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INTEGRATED RESEARCH SIMULATION STAND ADVANCED AIR TRAFFIC CONTROL SYSTEMS

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Abstract

The report will be considered by a comprehensive research stand-loop simulation of integrated air traffic control systems (KIS UVD), which includes both on-board and ground-based components of the air traffic control system. KIS UVD is intended for research, accompanying the development of new procedures and means of ensuring the advanced air traffic management concepts implementation. The need for establishment of such a stand by the interests of the support work to develop advanced avionics.

1 Introduction

The development of Complex Research Stand of Air Traffic Management System is carried out in the framework of Russian federal target research program. The necessity of this integrated research stand creation for perspective avionics development tasks is defined by the following reasons:

Aircraft crew becomes the full participant of air traffic planning and controlling and it is necessary to simulate the whole system;

The most part of new and perspective functions is connected with the redistribution of separation and safety responsibility to the crew and it is necessary to make the simulation taking into account the interaction between controller and pilot,

New on-board functions as surveillance are intended for use in difficult conditions and it is necessary to simulate these difficult and close to real conditions.

2. The KIS UVD creation targets

Designing stand-loop simulation KIS UVD has begun and is in the R&D works for creation of integrated modular avionics for advanced aircraft. Testing of new flight crew functionality requires research, work-related airborne and crew in the circuit of air traffic control (in coordination with other members of the air traffic, especially with the air traffic controllers). This is due to the following reasons:

- research should include a flight in extremely stressful conditions (high traffic on the airway, in the terminal area, on the airport surface, and in adverse weather conditions);
- recently introduced a new feature to a large extent involves the interaction of the pilot and the controller, which is necessary to model;
- current trends suggest not only a significant increase in situational awareness of the aircraft crew, but also based on this increasing shift of responsibility for separation from the controller to the pilot;
- current trends suggest that the organization of air traffic flows, their planning and time controlling more and more converge and intersect with ATC processes, and they are made in the process of collaborative decision-making by all stakeholders, including the flight crew.

All of this requires a mandatory co-simulation of actions of all active members of the planning and management of air traffic occurring on the range of the aircraft flight.

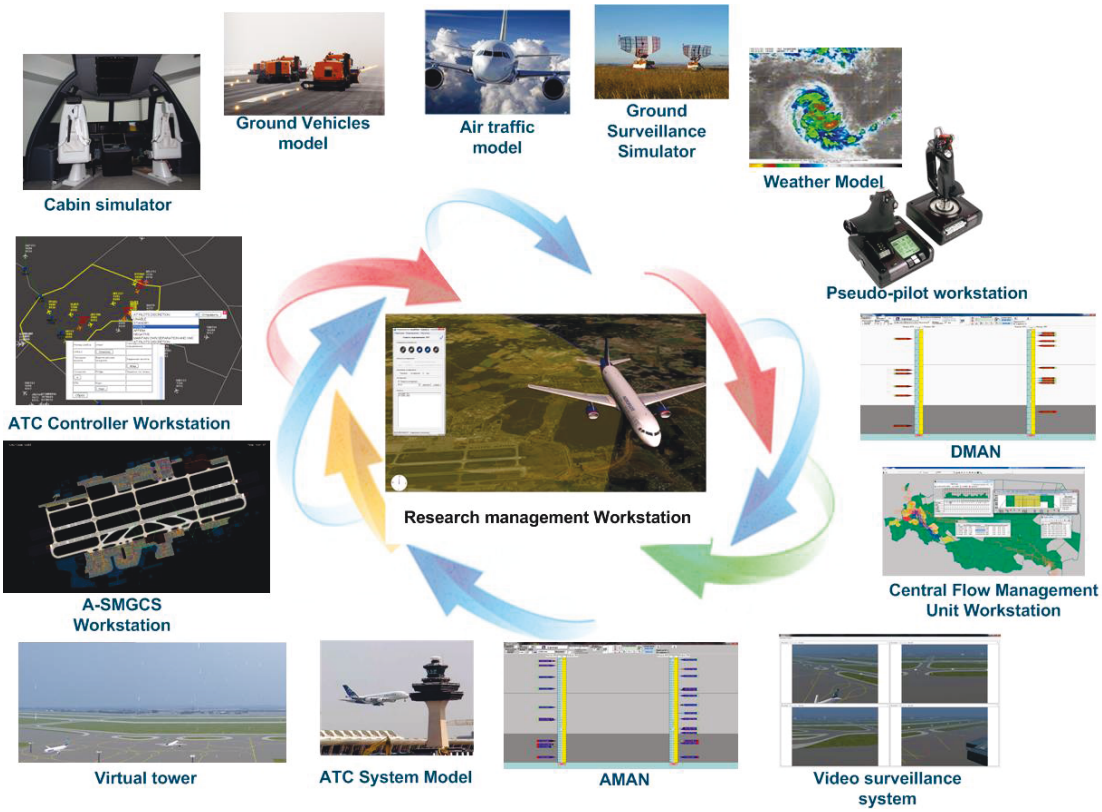

Figure 1. Research Stand Components

The tool creation for such integrated studies, primarily in the interests of working out a new on-board functionality and assessment of its potential effectiveness is the main goal of designing the stand KIS UVD

3. The Purpose of the Stand

The main purpose of the stand is the simulation studies in the interest of new on-board avionics functionality, new hardware and software to support for the crew, new methods and ways to implement effective and safe flying in conditions as close to real. In this case, the key element of the stand is the cockpit layout, integrated into its structure.

An additional purpose - the presence in the booth models of all the participants of air traffic planning and control allows you to use it as a tool to evaluate promising concepts, methods, techniques, technologies of air traffic system and its components, as well as assessments of their compliance with perspective on-board avionics.

4. Simulation

As already mentioned, simulation can be conducted in two modes: with human in the loop and without human in the loop (fast-time simulation). First mode allows to demonstrate controller-pilot interaction when advanced airborne procedures are performed, it allows to validate new technologies, new user interfaces.

The second mode allows to conduct researches by multiple fast-time simulation with statistics collection.

Aircraft's departure time from airports, speed on airways' segments, availability of certain airborne equipment and etc. could be appointed as a variable parameter during a series of statistical experiments. For example, in research of advanced airborne procedures the departure time was a normally distributed random variable with mean equals to scheduled time and with mean square deviation which is set in the experiment settings.

In order to estimate the potential benefits of the advanced concepts and technologies introduction it is accepted in the world practice

to assess the performance characteristics and metrics enshrined in international documents. Performance characteristics and metrics used in researches on the stand KIS UVD were selected as a result of the analysis of these documents as well as from materials of international air navigation conferences and from published research papers.

Currently the following performance characteristics are estimated:

- Airspace access;
- Airspace capacity;
- Efficiency;
- Environment;
- The flexibility of air traffic control;
- The predictability of air traffic;
- Safety.

Table 1 demonstrates the performance characteristics and metrics.

Table 1: Performance characteristics and metrics

Performance characteristics	Metrics
Airspace access	1. Percentage of requested flight level versus rejected flight level
Airspace capacity	1. Number of aircrafts in airspace segment per hour 2. Number of ATC operations 3. Number of aircrafts being under the ATC control at one time 4.Number of aircrafts under ATC control per hour
Efficiency	1.Kilograms of fuel per flight 2.Average delay caused by queuing and interval management 3.Number of exchanged CPDLC messages 4.Number of sending to holding zones 5.Number of deviations from a route and average time of deviations
Environment	1. Kilograms of CO2 emissions.
The flexibility of air traffic control	1. Number of approved changes to the flight plan 2.Number of offered alternatives 3. Average response time to new conditions
The predictability of air traffic	1. Delays of arrival flow 2. The average deviation of the actual arrival time from the scheduled
Safety	1. Number and degree of conflicts 2. Number and average time of separation violations 3. Number of detected and resolved potential conflicts

The process of research on the KIS UVD stand consists of several stages.

1. Preparation stage. The first stage of the research is preparation stage. At this stage the experiment scenario is created, researcher configures the stand. Rich user interface of the Research Manager Workstation allows to create various scenarios that meets all specific aspects of the current researched technology or concept. The researcher can configure the stand depending on the simulation mode and research goal, choose or creates new variant of research air traffic flow, set for each aircraft time of departure, flight levels, equipment, set parameters of simulation process, set parameters of random factors and much more

2. Simulation. At the stage of the simulation a series of a given number of experiments are conducted. The researcher can control the simulation: increase and decrease speed of the simulation, suspend or stop the experiment. Also during the simulation researcher can monitor the air traffic situation on 2D and 3D model visualization, as well as monitor the exchanges of CPDLC messages. During the experiment these metrics are calculated, then they are stored in database for further processing.

3. Data processing. The last stage is a data processing. Researcher analyses results, constructs diagrams and makes conclusions. To

assist this stage the Research Manager Workstation allows to export experiments data to Microsoft Excel, then using the capabilities of this mathematical package researcher can obtain additional metrics, build charts and graphs. Based on the metrics researcher draws conclusions about the impact of the new procedures, technologies on the performance characteristics. Therefore the results of research are:

- calculated metrics;
- comparative visualization of the data (graphs, histograms, etc.);
- quantification of changes in the performance characteristics;
- the conclusions drawn on the basis of received information.

5. Conducted researches

The following researches were conducted on the KIS UVD stand:

1) Testing of interaction between the pilot and ATC controller based on digital datalink - CPDLC;
2) Testing of the Arrival Management (AMAN) system prototype that provide assist in metering and sequencing arrival air traffic flow in airport Sheremetyevo (SVO);
3) Assessment of the potential benefits from the use of electric taxiing system by simulation of ground movement on airport Sheremetyevo (SVO) surface;
4) Assessment the influence on air traffic characteristics advanced ADS-B-based functions
   - In-Trail Procedure (ITP), which enables aircraft that desire flight level changes in procedural airspace to achieve these changes on a more frequent basis, thus improving flight efficiency while maintaining safe separation from other aircraft;
   - Flight-Deck Interval Management (FIM) procedure, a set of airborne capabilities designed to support a range of interval management operations whose goal is precise inter-aircraft spacing;
   - Airborne Conflict Management (ACM) procedure, which enables aircraft to detect, prevent and resolve air traffic conflicts, thus performing self-separation;
   - SURF procedure - airborne traffic situational awareness on airport surface.
5) Testing of the Departure Management (DMAN) system prototype that provide assist in sequencing departure air traffic flow in airport Sheremetyevo (SVO), testing of DMAN/A-SMGCS systems interaction and collaborative decision making;
6) Assessment of the potential benefits from the use various ATFM procedures.

Conclusion

The KIS UVD complex is being developed as universal tool for efficiency assessment and flight features in the any conditions from the ATM system side and from the aircraft point of view.

For example, nowadays complex allows to develop:

- different functions and procedures of onboard Airborne Separation Assurance System;
- Perspective applications of navigation and surveillance functions;
- Ground movement navigation function;
- Different algorithms for air traffic flow planning and management.

Complex is being developed with taking into account the wide list of potential users:

- the developers of methods and algorithms of flight control for single aircraft and air traffic flows,
- air traffic flow planning and management participants,
- the aircraft producers specialists and operators which tasks include analyze and forecast of airspace usage problems and air traffic efficiency problems.

The originality of KIS UVD complex consists in the integration of simulation models with workstation models and real avionics, as

well as in the practical absence of such domestic universal systems designed to address the diverse research applications.

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