AEROSPACE SYSTEMS FOR MONITORING AND CONTROL

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ANALYSIS OF THE FLIGHT OBJECT CONCEPT

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Abstract. *The article represents an analysis of the Flight Object concept implementation in Europe. The objectives, features and interoperability performances of the Flight Object are considered. The multi-objective model for the efficiency estimation of the Flight Object implementation has been developed. The integral efficiency criterion is defined using the Harrington's desirability generalized function.*

Keywords: air traffic management**;** flight object; interoperability; multi-objective efficiency estimation.

1. Introduction

Starting from Wright Brothers' times the development of aviation has been in continuous progress. Nowadays aviation all over the Europe goes after the last word of EUROCONTROL. This is an organization, which is carrying out the plan on supporting aviation partners in achieving safe and efficient air traffic operations by keeping the dynamics of the data gathering and reporting mechanisms development. It is possible only due to maintaining the high level of the producing and integrating various hi-tech equipment, which helps to prevent safety risks while meeting different challenges both in capacity and performance on the way to implement Single European Sky. Today's increasing amount of flight operations requires an environment with a consistent view of the flight, which is inherent part of the realization of vision for future air traffic management (ATM). Nowadays different up-to-date programs ensure the provision of aeronautical information on a large-scale extent. Ongoing work in Europe shows that a new concept to support the sharing of consistent flight data between all stakeholders may become at an early date possible through the implementation of the Flight Object (FO).

2. Analysis of research

In late 2004 EUROCONTROL Flight Object Interoperability Proposed Standard (FOIPS) study was tasked with defining the model for the FO, supported by a network of Flight Object Servers (FOS) on the basis of two interfaces: the interface between FOS and its clients, and the interface between different instances of a FOS, in support of en-route and terminal air traffic control operations (fig. 1).

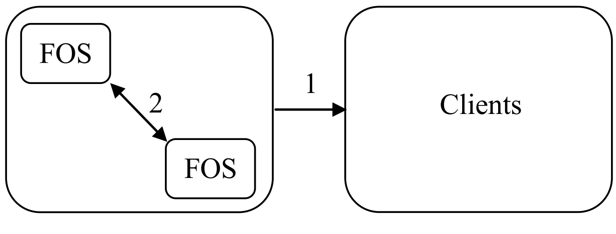

Fig. 1. Interfaces

The result of this work was composed of two complementary models: an "analysis model" – a model of the FO, defining standard set of services that it has to provide; and "usability model" – a set of access rights that determines under what conditions each stakeholder can invoke the services defined in the analyzing model. The next steps towards the implementation of the FO are the development and validation of FOS prototypes planned under Single European Sky ATM Research (SESAR) [1].

3. A basis of flight data exchanging

Flight Data Processing System (FDPS) is a part of automated air traffic control (ATC) system, which allows air traffic controllers (ATCO) to store and update information for each flight, perform automatic calculations, route flight information and print specified flight trips, to give the controllers up-to-date information on the flights in progress. With flight data processing software, the controllers are able to view, modify, activate and cancel flights that have been assigned to their control. Thus, this system is a basis of exchanging of real-time dynamic aeronautical and flight information [2].

Using FDPS storage is one of main keys for FO operating, which will provide its users even with such information as aircraft performance, ensuring consistent view of the flight data across all FDPSs. With the help of the FO, interoperability between other different entities can reach the highest level of efficiency. They are: system instances working for both civil and military Air Traffic Service Units (ATSUs) (because above-mentioned interfaces could propose mechanisms and offer platform for civil-military coordination, which has never been on such focus before), The Central Flow Management Unit (CFMU) or a combination of the above, aircraft (ACFT) Flight Management System (FMS), ACFT operators, and airport authorities (fig. 2).

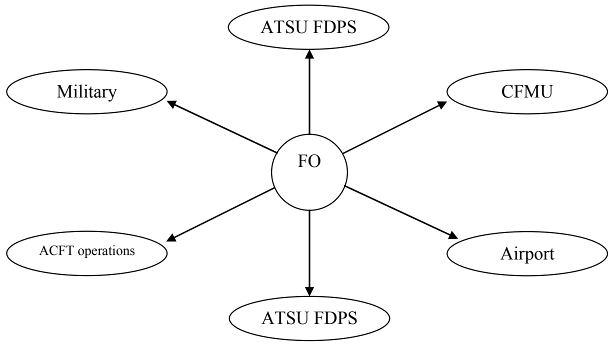

Fig. 2. Stakeholders

4. The FO interoperability

If we take current situation, logically, single FO is realised for each flight, because flight information dispersedly flows down to different systems for both ATC and pilot purposes. The question is creating consistent view of all flights through the distribution by the network up-to-date information to all stakeholders; and the answer – FO, as the common reference for shared data. This is how target has to look like.

One and definitely the most important pillar we lean on in aviation is safety, which requires non-stop control of the situation in the air: access to the latest confirmed flight data and intentions of each flight with the appropriate level of accuracy, availability, performance and consistency. For instance, if a new route of an aircraft is agreed by all area control centers (ACCs) along with CFMU, and then accepted by the pilot, ATSU applies the update to the FO and makes it available to all CFMU and ATSUs interested in interoperability (IOP) with the information that the modification has already been agreed by all actors involved. The update of FO implies the updates of its copy all over the IOP area. In case of the rejection, the reason can be added. The flight data manager (FDMP), being anyway the final responsible party for the flight, is also allowed to actualise the modification even without the acceptance of all the stakeholders (fig. 3).

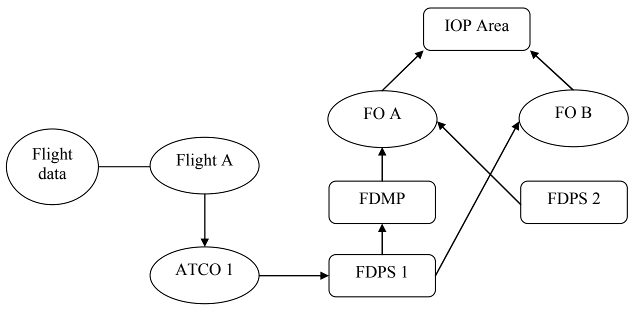

Fig. 3. Flight Object Concept

5. Interoperability objectives

Rising of crisis situations with disparate and intensive traffic in Europe pushes to assemble all concerned parties in strictly maintaining main objective of the interoperability – allowing consistent view of the flight data (for this effective interfaces are essential) and the coordination of it, indeed between systems, which were not as yet responsible for the flight. Complementarily, safety improvement and the same view of the FO by its users are also determinations of interoperability objectives, which supply and support provision of consistent information. To add more, each FDPS has to work properly independently, but in case of system failure, other FDPS connected to network should take upon themselves operating with those processes, which were initially managed by failed system, and once it will be able – to provide immediate recovery of the flight data for supporting day-to-day operations of the European ATM network. Finally, unceasing sharing of goals and ideas helps to go forward to desired level of efficiency of safety management, which is remaining the absolute priority and towards defining new objectives in quest for excellence.

6. The features of the FO

A huge part of flight data is comprised by the expected trajectory of the flight. Since different FDPSs path prediction processes differ from each other, using of terminative predictions may not bring insurance in consistency between different FDPSs. It can be explained with the fact that independent models are using different methods to build their own paths, and because of such diversity, resultative trajectories will not be the same. In this way, as an alternate, Flight Script concept may be taken. It keeps the flight data necessary at the input to the trajectory prediction process, and while using in combination with other data, makes possible creating consistent, but still not identical, trajectories for each flight by the FDPSs. Then FDMP creates a conjoint trajectory, overtaking whole IOP Area, which is shared via the FO.

Worthy to note that the calculation of the trajectory includes not only the 2D route, but also 4D aircraft position, track angle and speed. It even holds a record of instructions given by the air traffic controller and this has a very simple explanation. This data is contained in the FO in order to make possible creating a platform for a conventional and generally accepted understanding of what air traffic controller's instructions have led to the creation of the terminative path made available in the FO [3].

7. Efficiency of the FO concept implementation

The estimation of efficiency of FO concept implementation in ACC is the multi-objective optimization problem. There are following optimality criteria: cost of the FO algorithms implementation c_1, regularity of flights c_2 and air traffic control complexity c_3.

It is purposed to use the multi-objective model for the efficiency estimation of the FO implementation.

Let's introduce the notations: x – the alternative choice (x_1 is operations with FO, x_2 is operations without FO); $i=\overline{1,3}$ – number of optimality criterion c.

The values of $c_2(x_1)$ and $c_3(x_1)$ can be determined in two ways: by simulation of ATC processes with using of FO in ACC, where the FO implementation is planned, or using the statistical data from ACCs, where the FO concept was already implemented.

The normalization of optimality criteria values is performed using expression:

$$\bar{c}_i(x)=1-\frac{c_i(x)}{\max\limits_x c_i(x)},$$

where $\bar{c}_i$ – normalized value of criterion c_i. In case of $\bar{c}_i<0{,}05$ it is assumed that $\bar{c}_i=0{,}05$.

The integral efficiency criterion C is defined using the Harrington's desirability generalized function [4]:

$$C(x)=\sqrt[3]{\prod_{i=1}^{3}\bar{c}_i(x)}.$$

The implementation of FO is advisable if the following inequality is true:

$$C(x_1)>C(x_2).$$

8. Conclusions

The research shows that the major volume of work on this topic was done between 2005 and 2009, when the model of the FO and its interfaces were described. It is expected that the next steps towards the implementation of the FO are the development and validation of FOS prototypes planned under SESAR. Results of the research are of great promise, because it is the light at the end of the tunnel which leads us to proper level of the safety management. Driving excellence in ATM performance, creating platforms for civil-military coordination, achieving environmentally-friendly and efficient air traffic operations, and finally getting a consistent view of the flight – all these inherent parts of the realization of vision for future air traffic management could help to reach the implementation of the FO [5].

The increase of the crisis situations connected with a large amount of traffic all over the Europe inspires our minds to create an environment with a consistent view of the flight for the purposes of the safe management. New concepts of the support of sharing the consistent flight data may become true very soon through the implementation of the FO. This conception, based on FOS, will allow us to store and modify dynamic aeronautical and flight information on a basis of real-time exchanging. It will provide to stakeholders such types of information that were never lit alike – 4D routes, aircraft performances, records of air traffic controller instructions, new trajectory management principles and etc. Perspectives of this concept are great and cannot be exaggerated. Moreover, with the course of time it can be expected that FO's data storages may be used for the development of different software including those for civilian needs.

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Проведено аналіз впровадження концепції об'єкта польотної інформації у Європі. Розглянуто призначення, особливості та характеристики інтероперабельності об'єкта польотної інформації. Розроблено модель багатокритеріальної оцінки ефективності впровадження концепції об'єкта польотної інформації. Визначено інтегральний критерій ефективності із застосуванням узагальненої функції бажаності Харрінгтона.

Ключові слова: багатокритеріальна оцінка ефективності; інтероперабельність; об'єкт польотної інформації; організація повітряного руху

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Проведен анализ внедрения концепции объекта полетной информации в Европе. Рассмотрены назначение, особенности и характеристики интероперабельности объекта полетной информации. Разработана модель многокритериальной оценки эффективности внедрения концепции объекта полетной информации. Определен интегральный критерий эффективности с применением обобщенной функции желательности Харрингтона.

Ключевые слова: интероперабельность; многокритериальная оценка эффективности; объект полетной информации; организация воздушного движения

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