On-board instrumental surveillance application functional prototype development and its research on the working-out interaction controller-pilot complex research stand

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ATM modernization as result of CNS/ATM concept

New ATM procedures and technologies

Simulation for the validation and experimental development
Prospective procedures deployment

Performance Improvement Areas

**Airport Operations**

- **Block 0 (2013)**
  - BO-65: Optimisation of approach procedures including vertical guidance.

- **Block 1 (2018)**
  - B1-65: Optimized airport accessibility.

- **Block 2 (2023)**

- **Block 3 (2028 & >)**
  - B3-15: Integration of ATM/SM/SMAN.

**Globally Interoperable Systems and Data**

- **Block 0 (2013)**
  - BO-30: Service improvement through digital automatisation information management.

- **Block 1 (2018)**
  - B1-30: Service improvement through integration of all digital ATM information.

- **Block 2 (2023)**
  - B2-25: Improved coordination through multi-centre ground-ground integration (GA) and flight object frame.

- **Block 3 (2028 & >)**
  - B3-25: Improved operational performance through the introduction of real-time ATM.

**Optimum Capacity and Flexible Flights**

- **Block 0 (2013)**

- **Block 1 (2018)**
  - B1-15: Optimized operations through enhanced en-route trajectories.

- **Block 2 (2023)**
  - B2-55: Increased capacity and efficiency through dynamic utilisation of the network.

- **Block 3 (2028 & >)**
  - B3-10: Traffic complexity management.

**Efficient Flight Path**

- **Block 0 (2013)**
  - BO-05: Improved safety and efficiency through the initial application of delta type en-route.

- **Block 1 (2018)**
  - B1-05: Improved safety and efficiency in departures and approach.

- **Block 2 (2023)**
  - B2-05: Optimised arrivals in dense airspace.

- **Block 3 (2028 & >)**
  - B3-05: Full 4D trajectory-based operations.

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Conflict Detection & Airborne Conflict Management

airborne conflict prediction, detection and resolution by self-separation
In-Trail Procedure (ITP)

flight level change in one-direction flow in procedural airspace

Reference aircraft

ITP aircraft

Other aircrafts

FL360
FL340
FL320

Less than standard longitudinal separation minimum but more than ITP criteria

More than standard longitudinal separation minimum
On-board surveillance function applications

Airborne Spacing – Flight Deck Interval Management

airborne procedure for longitudinal interval management toward reference aircraft
On-board surveillance function applications

ReRoute

- Generating of New Flight Plan to flyby Restricted Airspace Areas by existing flight ways
- Support of controller-pilot messages exchange
On-board surveillance function applications

Enhanced Traffic Situational Awareness On The Airport Surface With Indications And Alerts

- Airport Map Displaying
- Surround Traffic Displaying
- Movement Route Displaying
- Conflict Situation Alerting
Comprehensive Research Stand-Loop Simulation of Integrated Air Traffic Control Systems (KIS UVD)

- Allows to simulate from gate to gate
- Incorporates ground-based components of ATM system and aircraft
  - Implements a distributed loop simulation in real time with humans in the loop and fully automatic simulation in fast mode to get a statistic data
  - Allows to configure the component set for the experiments and demonstrations

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Stand Tasks

Research and experimental development of perspective on-board surveillance and navigation function software application

Experimental development of the Interaction between controller and pilot / avionics by the CPDLC

Simulation of New ways and technologies for the queuing and management of arrival and departure traffic (AMAN/DMAN)

A-SMGCS simulation

Research and experimental development of the Air Traffic Flow Management algorithms

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Simulation modes

Real-time Simulation –
demonstration and research of airborne procedures in human-in-the-loop mode, human-machine interface research

Fast-time Simulation –
research of airborne procedures by multiple run simulation in fast-time mode, statistics collection
Research Stand for Hardware-in-the-Loop Simulation of Air Traffic Control Systems (KIS UVD)

Cockpit simulator

Air traffic model

ATC automation system model

Weather model

Ether model

Ground surveillance model

AMAN/DMAN

Central Flow Management Unit workstation

Research manager work station

Stand «Aerodrome»

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Cockpit Simulators

Cockpit Simulator DKS IMA 9/11, FGUP «FRC»

Cockpit Simulator MS-21, GosNIIAS

Cockpit Simulator, FGUP TsAGI

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Cockpit Simulator Workplace

Simulates

- Controlled flight execution (includes airport surface movement)
- Experimental development of the Interaction between controller and pilot / avionics by the CPDLC
- Perspective on-board functions experimental development

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ATC controller workplace

Upgraded MK-2000 system with perspective ATC functions (CPDLC, ITP, rerouting, MONA, etc.)

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Arrival Manager & Departure Manager Workplaces

- Helps ATC controllers to regulate Aircraft Traffic Flow
- Situational control and identification of possible longitudinal separation breaches on Runway and TMA
- Automatic management and optimal control measures generation of air traffic sequence
- Manual control of aircrafts

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Central Flow Management System

- Airspace usage analyze
- Flight plans actualization based on the data from the ATC system and surveillance system
- Actual planning data provision for all operators
- Automatic and Automated air traffic flow by the departure slots assign

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Airport surface management

- Precision digital airport model
- Optimal movement routes generation
- Conflict detection on the air field

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Airport video surveillance system

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Virtual tower (real and synthetic vision)

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Aircraft flight model

- is intended for aircraft flight simulation and simulation of air situation close to real

Simulates

- aircraft movement on all flight phases
- flight crew and controller interaction
- planned flight trajectory calculation and its correction in order to controller’s commands
- perspective on-board procedures realization
- flight management system work
Automated ATC System Model

- simulates the actions of the controlling ATC system service to control and manage aircraft

Controlling operations Simulation

- on the departure (departure aircraft flow management, takeoff control, SID route control)
- on the route (aircraft route flight control, flight level changing operations, conflict detection and resolution, aircraft self-separation process control)
- on the arrive (sequence generation on the top of descent, holding zone usage, STAR changing)

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Hazard weather model

Evolution Simulation for the following thunderstorm cloud types:

• Single-cell
• Multi-cell
• Super-cell

Single-cell thunderstorm cloud model

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Ground vehicles model

- simulates ground vehicles movement on the selected airports

**Simulated operations**

- movement to the target place (i.e. to the aircraft stand location) in accordance with movement rules
- automatic blocks detection and bypass them by rules
- maintenance of target aircraft
**Research manager work station**

*On-board surveillance application prototype development and its research on the complex research stand*

**Allows to the operator:**
- generate aircraft flows and simulation scenarios
- prepare input information and stand components to make experiments and researches
- monitor (2D & 3D visualization) and control of the simulation
- preview and analyze of the experiments results
Research phases

Prepare phase
- flow, scenario and
  experiment generation

Experiment phase
- series of experiments
- simulating monitor
- CPDLC messages recording
- metrics calculation

Results processing
- results analyze
- diagrams and graphics

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Aircraft flows preparing

Different research tasks require different aircraft flows

ATFM tasks require real flows (about 6000 aircraft per day)

ITP requires unidirectional flow

FIM requires merging flows

ACM requires conflicting cross flows

It is necessary to have tool for creating and editing research flows
Aircraft flow preparing

Create new flow based on the library flow

or

import from KIM Database

Library flow filters

- by date
- by flight ID
- by departure and arrival airports
- by flight plan waypoints
- by flow number
- by FIR code

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Flight cloning – flight differ by departure time

Each flight can be edited:

- flight ID
- aircraft equipment
- departure date/time
- waypoints and flight levels
- arrival airport
Hazard weather scenarios

Thunderstorm clouds scenario

Positioning and timing for clouds

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Airports definition

- AMAN/DMAN settings
- Runway work rules for any airports
- Separation rules for runway
- Runways interference
- Aircraft placement options for airport surface

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Simulation scenario:
• aircraft flow
• start simulation date/time
• flight plan for cockpit simulator or pilot-operator workplace
• simulated aircraft control mode
• FIR for controller workplace
• Airports for AMAN, DMAN, A-SMGCS;
• hazard weather scenario

Simulation scenarios are saved on the library
Experiment settings

Experiment:
- scenario;
- experiment time
- target procedure
- each aircraft equipment
- standard deviation for departure time
- target FIRs for experiment
- calculated metrics

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## Experiments and Demonstration

<table>
<thead>
<tr>
<th>Activity</th>
<th>Year</th>
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<tbody>
<tr>
<td>Arrival Management to Sheremetevo (AMAN – Controller – Cockpit simulator)</td>
<td>2012</td>
</tr>
<tr>
<td>Electric landing gear usage simulation (for UAC)</td>
<td>2013</td>
</tr>
<tr>
<td>MAKS-2013 exposition</td>
<td></td>
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<tr>
<td>On-board surveillance application usage simulation (ITP, ACM, FIM)</td>
<td>2014</td>
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Conclusion

1. Comprehensive Research Stand-Loop Simulation of Integrated Air Traffic Control Systems (KIS UVD) is developed under the R&D programs 2011-2015

2. KIS UVD allows to make real-time simulation mode with human-in-the-loop for human-machine interface research and fast-time simulation

3. KIS UVD allows to make researches on the all flight phases from gate to gate

4. Architecture allows to connect new simulation components

5. Included tools allow to prepare simulation scenarios and analyze results
Thank You