner D1…, 2007), so the prediction method would be more suitable. However, the conformance method was chosen as the initial method for the SKY-Scanner DSS prototypes, as it is simpler and aligns well with the requirement to control the norm adherence. The subsequent prototypes should incorporate the prediction.

## Conceptualization of Aircraft Approach and Departure Norms

In this section, we review the norms that are relevant to the DSS. The SKY-Scanner system tracks the aircraft with a range of 6 NM from the ATZ barycentre. The area under concern constitutes a small part of the terminal airspace. The final approach segment, in which the alignment and descent for landing are accomplished, cannot be longer than 10 NM (Procedures – Operations – Volume II, 2006, Section 2.6.2). So, most of the aircraft in the observed zone are either approaching the land or departing from the airport.

Procedures for Air Navigation Services – Air Traffic Management (Procedures – Air Traffic Management, 2007) define the aircraft separation rules – preventing collisions and wake turbulence avoidance. The approach and departure procedures (Annex 4…, 2009, Chapter 1) define a series of predetermined maneuvers by reference to flight instruments with specified protection from obstacles from the en-route space to the point from which the landing can be completed, or from the aerodrome to the point at which the en-route phase commences.

In the SKY-Scanner DSS it is suggested to conceptualize each norm as a combination of the factor, norm pattern, and the expected value. The factor is a quantitative attribute of the aircraft trajectory or of several aircraft trajectories. We will consider only the factors that are present or can be calculated from the SKY-Scanner DSS input data. A norm typically defines an expected value for the factor (denoted as $v_N$ – the normative value). The norm pattern defines how the expected value is interpreted.

*Limit-based Norms*. Some norms state that the actual value of the factor should be greater or smaller than the expected value. These norms are categorized as limit-based, and the respective norm patterns are denoted as "<=$v_N$" and ">=$v_N$". Examples of limit-based norms:

- A minimum of 5.6 km (3.0 NM) radar separation shall be provided between the aircraft on the same instrument landing system (ILS) localizer course (Procedures – Air Traffic Management, 2007, Section 6.7.3.2.5). The norm pattern is ">=$v_N$".
- The maximum indicated airspeed (IAS) for the turn is 210 knots (nautical miles per hour, Fig. 4). The norm pattern is "<=$v_N$".

*Deviation-based Norms*. There are norms stating that the factor value should be equal to the expected value, and a deviation to either side (positive or negative deviation) results in a violation of the norm. Some examples of deviation-based norms:

- The track is the projection on the earth's surface of the path of an aircraft, the direction of which is expressed in degrees from the north (Procedures – Air Traffic Management, 2007, Chapter 1). The procedures indicate the track required for the procedure (Annex 4…, 2009, Section 11.9), e.g., 236° (Fig. 5).
- The glide path is a descent profile determined for vertical guidance during the final approach (Procedures – Air Traffic Management, 2007, Chapter 1). It is expressed in degrees and presented in the procedures, e.g., "GP 3.33°" (Fig. 6).

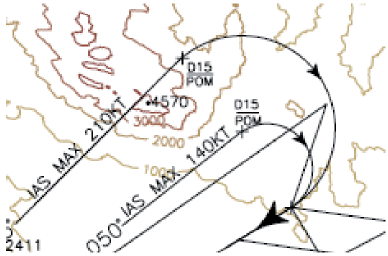



*Fig. 4.* ***IAS constraint in the approach chart "IAS MAX 210KT" (IAC No. 349, 2003)***

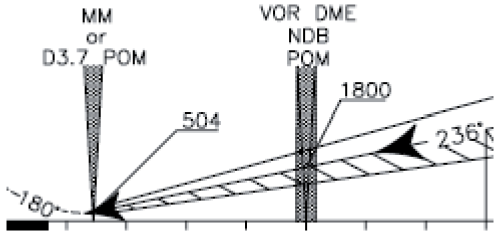
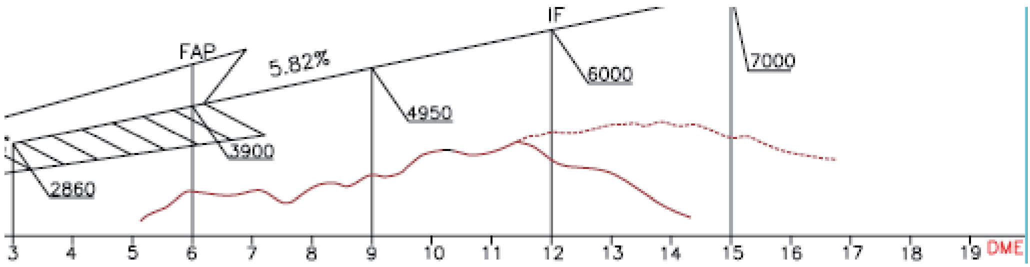



*Fig. 5.* ***Track indicated in the approach chart "236°" (IAC No. 349, 2003)***

| |
|---|
| TRANSITION ALT 8000 |
| RDH 15.6 M |
| GP 3.33° |

*Fig. 6.* ***Glide-path indicated in the approach chart "GP 3.33°" (IAC No. 349, 2003)***

Determining the type of some norms may be ambiguous. For example, consider the altitude constraints, such as "3900 feet at 6 NM from the distance measurement equipment (DME)". The approach procedures provide a profile view (Fig. 7) showing the required altitudes / heights (Annex 4…, 2009, Section 11.10.6.3). The approach charts depict the minimal allowed altitude value. So, this norm could be interpreted as limit-based (norm pattern ">=$v_N$"). But if the aircraft height is much greater than the expected value, it will be unable to land. So, the norm can also be considered as deviation-based with tolerance for the negative deviation (the observed values smaller than norm) smaller than for the positive deviation (observed values greater than the norm).




*F i g. 7.* ***Altitude constraints in the approach chart (IAC No. 349, 2003)***

## Risk Management Terminology

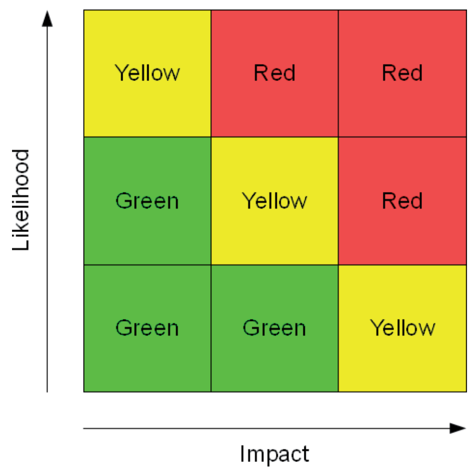
The ISO 31000 standard defines risk as a combination of the probability of an event and its consequence (ISO Guide 73…, 2009). It is noted in the standard that in some situations risk arises from the possibility of deviation from the expected outcome of the event. Probability is an extent to which an event is likely to occur (ISO Guide 73…, 2009). The term “probability” may be replaced by a more gentle term “likelihood” in some contexts (Mahler, 2009).

The risk management process is a tool for handling risks (Renn, Graham, 2005). Risk management consists of five main processes: definition of scope, risk assessment, risk treatment, risk communication and monitoring, and review (Risk Management..., 2006). The term “risk assessment” refers to the overall process of risk identification, risk analysis, and risk evaluation. Risk assessment focuses on what events may occur and what their probability (or likelihood) and consequences would be. Both components of risk may be described either qualitatively or quantitatively. Once a risk is identified, it can be analyzed in order to estimate the risk level by combining the estimated probability and the consequences (Mahler, 2009). Impact and probability (likelihood) may be expressed or combined differently, depending on the type of risk and the scope and objective of the risk management process (Risk Management..., 2006).

During the risk evaluation phase, decisions have to be made concerning which risks need treatment and which do not, as well as concerning the treatment priorities. The decisions are usually based on the level of risk but may also be related to thresholds specified in terms of consequences, likelihood and other criteria (Risk Management..., 2006).

The well-known traffic light model (Fig. 8) is often used in determining the tolerability and acceptability of risk (Renn, Graham, 2005). In this variant of the model, the red zone signifies intolerable risk, the yellow one indicates tolerable risk in need of further management actions, and the green zone shows acceptable or even negligible risk.

## Risk Definition in the SKY-Scanner DSS




*F i g. 8.* ***Traffic light model example: “red” – prohibition or substitution needed, “yellow” – reduction needed, “green” – acceptable risk***

There is not enough data to reliably estimate the possible norm violation consequences which may vary from radiating acoustic noise in highly populated areas to disrupting the traffic in the airport traffic zone (SKY-Scanner D1…, 2007). Additionally, the ATC standards strive to ensure safe separation and depend on the accuracy of the aircraft position provided to the controller (Airborne Collision..., 2006). The expected values in these norms are defined with a "safety margin". The use of precise tracking equipment will increase the controller's certainty of the aircraft position and eventually will probably lead to the change in the ATC rules. However, the current systems have to follow the existing rules.

Based on the context of the general risk terminology, the concept of norm violation risk in the SKY-Scanner DSS is defined. As stated in the previous section, the risk level evaluation should not necessarily be based on the combination of the probability (likelihood) and consequences. In the SKY-Scanner DSS, risk levels are defined based on the likelihood part of the risk definition. Likelihood is defined as a measure how close the aircraft is to violating the norm (conformance method).

A separate risk definition is formulated for each norm factor. Examples of factors:

- Factor 1: "horizontal separation between aircraft";
- Factor 2: "track";
- Factor 3: "glide path";
- Factor 4: "altitude".

In the SKY-Scanner DSS, an individual risk evaluation maps the observed factor value to a discrete scale of risk levels. The minimum number of levels is two: "no risk" when the norm is observed, and "risk" when the norm is violated. This is not sufficient for human controllers. Several risk levels are needed to help the controllers prioritize the situations. Also, there is a need to know in advance when the constraint is not yet violated but there is a risk of violation. In these examples, the traffic light model with three levels ("red", "yellow", and "green") is used. In general, there may be as many discrete levels as needed.

For convenience of the visual representation of risk definition the "risk value" function is used, which maps the observed factor value to a number from the interval [0, 1]. Zero means the lowest risk level (e.g., "green" or "no risk"), 1 means the highest risk level (e.g., "red" or "risk"), and values in the interval (0, 1) mean the intermediate risk levels. As mentioned above, the real function of risk for the aircraft which is close to violating the norm is unknown. In the SKY-Scanner DSS, risk value will be represented as a piecewise linear function. This is sufficient, because the risk level but not the absolute value of risk is of interest.

In line with the norm categories, two types of risks are defined: limit-based and deviation-based (Fig. 9). The following examples provide a semi-formal definition for risks of the two types.

***Loss of Separation – Limit-based Risk***

Aircraft separation constraints are defined as limits ("a minimum of 5.6 km (3.0 NM) radar separation shall be provided"; Procedures – Air Traffic Management, 2007, Section 6.7.3.2.5).

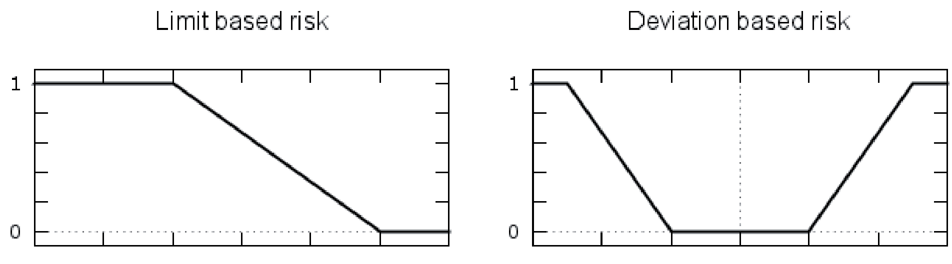



*Fig. 9.* ***Representations of risk value for two risk types***

Separation constraint is represented as three values: $v_N$ (the factor value in flight rules), $v_{LOW}$ (the threshold for determining a possible violation risk) and $v_{UP}$ (the threshold for signaling a high risk). Segments representing risk levels are (Fig. 10):

- "green": >= $v_{LOW}$;
- "yellow": [$v_{UP}$, $v_{LOW}$];
- "red": [0, $v_{UP}$];

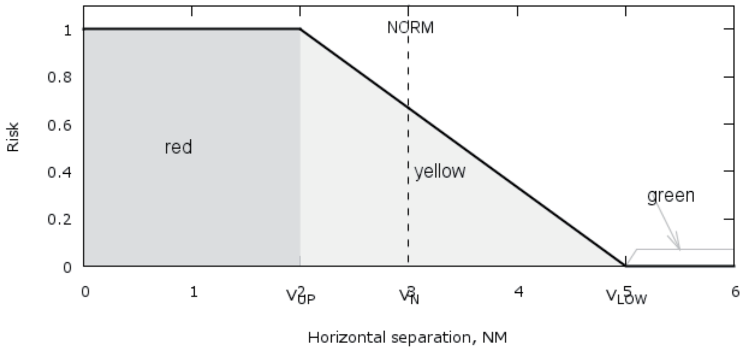



*Fig. 10* ***Risk of the loss of separation ($v_N$ = 3NM (value in flight rules), $v_{LOW}$ = 5NM, $v_{UP}$ = 2NM)***

***Path Violation – Deviation-based Risk***

In this section, we focus on the term "deviation" (of the observed value from the norm) rather than the "norm" itself. The general idea is shown in Fig. 11. The deviation should always be zero ($d_N = 0$). Each norm is given some "allowable deviation" defined by $d_{LOW1}$ and $d_{LOW2}$ values and "risk deviation" defined by values $d_{UP1}$ and $d_{UP2}$. Deviation in the interval [$d_{LOW1}$, $d_{LOW2}$] is acceptable (the risk level is "green"). When the deviation is in the interval [$d_{UP1}$, $d_{LOW1}$] or [$d_{LOW2}$, $d_{UP2}$], the risk level is "yellow". When the deviation is less than $d_{UP1}$ or greater than $d_{UP2}$, the risk level is "red".

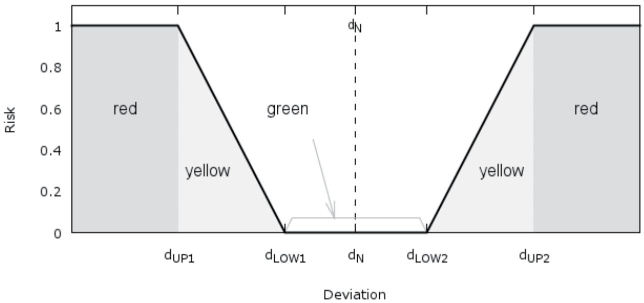



*Fig. 11.* ***General idea of deviation-based risk***

We examine the altitude violation risk as an example of deviation risk definition. One of the segments in the approach procedure provides a profile view showing the required altitudes / heights at predefined points (at some distance from the touchdown point) (Fig. 7). Altitude violation risk model parameters can be defined as follows: a greater tolerance for the positive deviation (above the norm) $d_{LOW2}$ = 2% and $d_{UP2}$ = 5% and a small tolerance for the negative deviation (below the nom) $d_{UP1}$ = –0.5% and $d_{LOW1}$ = 0%. This gives an asymmetric risk value function (Fig. 12).

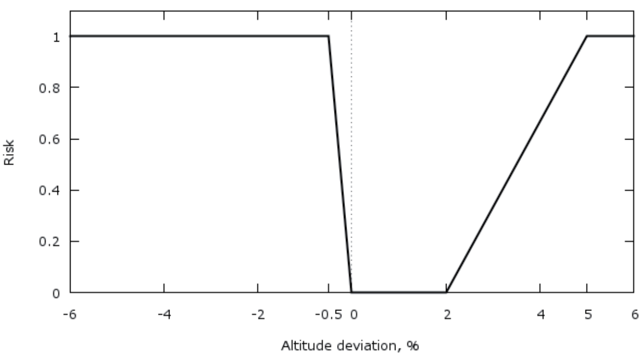



*Fig. 12.* ***Altitude violation risk***

***Concept of Risk***

In the SKY-Scanner DSS, the n-level risk is characterised by five elements:

1) risk factor (e.g., "altitude" or "indicated airspeed");

2) risk type (“limit” or “deviation”);

3) the norm pattern (“$>=v_N$”, “$<= v_N$”, “$= v_N$”);

4) the expected value of the factor;

5) a set of risk level thresholds.

If the risk type is “limit”, the set of thresholds consists of n-1 constants defined in terms of factor measurement units. If the risk type is “deviation”, the set of thresholds consists of n-1 pairs of constants defining the allowable deviation levels. The threshold values in the examples are chosen for demonstration purposes only and are subject to be fixed by experts.

## Conclusions

This paper presents the SKY-Scanner DSS – a real-time decision support system for air traffic controllers, focused on aircraft trajectory norm adherence in the approach and departure phases of flight.

Precise aircraft position data received from the new surveillance equipment enable checking aircraft trajectory adherence to the fine-grained norms for the aircraft approach and departure. The SKY-Scanner DSS is based on the assumption that the precise position data are available from radar and lidar data fusion. Other precise data sources could also be used, such as the DSS input, i.e. Automatic Dependent Surveillance-Broadcast (ADS-B).

In order to check the norm adherence, norms have to be operationalized, i.e. represented in a system. The conformance method is suggested: the norm violation risk is modeled from the perspective of how close the aircraft is to violating the norm. The SKY-Scanner DSS prototype demonstrates that the conformance-based alerting method is suitable for checking the approach and departure norm adherence in real time.

The norm violation risk model is suggested. Each norm is translated into a risk definition in the SKY-Scanner DSS.

The suggested attitude treats the norms for the aircraft comprehensively. We identify norm types and patterns. The constructed model of risk aims to cover all norms in the approach and departure phases of the flight.

The suggested norm violation risk model is suitable for representing the approach and departure norms for the aircraft. The model is demonstrated on examples of path violation and aircraft separation norms. The use of discrete risk levels satisfies the need to abstract from unnecessary details and thus facilitates the human user in making the decision.

Currently, each norm results in a separate indicator in the SKY-Scanner DSS. A method to combine these indicators could be employed to further concentrate the information presented to the user. The further research also includes the use of a predicted trajectories in risk estimation. Prediction-based alerting methods are better for predictable trajectories, such as aircraft approach and departure trajectories. However, it should be noted that the use of trajectory prediction is inherent in the description of some factors, e.g., time-based separation.

**LITERATURE**


*Airborne Collision Avoidance System (ACAS) Manual* (2006). First Edition. International Civil Aviation Organization, 2006. 205 p. ICAO Doc 9863 AN/461.

*Annex 4 to the Convention on International Civil Aviation, Aeronautical Charts* (2009). Eleventh Edition. International Civil Aviation Organization, July 2009. 163 p. [accessed 10 July 2011]. Available from: <http://dcaa.slv.dk:8000/icaodocs/Annex%204%20-%20Aeronautical%20Charts/>.

CRISPINO, M.V.; GRECO, F. (2007). SKY-Scanner alignment with the SESAR programme. *Second ATM R&D projects co-ordination and networking meeting*, November 2007 [accessed 10 May 2011]. Available from: <http://www.caats2.isdefe.es/private/evt/11914873260 31000/SKY-Scanner_Francesco Greco NERGAL.pdf>.

*IAC No. 349, Instrument Approach Chart* (2003). VatIta Dispatching, May 15, 2003.

*ISO Guide 73:2009 Risk Management, Vocabulary*. International Standartization Organization, 2009.

KUCHAR, J. K. (2001). Managing uncertainty in decision-aiding and alerting system Design. In *Proceedings of the 6th CNS/ATM Conference*, Taiwan, March 2001, p. 27–29 [accessed 10 July 2011]. Available from: <http://www.mit.edu/~jkkuchar/Taipei01.pdf>.

LAPIN, K. (2010). SKY-Scanner: time-critical decision support system surveilling aircraft landing and take-off. In *9th Innovative Research Workshop & Exibition*, December 2010. EUROCONTROL, 2010, p. 19–26 [accessed 10 July 2011]. Available from: http://inoworkshop.eurocontrol.fr/2010/download.php?pid=155_68182

MAHLER, T. (2009). *Legal Risk Management. Developing and Evaluating Methods for Proactive Legal Analyses, with a Particular Focus on Contracts*. University of Oslo, 2009. 349 p.

OGILVIE, D. T.; FABIAN, F. H. (1998). Strategic Decision Making in the 21st Century Army: A Creative Action-Based Approach. In *Fifty-eight Annual Academy of Management*, Stephen J. Havlovic (ed.). Best Paper Proceedings, August 1998, p. 1–7.

*Procedures for Air Navigation Services – Air Traffic Management* (2007). Fifteenth edition. International Civil Aviation Organization, 2007. 432 p. ICAO Doc 4444 ATM/501 [accessed 10 July 2011]. Available from: <http://xa.yimg.com/kq/groups/18778457/1649655487/name/Doc4444-15ed-2007-amd1-5-org.pdf>.

*Procedures for Air Navigation Services – Aircraft Operations*. Volume II:. *Construction of Visual and Instrument Flight Procedures* (2006). Fifth edition. International Civil Aviation Organization, 2006. 783 p. ICAO Doc 8168 OPS/611 [accessed 10 July 2011]. Available from: <http://dcaa.slv.dk:8000/icaodocs/Doc%208168%20-%20Aircraft%20Operations/Volume%202%20-%20Construction%20of%20Visual%20and%20Instrument%20Flight%20Procedures.pdf>.

RENN, O.; GRAHAM, P. (2005). *Risk governance towards an integrative approach*. Whitepaper. Geneva, International Risk Governance Council, September 2005. 157 p. [accessed 10 July 2011]. Available from: <http://www.irgc.org/IMG/pdf/IRGC_WP_No_1_Risk_Governance__reprinted_version_.pdf>.

*Risk Management: Implementation principles and Inventories for Risk Management/Risk Assessment methods and tools* (2006). European Network and information Security Agency (ENISA), June 2006. 177 p. [accessed 10 July 2011]. Available from: <http://www.enisa.europa.eu/act/rm/cr/risk-management-inventory/files/deliverables/risk-management-principles-and-inventories-for-risk-management-risk-assessment-methods-and-tools>.

SALERNO, M.; RONDINELLA, D.; CRISPINO, M.V.; COSTANTINI, G.; CAROTA, M.; CASALI, D. (2008). SKY-Scanner: a new paradigm for air traffic management. *International Journal of Circuits, Systems And Signal Processing*, no. 2 (2), p. 131–139 [accessed 10 July 2011]. Available from: <http://www.naun.org/journals/circuitssystemssignal/cssp-79.pdf>.

*SKY-Scanner D1: System and Testing Requirements Report* (2007). SKY-Scanner consortium, 2007. 63 p. [accessed 10 May 2011]. Avairlable from: <http://www.sky-scanner.it/Del/SKY_Scanner_D1-SystemTestingRequirementsReport.pdf>.

*The ATM Target Concept* (2007). Definition Phase, Milestone Deliverable D3. SESAR Consortium, 2007. 108 p. [accessed 10 May 2011]. Available from: http://www.eurocontrol.int/sesar/gallery/content/public/docs/DLM-0612-001-02-00.pdf

## NORMŲ OPERACIONALIZAVIMAS SPRENDIMŲ PARAMOS SISTEMOJE SKY-SCANNER LĖKTUVŲ LEIDIMUISI IR KILIMUI

**Laura Savičienė**

S a n t r a u k a

Straipsnyje supažindinama su realaus laiko sprendimų paramos sistema „SKY-Scanner DSS“ (angl. DSS – *Decision Support System*) skrydžių vadovams (dispečeriams). „SKY-Scanner DSS“ yra grindžiama lazerio naudojimu orlaiviams stebėti ir skirta padėti skrydžių vadovams priimti sprendimus tupiant ir kylant orlaiviams. Sprendimo parama grindžiama norminiais reikalavimais orlaivių trajektorijoms. Pasirinktas atitikties metodas. „SKY-Scanner DSS“ tikrina, ar orlaivių trajektorijos atitinka norminius reikalavimus, ir pateikia rezultatus kaip pažeidimo riziką. Straipsnyje sprendžiamas norminių reikalavimų (normų) atvaizdavimo sprendimų paramos sistemoje (operacionalizacijos) uždavinys. Siūloma norminius reikalavimus orlaivių trajektorijoms atvaizduoti į pažeidimo rizikos apibrėžimus sistemoje. Normos yra dviejų rūšių: susijusios su apribojimais (angl. *limit-based*) ir susijusios su nukrypimais (angl. *deviation-based*). Siūloma formalizuoti pažeidimo rizikos sąvoką „SKY-Scanner DSS“ kontekste. Pažeidimo rizika apibūdinama rizikos faktoriumi (orlaivio trajektorijos atributu), rizikos tipu, normos šablonu, normine normine faktoriaus reikšme reikšme ir slenksčių aibe. Rizikos įvertinimas atvaizduoja stebimą veiksnio reikšmę į diskretų rizikos lygį. Pateiktuose pavyzdžiuose naudojami šviesoforo lygiai: žalia, geltona ir raudona.