Air Traffic Control software implemented in RADAR

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Abstract: *This study presents the flight plan data related to aircraft performance and is tested against the aircraft performance database. The Significant Meteorological Information Reports - SIGMET will be generated by the system according to the selected turbulence areas by attaching different AIS data to an exercise that can change the simulation objectives. The exercise must be assigned to one or more courses to be able to attach meteorological data when viewing a data recording; changes can be made to the aircraft as in a normal exercise run, while the other instructions will be loaded from the recorded data file. A data recording is airspace dependent, changing the airspace can make the data recording fail during playback. Video Recording is only available for the RADAR Simulator. A video recording can be made at any time during a simulation session; a data recording can be selected only at the beginning of the simulation session and cannot be started during the simulation session; if the simulator is integrated with the Voice Communication System and the audio channels, then a sound recording window will automatically pop-up. For this study, an ideal case, for the configuration presentation we will assume that the 3D Tower Simulator is composed of 4 LCD/Projectors to create the out-of-the-window view, 180 degrees, 2 Pseudo-Pilots, and 1 Supervisor/FEEDER Position. The 4 image generators will be provided by SIM01, SIM02, SIM03, and SIM04. The Pseudo-Pilots positions will be provided by SIM05 and SIM06. The Supervisor/Feeder Position will be provided by SIM07. For the Tower Controller Working Positions, we will provide the following information displays: DE – Flight Data Equipment/Clearance Delivery, MET – Meteorological Information, LCP –Lights Control Panel, and a RADAR Image. Station SIM08 will be used. Stations SIM01, SIM02, SIM03, and SIM04 are equipped with one large LCD Display or a Projector; Stations SIM05 and SIM07 are equipped with 2 monitors, one for the RADAR Image and the other one for the bird-eye view over the airport; Station SIM06 is equipped with one monitor for the bird-eye view over the airport; Station SIM08 is equipped with 4 monitors providing all necessary information for the Tower Controller Working Positions. SIM07, as presented above, is the FEEDER/SUPERVISOR for the RADAR Simulator, the approach* *sector is "TMA" and the application will be started on the second monitor, the first monitor is used for the 3D Tower Simulator. SIM07 is also FEEDER/SUPERVIZOR for the 3D Tower Simulator, the station function will be "3DTWR" and the sector will be the previously created 3D Tower configuration, "TOWER". On SIM08 will add a RADAR Image for the Tower Controller Working Positions, sector is "TMA", the application will be started on monitor 4, and the station function is "TWR". Usually, for an aircraft departing from an airport inside an approach sector, the first owner will be the tower until passing the maximum flight level/ altitude for the tower, the second owner will be the approach sector and the third owner will be the en-route sector. In this case, the tower sector has power over the approach sector, and the en-route sector, the approach sector has power over the en-route sector. The outside FIR sectors will be used in the determination of the next en-route sector, for coordination purposes. If the VFR points do not appear on the RADAR Map after the "DRAW" button has been pushed, use the "MAP MENU" – "VFR" button. The aircraft performance database is not airspace structure dependent. When a new airspace structure is created the aircraft performance database will remain unchanged.*

Key Words: *ATC, ATM, FMS, Flight Simulator*

1. INTRODUCTION

The modern aerial surveillance system is in a continuous process of change, from ground-based radars to selective surveillance cloud technologies. New software technologies such as climb/descent procedures using ADS-B Automatic Dependent Surveillance–Broadcast, improved safety, and efficiency of surface operations, and improved synthetic vision systems are already being developed [1].

2. STATE OF ART FOR ATC SOFTWARE IMPLEMENT IN RADAR

The point target radar range equation estimates the power at the input to the receiver for a target of a given radar cross-section at a specified range [1, 8].
The model is deterministic and assumes isotropic radiators. The equation for the power at the input to the receiver is:

$$P_r = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 L R_t^2 R_r^2} \tag{1}$$

where the terms in the equation are: P_r - received power in watts; P_t - peak transmit power in watts; G_t - transmitter gain in decibels; G_r - receiver gain in decibels.

If the radar is monostatic, the transmitter and receiver gains are identical. λ - target's nonfluctuating radar cross section in square meters; L - general loss factor in decibels that accounts for both system and propagation loss; R_t - range from the transmitter to the target; R_r - range from the receiver to the target [8-9]. If the radar is monostatic, the transmitter and receiver ranges are identical.

The equation for the power at the input to the receiver represents the signal term in the signal-to-noise (SNR) ratio.

To model the noise term, assume the thermal noise in the receiver has a white noise Power Spectral Density - PSD given by: [1, 8]

$$P(f) = kT \tag{2}$$

where k is the Boltzmann constant and T is the effective noise temperature. The receiver acts as a filter to shape the white noise PSD [2-6].

Assume that the magnitude squared receiver frequency response approximates a rectangular filter with bandwidth equal to the reciprocal of the pulse duration, 1/τ. The total noise power at the output of the receiver is:

$$N=\frac{kTF_n}{\tau} \tag{3}$$

where F_n is the receiver noise factor [1, 7-10].

The product of the effective noise temperature and the receiver noise factor is referred to as the system temperature and is denoted by T_s, so that $T_s=TF_n$.

Using the equation for the received signal power and the output noise power, the receiver output SNR is:

$$\frac{P_r}{N}=\frac{P_t\tau G_tG_r\lambda^2\sigma}{(4\pi)^3kT_sLR_t^2R_r^2}. \tag{4}$$

Solving for the required peak transmit power:

$$P_t=\frac{P_r(4\pi)^3kT_sR_t^2R_r^2\,L}{N\tau G_tG_r\lambda^2\sigma} \tag{5}$$

$$\Phi_w(\omega)=\frac{\sigma_w^2L_w}{\pi U_0}\cdot\frac{\left[1+3\left(L_w\cdot\frac{\omega}{U_0}\right)^2\right]}{\left[1+\left(L_w\cdot\frac{\omega}{U_0}\right)^2\right]^2} \tag{6}$$

$$L_w=\begin{cases}580\,[m] & if\quad h>580\,[m]\quad\Leftrightarrow\quad h>1750\,[ft]\\ h\,[m] & if\quad h<580\,[m]\quad\Leftrightarrow\quad h<1750\,[ft]\end{cases} \tag{7}$$

$$L_w=580\,[m]\;\Leftrightarrow\;\;L_w=1750\,[ft] \tag{7a}$$

$$\sigma_w=7\,[m/s]\;\Leftrightarrow\;\;\sigma_w=21\,[ft/s] \tag{7b}$$

$$\Phi_u(\omega)=\frac{2\sigma_u^2L_u}{\pi U_0}\cdot\frac{1}{1+\left(L_u\cdot\frac{\omega}{U_0}\right)^2} \tag{8}$$

$$\Phi_v(\omega)=\frac{\sigma_v^2L_v}{\pi U_0}\cdot\frac{\left[1+3\left(L_v\cdot\frac{\omega}{U_0}\right)^2\right]}{\left[1+\left(L_v\cdot\frac{\omega}{U_0}\right)^2\right]^2} \tag{9}$$

$$\Phi_w(\omega)=\frac{\sigma_w^2L_w}{\pi U_0}\cdot\frac{\left[1+3\left(L_w\cdot\frac{\omega}{U_0}\right)^2\right]}{\left[1+\left(L_w\cdot\frac{\omega}{U_0}\right)^2\right]^2} \tag{10}$$

$$\Phi_w(\omega)=|G_w(j\omega)|^2\Phi_N(\omega)=|G_w(j\omega)|^2 \tag{11}$$

$$\mathrm{G}_u(s)=\sigma_u\sqrt{\frac{2L_u}{\pi U_0}}\cdot\frac{1}{1+\left(\frac{L_u}{U_0}s\right)} \tag{12}$$

$$G_v(s)=\sigma_v\sqrt{\frac{L_v}{\pi U_0}}\cdot\frac{1+\sqrt{3}\left(\frac{L_v}{U_0}s\right)}{\left[1+\left(\frac{L_v}{U_0}s\right)^2\right]} \tag{13}$$

$$G_w(s)=\sigma_w\sqrt{\frac{L_w}{\pi U_0}}\cdot\frac{1+\sqrt{3}\left(\frac{L_w}{U_0}s\right)}{\left[1+\left(\frac{L_w}{U_0}s\right)^2\right]} \tag{14}$$

$$L_w=h \tag{15}$$

$$L_u=L_v=\frac{h}{(0.177+0.000823\cdot h)^{1.2}} \tag{16}$$

$$\sigma_w=0.1\cdot W_{20} \tag{17}$$

$$\frac{\sigma_u}{\sigma_w}=\frac{1}{(0.177+0.000823\cdot h)^{0.4}} \tag{18}$$

$$W_{20}\ \rightarrow 20\ [ft] \tag{19}$$

$$L_u=L_v=L_w=1750\ [ft] \tag{20}$$

$$\sigma_u=\sigma_v=\sigma_w \tag{21}$$

$$V_{wind}=\begin{cases}0 & if\quad x<0\\ \frac{V_m}{2}\left[1-\cos\left(\frac{\pi x}{d_m}\right)\right] & if\quad 0\le x\le d_m\\ V_m & if\quad x>d_m\end{cases} \tag{22}$$

$$p_g=\frac{\partial w_g}{\partial y}\qquad q_g=\frac{\partial w_g}{\partial x}\qquad r_g=-\frac{\partial v_g}{\partial x} \tag{23}$$

$$p_g=\frac{\partial w_g}{\partial y}\qquad q_g=\frac{\partial w_g}{\partial x}\qquad r_g=\frac{\partial v_g}{\partial x} \tag{24}$$

$$p_g=-\frac{\partial w_g}{\partial y}\qquad q_g=-\frac{\partial w_g}{\partial x}\qquad r_g=\frac{\partial v_g}{\partial x} \tag{25}$$

The significant meteorological information reports - SIGMET that are continuously transmitted to the pilots are generated by the system according to the turbulence areas that are selected by attaching different AIS data to an exercise that can thus modify the simulation objectives in real time.
In the future, ATM will be carried out in a progressively significantly developed environment, continuously in terms of ground and airborne technologies. All aircraft will be equipped with state-of-the-art avionics systems, thus making them capable of various forms of efficient and environmentally friendly free flight, as well as having self-separation capability and enhanced cockpit situational awareness in certain circumstances. Currently existing airborne service models will have to adapt progressively [1].

3. EXPERIMENTAL RESULTS AND CONCLUSIONS

The figures below show some software and technologies currently available, while other capabilities are planned and proposed through international development.

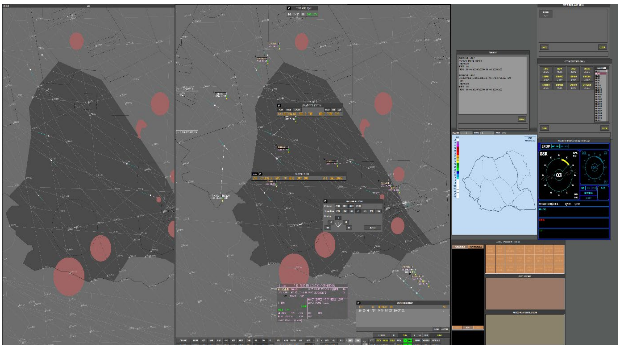

Fig. 1 Flight Simulator Display

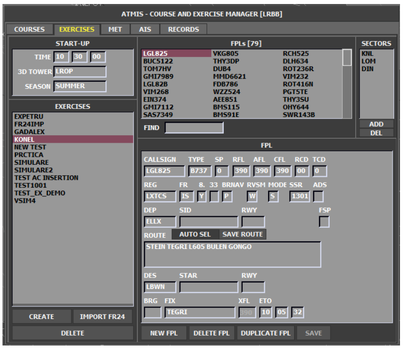

Fig. 2 ATMIS - Course and Exercise Manager

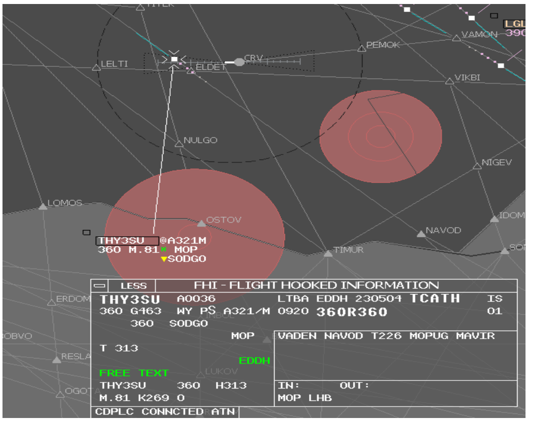

Fig. 3 Case Study – KONEL sector with 79 aircraft

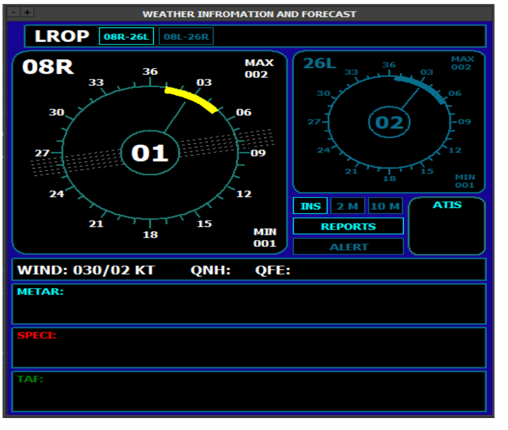

Fig. 4 Weather Information and Forecast

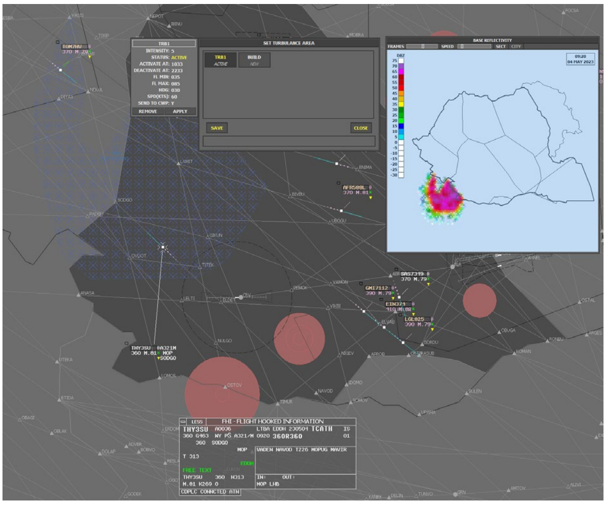

Fig. 5 Turbulence simulated – windows by modeling & monitoring atmospheric turbulence #1

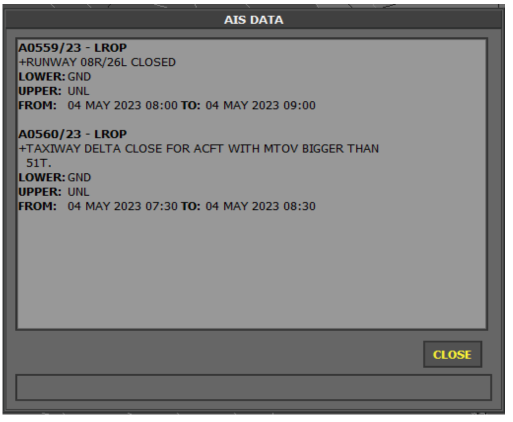

Fig. 6 AIS DATA

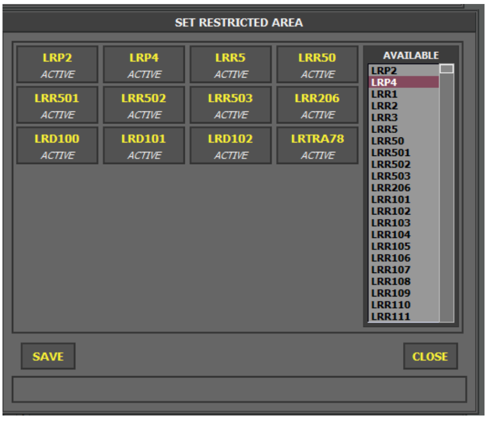

Fig. 7 Set restricted area

Fig. 8 ATMIS pseudo-pilot menu

In this work, the requirement to provide ATM services with a modular and fully adaptable, continuous architecture is oriented towards airline services so that it can easily absorb and integrate future technology and service optimizations.

In the final phase, this capacity will be determined through an ongoing assessment. State-of-the-art automation capabilities include various safety and air conflict alert tools, pre-takeoff clearance and inter-facility air traffic control data messaging, and an integrated capability to manage runway landings and takeoffs.

These automated systems will provide some of the factors that contribute to the expansion of air routes preferred by users and the improvement of the ability to manage air traffic flows.

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REFERENCES

[1] * * * Global Air Navigation Capacity & Efficiency Plan 2013-2028, DOC 9750.
[2] * * * http://www.MathWorks, Inc. Aerospace Blockset, 2023.
[3] M. Rauw, *FDC 1.2. - A SYMULINK Toolbox for Flight Dynamics and Control Analisys*, 2001.
[4] B. Etkin, *Dynamics of Flight-Stability and Control*, Wiley, New York, USA, 2-nd edition, 1982.
[5] D. McLean, *Automatic Flight Control System*, Prentice Hall, Hertfordshire, UK, 1990.
[6] G. J. Balas, J. C. Doyle, K. Glover, A. Packard, R. Smith, *μ-Analysis and Synthesis Toolbox for use with MATLAB, User's Guide.*
[7] R. Y. Chiang, M. Safonov, *MATLAB- Robust Control Toolbox,* by The MathWorks, Inc.
[8] M. Thurber, *Avionics for NEXTGEN*, 2015.
[9] * * * ATM https://apcae.files.wordpress.com/2009/05/doc-4444.pdf
[10] B. L. Stevens, F. L. Lewis, *Aircraft Control and Simulation*, John Wiley, USA.