FLIGHT SIMULATORS – FROM ELECTROMECHANICAL ANALOGUE COMPUTERS TO MODERN LABORATORY OF FLYING

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ABSTRACT

This article presents discussion about flight simulators starting from training simulators, applied in military and civil training tasks, up to the domestic simulators. Article describes history of development of flight simulation equipment. At the end of this paper new unit of Silesian University of Technology – Virtual Flight Laboratory – is presented.

Keywords: flight simulator, history of flight simulators, virtual flight laboratory.

INTRODUCTION

The development of modern technology is closely dependent on computers and digital techniques. The use of proper tools allows for constructing new appliances and enables efficient trainings. Effective skill development is possible with different types of simulators [2]; they are incredibly significant in different branches of industry, as the only safe and effective method of training in many cases. Also in case of aviation industry the need for ground training was recognised very early. The history of flight simulators reaches the beginning of 20th c. and starts soon after the Wright brothers' first flight in a motor aeroplane [6]. One of the first available simulators reproduced the rudder elements of Antoinette 7 plane. It was made of two half-barrels piled in such a way that they were in a state of unsteady balance. Sitting in the cockpit, the pilot attempted to set the crosswise gauge in balance with the horizon with the use of rudder. The instructor observed the rudder, and on the basis of his own experience, decided about the position of the construction. The first milestone in the early years of

the development of such devices was the introduction of steering drives and mechanisms setting the position of the cabin. The first such construction was built in 1917 in France.

In 1929, along with the first commercial flight simulator called "Link Trainer" (and also "the Blue Box", due to its colour) made by Link Company, the branch of planes started its sudden development. This was caused by the interest of military commanders in the simulators. It was noticed that simulators allowed for trainee's adaptation to flight instruments, acquisition of habits and skills necessary during the flight but also allowed training for dangerous flights e.g. in a situation of limited visibility (what is particularly important in military situations) in safe circumstances.

After a series of primitive flight simulators in 1941 Wing Commander Iles constructed a fully automated pneumatic simulator Silloth trainer. One of the first devices of this series reflected a C100 DF plane and was used to train cabin crews in navigation. Later versions simulated two- or three-engined bombers. The flying fortresses of that time required a cabin crew of a number of people, therefore, it was essential to train the

whole crews in communication techniques and their preparation to react appropriately in crisis situations.

The first drafts of electronic simulators were made as early as in 1929 in Germany. However, no simulator was build according to this project. In Great Britain, at more or less that time, a project by G.M. Hellings based on electromechanical analogue computer was designed. The project assumed simulating the characteristics of different types of planes. Mechanical version of this project was made by General Aircraft Limited and functioned in Empire Central Flying School. In 1943 Bell Telephone Laboratories produced a simulator of PBM-3 plane. It was built on the basis of the plane cockpit with rudder instruments operated with a primitive computer calculating the flight parameters. In the same year, Curtiss-Wright Corporation, headed by doctor Dehmelem, built an advanced simulator Z-1 of AT-6 plane, which was steered by a primitive analogue computer allowing flights on the basis of instruments.

Until 1949 Curtis-Wright sold thousands of their own simulators, with improved analogue computers to simulate different stages of flights and types of airframes. Up to then, all the available simulators were used for military purposes. The first civil simulator used by the airlines was a simulator designed in 1948, reflecting Boeing 377.

In 1950's and 1960's at University of Pennsylvania, simulator UDOFT (Universal Digital Operational Flight Trainer) was built. It offered elaborated possibilities to make calculations concerning the flight. More importantly, the calculations were made in real time. Unfortunately, a large problem in 1950's was high failure frequency of computers, therefore, the work with such simulators was interrupted by long service breaks.

the first visual simulators commonly used in civil simulators were based on physical model of the terrain and a TV camera that moved in above the terrain to generate views in the cockpit. The camera was initially black and white (1950's) and then colour (1960's). The first attempts to generate the image fully controlled by computer were made by General Electric. In 1971 McDommel-Douglas Electronics Corporation built a simulator Vital II, which simulated landing at night and screened the images in a fully vectored manner.

In 1980's a lot of flight simulators were designed on such computer models as VAX and SEL 32/77. This gave the foundations to build fully digital simulators, also the amateur. The first simulator for domestic use was designed at the turn of 1979. The project was started by Bruce Artwick, making the versions available for Apple and TRS-80 computers. The version from 1980 screened the world made of 36 squares sized c.a. 1 km making a grid 6x6. There was also a hangar with an airport and mountains.

In 1982 Microsoft started cooperation with Bruce Artwick and a company called Sublogic, what resulted in Microsoft Flight Simulator. The simulator had Cessna plane panel and the images of 5 cities (Chicago, Seattle, Los Angeles and New York/Boston). The simulator required an IBM PC class of computer with a processor clocked 4.77 MHz and 64K of RAM memory. In 1983 another version for Apple computers was released. It had the base of 80 airports, buildings and bridges. In 1984 the versions for Commodore and Atari computers were better developed and used 8 colours. Two years later the versions for Amiga and Atari ST, due to their better graphical processing units, worked in 320×240 dpi resolution and used 16 colours. In subsequent years graphics and the texturing were developed. Additional supplements were also released which allowed diversification of tasks during flights [4]. In 2006 a version of Microsoft Flight Simulator marked with X symbol was released (FSX). It showed the whole globe and all the communication airports in the world., e.g. all flying club airfields in Poland, what proves the coverage and detailed approach in the virtual world. It is considered to be one of the best simulators available for both professional and domestic use. After this release, Microsoft withdrew from simulator market, however the product was developed by Lockhead Martin under the name Prepar 3D.

Apart from the development of simulators and simulating software, there has been a lot of research aimed at improving the effectiveness of trainings [3] and lowering their costs [1, 7] as well as decreasing the tiresomeness of long-lasting trainings in such type of device [5].

DISCRIPTION OF SIMULATOR'S WORK

In order to describe the operations of simulators Microsoft Flight Simulator X will be used. The programme is well developed, uses a lot of modern solutions and is the most popular flight

simulator in the world market. The popularity is caused by the fact that the simulator can be used for both professional and domestic uses.

Communication in the simulator

there is a number of methods of communications in FSX – the producer focused on the most realistic approach to the problem of communication. Due to lack of possibility to understand human speech by computers, the communication is made by selecting the text from the list proposed by the computer. Setting the radio frequency is done in the same way as in reality – by setting the right frequency on a radio panel it is possible to connect to the control tower for the area or the area control. Having selected the right frequency the pilot notifies their intention and, depending on the situation, obtains detailed instructions of taxiing and landing, with consideration for appropriate entry into airport circle (left or right) and the order of landing , due to the presence of other aircrafts. The simulator allows the pilot to contact ATIS services (providing information about the conditions in a given airport and a method of approach), what is required in contacts with the tower. What is more, advanced communication is possible after logging to VATSIM network, for example.

Navigation and navigation systems

In Microsoft simulator a full range of navigation aids are available: VOR, NDB and ILS. The frequencies of radio lanterns are exactly the same as in reality. Practical approach of the designers is manifested in the fact that after setting the frequency of radio lantern it is possible to overhear its signal in the Morse code, what allows checking the correctness of the setting. After selection of radio lantern, its signal appears in the navigation equipment, what allows training flights without visibility (IFR). The simulator provides also GPS aids – both in Civil aviation and in large airline planes. It is possible to set the flights on SID and STAR points (the points are exactly the same as in reality). Simulator producer attempted to reflect real air navigation. It is also possible to make VFR flights, however, they require the pilot to compare the maps with the ground images of the Earth. In real aviation navigation is based on characteristic objects such as chimneys, mines, power plants, lakes and rivers. Unfortunately, the simulator without extensions does not offer the

precise reproduction of such objects. For this reason, extensions improving the view of the Earth and adding characteristic objects in the area of flights are advisable.

Another important addition is airports. The simulator was developed in 2006 and since then large number of airports were modified or rebuilt. In the original version there are, unfortunately, no airport buildings and some mistakes happen, what generate a lot of problems during flights with VASTIM network. A pilot, who does not have updated view of the airport can find himself in a situation of landing in the place with no runway in VATSIM network. That is why it is so important to have an updated data. A lot of airports are available in freeware version of the simulator. Virtually all Polish airports are also available. Yet, FSX was released 6 years ago thus it needs updating, as they do not reflect the current state.

VATSIM virtual space

VATSIM is a computer network, whose main objective is to ensure flight control to simulator pilots. After the connection the pilot receives instruction concerning the flight and sees the aircrafts of other users of VATSIM system. the communication with other controllers and pilots are also possible. All the procedures and regulation for aviation are also binding. VATSIM network counts presently c.a. 100 000 users, each with a unique identification number in PID system.

VATSIM system requires precision and piloting skills in such a degree that allows:
- moving on taxiing ways and leaving them,
- maintaining the altitude with the accuracy of 200 ft, the course accuracy of 10 degrees and speed accuracy of 10 knots,
- making appropriate manoeuvre of take-off and landing,
- the skill of map reading and ICAO alphabet.

SIMULATORS FROM THE CENTRE OF AVIATION TRAININGS AT SILESIAN UNIVERSITY OF TECHNOLOGY – VIRTUAL FLIGHT CENTRE

In 2011 The Faculty of Automation, Control, Electronics and Computer Science obtained a grant for the project of "Comprehensive modernization of auditorium halls in the culty of Automation, Control, Electronics and Computer Science

in Gliwice and building a Virtual Flight Laboratory" in the framework of Regional Operational Programme of Śląskie Voivodeship for 2007 – 2013, Priority 8 "Educational infrastructure", Activity 8.1 "Infrastructure of higher education" – "Regional Operational Programme of Śląskie Voivodeship – real response for real needs", co-financed by European Union from European Fund of Regional Development for 2007–2013. As a result of the project, the University purchased certified cabin flight simulators. The equipment includes two mobile simulators by FlyIt and a few stationary simulators by Elite.

Mobile FlyIt simulators

Full-size helicopter cockpit simulators (PHS – Professional Helicopter Simulator) and plane simulators (PAS – Professional Aircraft Simulator). The cockpits and the surrounding infrastructure are built in trailers, thus they can be easily transported to the place of training. They are fully autonomic units that require only power source (in case of lack of it, the training can be run for 1.5 hrs with the use of built-in UPS's).

The simulators allow Visual Flight Rules (VFR) training and Instrument Flight Rules (IFR) trainings. The used software is based on Martin Lockhead Prepar3D (earlier version of Microsoft Flight Simulator X) therefore, terrain mapping is developed both visually and in terms of topology. The available database includes 24 000 airports with all navigation routes It is also possible to create own scenarios of flight. The realism of simulations may be proved by the fact that the software maps even the influence of air rush generated by the propeller, building the power to both the axes of motion and the elevator.

The sets have doubled controls for two pilots, intercom, headphones and are fully equipped with aviation instruments. Full IFR panel contains the indicators of motor controls, altimeter, speedometer, Vertical Speed Indicator, rotor speed meter (PHS). The cockpits are also equipped with compete radio panels containing navigation, NAV/COM, HSI, ADF, DME, transponder and radio communication panel.

Visual impressions are provided by rear projection system covering 90 degrees in perpendicular and 110 degrees in horizontal direction with the multimedia projectors of resolution of 1400×1050 dpi each, what allows to cover the whole are seen from the aircraft windows.

The control switches were located in exactly the same way as in the modelled aircraft. Helicopter simulator (PHS) ha 6 popular models of helicopters: Piston R-22, R-44 (VFR-IFR), Schweizer 300 (VFR-IFR), Enstrom 280 FX, Turbine-MD 500, Bell 206 (IFR), AS 350 B2.. It is worth to notice that the set contains helicopters with both piston and turbine engines. Plane simulator (PAS) allows to simulate flights in both single and double engined planes, what allows preparation for ME certificate (Multi Engine). In the list of available simulators there are most popular aircrafts in flying clubs and used for passenger transportation including Cessna 172, 182, 182RG, Piper Seneca III and Beach B 58 Baron.

The instructor owns an ICC-Instructor Command Center equipped with three (PAS) or four (PHS) LCD screens, which guarantee a full view over the situation in the air, all the gauges and their readings, as well as the map with the flight map. There are possibilities to simulate different weather conditions, rain, wind of any direction, height of fog and clouds. The instructor has also a possibility to trigger different types of failures, from equipment failures to engine failure. ICC stand allows for replaying the flight for further analysis of flight and the mistakes of the trainee pilot.

The simulator also has a four-core high performance computing unit with two graphic cards, which allow for projecting images in available screens and projectors. Moreover, it is equipped with a high class audio system allowing to play real sound effects, what enhances the impression of realism.

Elite simulators

Elite company delivered two simulators: S923 FNPT II MCC and S812 FNPT II. The cockpit of FNPT II MCC is a typical cockpit for training in multi-engine planes according to norms JAR STD 3A. The panel for pilot is equipped with a speedometer, turn coordinator, artificial horizon, altimeter, Vertical Speed Indicator and communication panel. The part responsible for engine control contains information about the temperature and oil pressure, fuel flow, engine revolution, head temperature. Moreover, there are indicators of trap trimmer and GPS according to Garmin standard. The simulator also have a transponder steering and autopilot. Technically, the pilot panel is projected on LCD screens, on which the mask can be placed with appropriate controls and

switches. The instructor sitting in front of two ICC screens can regulate the current plane position and flight parameters. The multiplicity of the meteorological settings are worth mentioning. Weather conditions, such as wind, can be set for a particular height and direction; the turbulences can be set at the levels from 0 to 12. As for visual effects, it is possible to switch on the cloud cover from CAVOK – cloudless sky, to 1/1 – complete cloudiness; the visibility in meters and the time of the phenomenon from the take-off. Large configuration possibilities are also possible in the area of setting different failures of the aircraft, which may happen during the flight. Instructor can evoke certain conditions at a given moment or schedule the incidents ahead. Route view can be seen on a map, with the flight and its altitude. It also shows the airports and navigation tools with their descriptions and frequencies. Interestingly, the simulators detect the season, time of day and year as well as adapt visual and weather conditions.

Terrain mapping in the simulator is based on a grid sized 1 km. Consequently, the heights in the simulator may differ from the real data. The height of the airports, as primary training areas, is accurate to 50 ft. If larger accuracy is required in the place that is not a primary training area, the producer provides technical assistance and the possibility to develop the database. Projection is made with standard textures covering the area. The objects such as bays, rivers, roads are completely vectorial. The runways with approach lights,, central and side, and PAPI/VASI agreeing with the airport data are in vectors. It is possible to use a RealView database, based on VIRGIS – Virtual Reality Geographic Information System, made by the Institute of Technology in Zurich. The system is characterised by high accuracy of land coverage up to 25 m, and 75% of the land is covered with the precision of 10 m. The whole system responsible for graphics was developed on OpenGL in C++ language. Due to that the hardware requirements in visual part are relatively low. One characteristic feature of Elite simulators, which is worth mentioning, is that they are very well developed in terms of the aerodynamics and real reproduction of flight mechanics.

All the simulator parameters are coherent with JAR STD 3A, what enables running any partial training and the flying time necessary to obtain a licence/certification – flight in a simulator significantly lowers the costs of certified licences.

Currently, the simulators are used to train Information Technology students (specialisation in ICT systems in aviation) and unique programme of ICT in air transportation. During laboratory classes, students deepen that techniques of three-dimensional modelling of images used in the simulators and gain specialised knowledge on the construction and functioning of air controls. They also learn about pilotage, procedures and systems used in aviation. They will not only allow understanding the functioning of simulators but also learning about the procedures and rules during real flights. Consequently, students gain both knowledge and skills on aviation and the possibility to get employed in this dynamically developing branch of economy. Apart from training purposes, the simulators are also used in research projects financed by European Union, such as EGALITE, HEDGE NEXT and SHERPA.

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