The use of virtual flight simulation for airspace design in aeronautical engineering education

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Use of virtual flight simulation for Airspace Design on Aeronautics Engineering Education

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Abstract—**The technology of current home PC flight simulators, specially its powerful graphics and the simulator physics models, makes them a useful resource for training and education. Although it is necessary that the teacher assists the student in understanding the simulator weak areas, so as to avoid picking up misconceptions, PC flight simulators and internet virtual worlds are becoming recognized as an important training resource in aeronautics disciplines such as engineering.**

This paper presents an innovative project, developed by Escuela Universitaria de Ingeniería Técnica Aeronautica (EUITA) of the Universidad Politecnica de Madrid, to help the students to master several aeronautics disciplines. The project includes the development of a complete set of educational simulations supported by commercial "of the shelf" flight videogame simulator and Internet Virtual World for pilot and air traffic control simulation.

Keywords- component; Videogame; flight simulator; internet virtual world; aeronautics; engineering.

I. INTRODUCTION

In order to facilitate the safe, orderly and expeditious flight of aircraft from one airport to another, airspace structures, such as airways, departure and arrival instrumental flight procedures, holding patterns, etc… are defined in the airspace. The design of these procedures is a critical element for the safety of aircraft operation, as those procedures assure aircraft separation from the terrain and contribute to aircraft separation assurance once on the air.

Aeronautic engineers are actively involved in airspace design and their related activities. Airspace and instrument flight procedure design principles and criteria are part of the syllabus of the aeronautical engineering degree at the Escuela Universitaria de Ingeniería Técnica Aeronautica (EUITA) of the Universidad Politecnica de Madrid. Mastering that discipline requires a broad technical knowledge (procedure designers need to know topics such as CNS/ATM Systems geodetics and mapping, Flight Management System database coding, aircraft performance, noise modelling, etc…), but also an in depth understanding of how aircraft flight (principles of flight) and a kind of sensitivity in order to understand and anticipate the impact of the procedures on aircraft operation.

According to the International Civil Aviation Organization (ICAO), flight procedure designer training must be competency based education. Being conscious that one of the basic problems in engineering education is the understanding of theoretical knowledge gained in engineering courses and its use in practice, at EUITA an innovative project has been developed to help the students to master this area of knowledge.

A specific course in the later stages of the degree on aeronautics is devoted to this discipline. The course includes a theoretical part devoted to the principles behind the standards, and a practical part. In the practical part the students master the practical abilities required by designing themselves instrumental flight procedures and develop the sensitivity required by flying, the procedures they have previously designed, on a low cost flight simulator. That way students can see the results of their work and better assimilate the design principles. This flight simulator has been specifically developed by professors of the Infrastructure, Aerospace Systems and Airport Department, for that purpose based upon a commercial "of the shelf" flight simulation videogame, called X-plane.

The innovative component of the project lays on the use of commercial "of the shelf" flight videogame simulator for recreating the virtually real environment of an aircraft cockpit on which real learning could take place.

More over professors of this academic course have developed a complete set of educational simulations, where the students and the learning process becomes the centre. Those educational simulations are at the same time instructive, motivating and fun.

Additionally, based the encouraging results of this experience, the same team of professors have investigated the suitability of one popular "Internet Virtual World" (devoted to aircraft, pilot and air traffic control simulation) for education purposes. The investigation discusses the functionality and features, and assesses its perceived limitations for its use in educational context with a particular focus on the ability to link /integrate the Virtual World with existing learning environments.

II. AIR NAVIGATION AND AIR SPACE DESIGN

Air navigation System encompass all the infrastructure, technical and human resources that are required to facilitate that the aircraft can define their trajectory and fly safely and expeditious from its origin to its destination [1]. In order to facilitate the orderly movement of the aircraft, airspace routes, airways, instrument flight procedures and others airspace structures need to be defined.

Airspace design is therefore an essential part of the air navigation System. It is intended as the implementation of instrument flight procedures and the development of a system of routes able to guarantee a safe and orderly flow of air traffic, both over flying and directed towards destination airports.

In an ideal world, airspace design would make it possible for arriving, departing and en-route flights to operate so that they did not have to cross one another, or climb and descend through each other's flight levels. Furthermore, approach and take-off flight paths would be free of obstacles. Unfortunately, however, this "ideal" design environment is seldom possible. It means that airspace designers need to take steps to reduce the likelihood of aircraft encounters and crossings, as well as to assure that the probability of an aircraft collision with the terrain is avoided, or at least reduced to a level "As Low As Reasonable Practicable" (ALARP).

The proper planning and design of routes, holding patterns, arrival and departure instrumental procedures, airspace structures and ATC sectorisation in both terminal and en-route airspace can be effective in reducing the likelihood of aircraft accidents or incidents. The converse is also true: poorly designed airspace can create situations where accidents or incidents are more likely to occur [2]. For example, while not actually causing them, poorly designed airspace can increase the risk of loss of separation between aircraft, and Controlled Flight Into Terrain (CFIT).

Airspace and procedure design should follow the principles laid down in ICAO Annex 6 "Aircraft Operation"[3], ICAO Doc 8168 (PANS-OPS) [4] and Doc 4444 (PANS-ATM) [5]. PANS-OPS provide criteria for the design of instrument approach, holding and departure procedures. PANS-OPS provisions also cover en-route procedures where obstacle clearance is a consideration. PANS-ATM provides procedures for air navigation services, whose basic tenets form the basis of airspace design. EUROCONTROL provides guidance material for airspace design and PANS-OPS procedure design through various documents such as the "Manual for Airspace Planning" [6] and the "Guidance Material for the design of Terminal Procedures for Area Navigation" [7].

Instrument flight procedure design is a complex field of activity. Air traffic volume grows worldwide, terminal airspaces are more and more congested, air navigation technology evolves and environmental issues are certainly not decreasing. More and more the procedure design expert has to address many issues and good and continuous training become one of the key elements in creating safe and efficient instrument flight procedures. For the contemporary procedure designer it is vital not only to know the design guidance material such as PANS-OPS, but more and more also other related topics such as geodetics and mapping, FMS (Flight Management Systems) database coding, aircraft performance, EU-OPS [8] and noise modelling. Mastering basic principles in those areas is a prerequisite.

Aeronautic engineers play a major role in airspace design and in related activities, concerning the design of instrumental flight procedures, radar maps and the management and optimization of national airway system. Therefore, instrument flight procedure design is one of the areas that aeronautical engineering degree students needs to master [9].

According to ICAO [10], Flight Procedure Designer Training must be competency based. This results in a fundamental difference from traditional education. Traditional education is centred on the teacher and the unit of progression is time. While in competency based education however, the teaching is centred on the learner and the unit of progression is the mastery of the skills [11,12,13,14].

In assure that the students gain the required competency professors at EUITA have design a program that combines and incremental use of flight simulation technologies in the learning process and a set of educational simulations. In particular, these set of educational simulations have been designed to be executed under two different state of the art simulation platforms presented in this article:

- A commercial of the shelf PC flight simulator used for recreating the virtually real environment of an aircraft cockpit on which real learning could take place.
- A popular "Internet Virtual World" devoted to aircraft, pilot and air traffic control simulation.

III. Incremental use of simulation technologies in competency based education and active learning.

Technology and teaching-learning are two concepts that have come into close relationship as the former has been developed. The incorporation of new technologies in the field of teaching is facilitating the implementation of new learning methodologies: constructivism, problem based learning, case-based learning, learning by doing, active learning, etc…

All these new forms of learning focus on the student not on the teacher, and represent a greater involvement of the student in the learning process. World experts in the field of education confirm the greater efficacy of these methods [15]. Dr. Larson from the MIT argues that students should do, practice, experiment, play and manipulate concepts, and also have fun [16]. Active learning could hardly more graphically been described than with the expression "learning by doing". This is important in business and humanistic teachings [17], and it is even more important in the scientific or technical disciplines where practices have always been a major component in learning.

In this sense, simulators, virtual laboratories and virtual worlds provide powerful tools through which students can "do and learn." Each of these technologies, as illustrated in fig. 1, are an incremental step in the process of enhancing interactivity, and provides students the opportunity to act and see how different decisions affect the outcome of a problem. The suitability of one or the other will depend on the characteristics and needs of the knowledge to be reinforced through these complementary ways of learning, an it will also depend on the number and profile of the students.

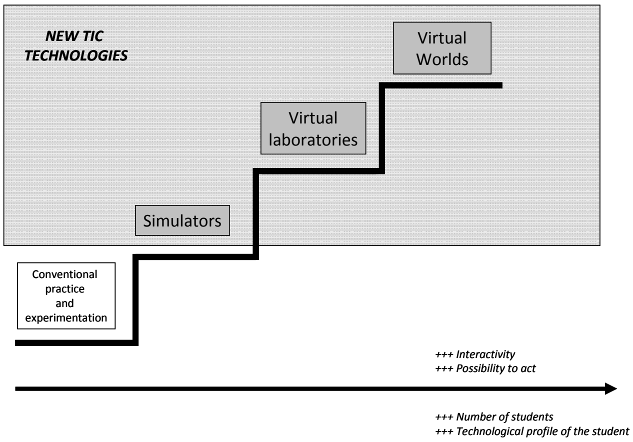

Figure 1. Incremental use of simulation technologies in the learning process.

In this sense, the project presented in this paper is a commitment to incorporate new technologies in the educational process promoting the students active participation through a experience centred on the student learning process. Besides teaching purposes, it is understood that from student's the point of view, it would be very exciting to have a series of educational tools, some of them accessible via the Internet, enabling them to reinforce and practice those skills outlined in the lectures.

IV. USE OF AN AD-HOC PC-BASED FLIGHT SIMULATOR IN THE LEARNING PROCESS.

Simulators are computer programs that let us work in a virtual environment with complex technical artefacts and test their operations as if they were a real environment. Simulation applications are often used to simulate real processes. Some of these applications have transcended the engineering field and have become consumer general purpose products, such as flight simulators.

Simulation environments are a privileged field for multidisciplinary activities in education. The simulators allow rapid and effective comprehension of complex concepts. A simulator has a major advantage over a text or a classroom teacher's explanation: interactivity. The students can "play" with different parameters and observe the results.

The first flight simulator in the aerospace industry was installed by the Pan American Airways in 1948. It had no screen and consisted of a series of analogue clocks that reproduced the basic instrumentation of the aircraft. This first simulator allowed pilots to be instructed in emergency situations, and practice whole flights only with the help of the instruments on board.

When most people think about flight simulators they picture the giant full-motion simulators used by the airlines. However, there are many other types of flight simulators as well, including commercial software packages that run on a home PC.

Pilots use these PC simulators in their initial training. This application helps them to get familiar with the flight instruments without any risk. It also offers the chance to get used to the aircraft instrumental response in situations that do not occur in normal conditions: engine failure, stalls, etc... An additional advantage is the wide range of aircraft, airports and airspace available for simulation. The performances of these PC simulators are so good that pilots keep using them after the initial training period.

These types of simulators are also used in the training of air traffic controllers. There are PC simulators that can reproduce the environment and the actions of an air traffic controller, including its interaction with aircraft and other controllers. Moreover, the integrated use of flight simulators and ATC simulators gives aeronautical engineering a number of possibilities to enhance the teachings related to air navigation and air traffic control.

The technology for these products has advanced considerably, allowing for surprisingly realistic experience. As a result PC flight simulator are gaining acceptance within the aviation community for been used not only as pilot training device, but also as training tool in other aeronautics disciplines such as engineering [18,19,20].

In this regard the Escuela Universitaria de Ingeniería Técnia Aeronaútica (EUITA) from the Technical University of Madrid has pioneered this field by building a flight simulator from a commercial of the shelf PC flight simulator. This simulator was used during the last year of the degree of aeronautical engineer, to master the skills needed in air navigation and flight procedures design, throughout the execution of a set of educational simulation exercises.

Fig. 2 presents the low cost simulator build for this educational experience. The simulator is based upon commercial of the shelf products describe here after.

- Simulation Engine: X-Plane is a flight simulator for personal computers produced by Laminar Research. It runs on iPhone/iPod Touch, Palm's WebOS, Linux, Mac or Windows. X-Plane could be packaged with other software to build and customize aircraft and scenery, offering a complete flight simulation environment. X-Plane also has a plug-in architecture that allows users to create their own modules, extending the functionality of the software. Simulator is configured on just two PCs connected by an Ethernet cable, one located at the cockpit and the other one at the instruction post. The main screen on the cockpit shows scenery view for the student and the auxiliary monitor, placed at the instruction post, can show panel or map or instructor console.

- Flight console: The AV-IFR is Flight Link's "flag ship" designed to be used for complex, high performance single engine as well as multi-engine training. It includes as mayor features: full size control wheel, Cessna style throttle, prop pitch and mixture control, servo-powered electric trim, heavy duty tactical feel gear and flap switches, push-to-talk and elevator trim switches on left side of grip AND four way view switch on right side of grip.

- Sub Panel: The Flight Link Sub Panel mounts to the bottom of the Flight Console and allows the pilot to control most of the systems found in all high performance single engine aircraft. It main features are: Magnetos key switch, Starter button, Master (ELEC., ALT., Avionics) rocker switches, Pitot heat rocker switch, Fuel pump rocker switch, Lights (NAV, Land, Taxi, BCN) rocker switches, Four position (off, left, both, right) fuel selector, Cowl Flaps, Three system operation buttons.

- Rudder Control Module. The Rudder Control Module (otherwise known as the RCM) uses industrial grade hydraulic cylinders which simulate accurate damping effect found while in flight.

- KR-1 Avionics Stack: It incorporates Bendix-King standard equipments for general aviation avionics. It main features are: realistic dual concentric radio knobs, orange gas plasma displays, two KX 165 NAV / COMM's, KR 87 ADF , KN 62A DME , KT 71 transponder , KFC 150 autopilot , OBS 1 & 2, altimeter and DG concentric knobs, individual marker beacon lights, full functioning red and green gear lights and HOBBS meter.

This simulator provides something different from what can provide the explanation from a teacher or a book: interactivity, the ability to act and see how different decisions affect the outcome of a problem.

With everything said so far, it seems surprising that the simulators are not essential learning tool in teaching. Unfortunately, the use of this type of simulators on teaching is affected by certain limitations. Simulators are still relatively complex and expensive tools that required skilled staff for installation, maintenance and use. Their use as teaching tools might involve a heavy workload. For example the use of flight simulators with a conventional approach to teaching involves sequential use of the facilities, with continuous teacher supervision, which makes it unfeasible to design a program for a large number of students.

It is necessary therefore to explore other technologies to extend the principles and benefits of the use of simulation training to a large group of students.

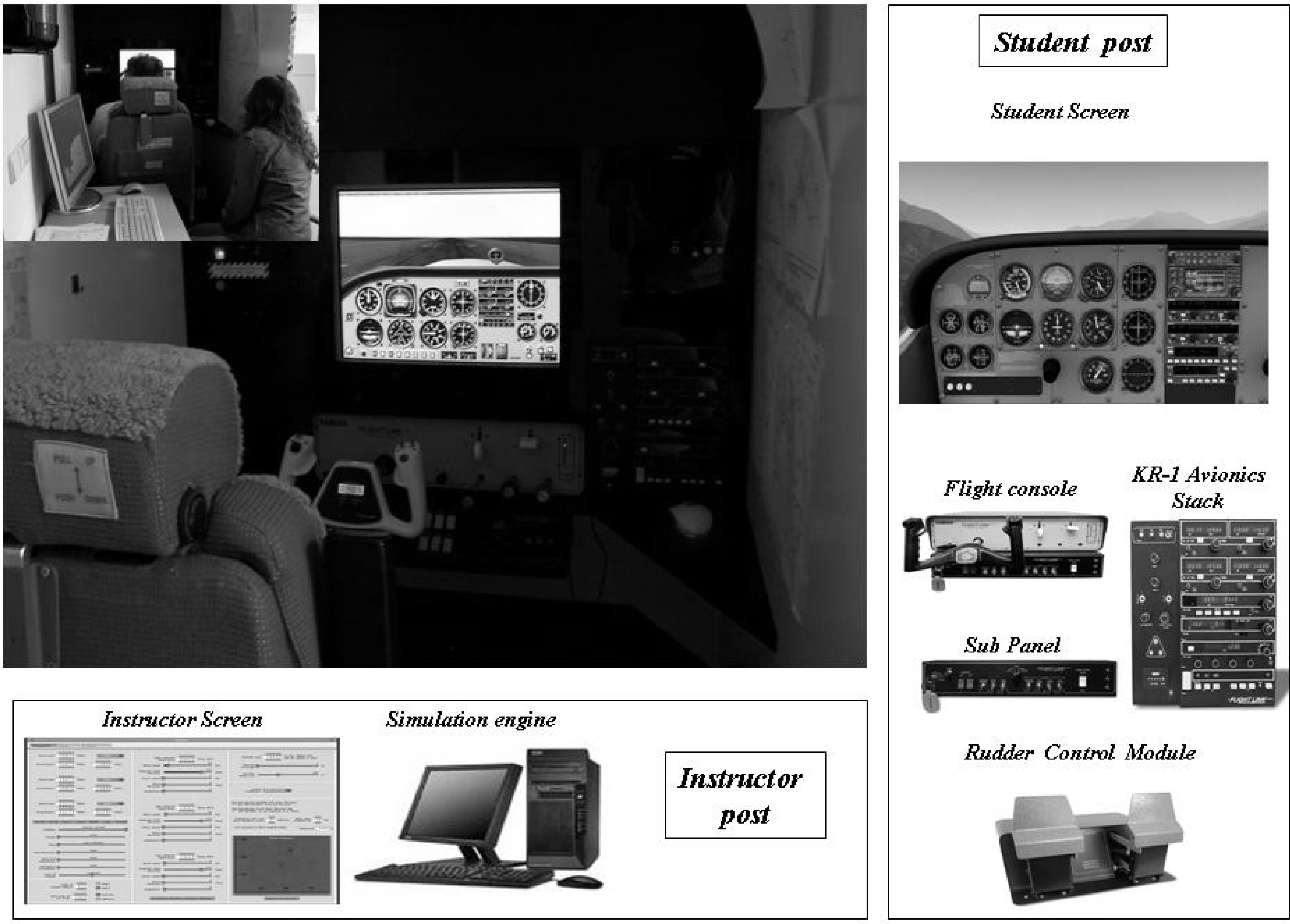

Figure 2. Low cost simulator for educational simulations.

V. USE OF AN AD-HOC FLIGHT VIRTUAL WORLD IN THE LEARNING PROCESS.

The state of the art in the integration of simulation technologies in the learning process is constituted currently by the "virtual worlds." For educational purposes virtual worlds can combine into a single environment the advantages of conventional simulators and its ability to reproduce reality of complex systems with the ease of access and interaction of virtual laboratories

A virtual world is a genre of online community that often takes the form of a computer-based simulated environment, through which users can interact with one another and use and create objects [21]. Virtual worlds are intended for their users to inhabit and interact.

Today's virtual worlds are immersive, animated, 3D environments that operate over the Internet, giving access to anyone in the world. Many online games take place in such environments. The computer accesses a computer-simulated world and presents perceptual stimuli to the user, who in turn can manipulate elements of the modelled world and thus experiences telepresence to a certain degree [22]. The model world may simulate rules based on the real world: gravity, topography, locomotion, real-time actions, and communication. Interaction with other participants is done in real-time, although time consistency is not always maintained in online virtual worlds. Some virtual worlds offer an online persistent world, active and available 24 hours a day and seven days a week.

In April 1999, Numedeon Incorporated launched Whyville as the first virtual world explicitly designed to engage young students in a wide range of educational activities. With a player base of over 3 million [23], Whyville has been particularly successful in attracting young teens [24].

Today a growing number of universities and other educational institutions are exploring existing general purpose virtual world platforms as a means to extend and enhance their offerings to students. Typically, educators create an online presence where students can interact, using their avatars to learn about new assignments or create projects that are viewable within the virtual world. Dartmouth College [25] has begun creating a virtual world to train community emergency response teams. In this world, volunteers learn how to cope with a range of emergencies by experiencing simulated, 3D disaster areas while engaging with others—virtually—to deal with unfolding events. Harvard University [26] created River City, a virtual world that presents users with an outbreak of disease, allowing them to move through the environment, make inquiries, and examine data to try to discover the source of the illness. Using a game engine, the University of British Columbia [27] developed a virtual world based on real archaeological sites in which students use contemporary materials and techniques to create replicas of structures of the time.

But perhaps the most popular virtual worlds in education is Second Life. This virtual world, primarily with a recreational purpose, also served as the basis for the development of multiple educational applications. In [28] http://es.elearning3d.wikia.com it is possible to find a complete list of references from Spanish-speaking higher education institutions that have used Second Life as virtual platform in education.

In the field of aerospace teachings, Purdue University has pioneered this field with an engineering course of aerospace design through a virtual world [29]. The university has developed an introductory course in aerospace design that coordinates several aerospace design engineering. Students working in teams by projects and develop documents and presentations.

More specifically there are virtual worlds on the internet focused on flight simulation and air traffic control that can be used as educational and entertainment networks. A virtual world of flight simulation is a cooperative simulation tool on the Internet with real scenarios of air navigation and air traffic control, where students/users can develop an active role, as pilot or air traffic controller.

Those virtual worlds are dedicated, independent, and free of charge, services to enthusiasts and individuals enjoying and participating in the flight simulation community worldwide. In general they supply high quality services to its users on demand.

The primary objective of these networks is to provide the flight simulation community a highly realistic aviation environment. That implies to provide:

- An experience which is "As Real As It Gets" while having fun in a friendly atmosphere,
- Supplying the required internet services, and
- Information and training in real life procedures for both pilots and air traffic controllers.

They include a real-time system for online flying (as pilot) and controlling (as air traffic controller), databases with aviation information, and organizing training and online events. They allow users, fly and/or control in the most realistic as possible, with real weather, through an online connection in real time via the Internet.

These virtual worlds are educational and entertainment networks. They are developed to meet the needs of entertainment enthusiasts into the world of aviation and virtual flight. The virtual flight community encompasses all fans of flight simulators. They enjoy the entertainment of flight simulation in different routes with different aircraft. On the other hand, they are educational networks because they are designed to form in the world of air navigation and air traffic control, ensuring the dissemination and acquisition of real and credible expertise among their users.

These networks allow fans to flight simulation and ATC simulation meet and interact in a realistic environment. They make it easier for pilots and controllers to interact as a community on the Internet in real air navigation and air traffic control scenarios. These communities have their internal code of conduct in form of terms of use. They are offered free of charge conditioned on the acceptance of the internal rules and regulations, normally published on their website. The network staff use to provide technical support and in most cases they also provided the approved software required to connect to the network.

The most extended flight simulation virtual world is IVAO, the International Virtual Aviation Organization. In particular the mission of IVAO (The International Virtual Aviation Organization) is "to provide an environment for a realistic flight and air traffic control simulation via the internet, utilizing IVAN (International Virtual Aviation Network) without charging money and available to anyone who agrees with the membership requirements". Fig. 3 shows the main components and elements that make up these virtual worlds, and thus are available and accessible to users.

The experience shows that virtual worlds can represent a powerful media for instruction and education that presents many opportunities but also some challenges [30]. The use of virtual worlds can give teachers the opportunity to have a greater level of student participation. It allows users to be able to carry out tasks that could be difficult in the real world due to constraints and restrictions, such as cost, scheduling or location. Virtual worlds have the capability to adapt and grow to different user needs and they can be a good source of user feedback, the typical paper-based resources have limitations that Virtual Worlds can overcome.

Virtual world can also be used as virtual learning environments, as in the case described in this paper. Virtual worlds allow users with specific needs and requirements to be able to access and use the same learning materials from home, as they would be receiving if they were in the presentation. This can help users to keep up to date with the relevant information and needs while also feeling as though involved. Having the option to be able to attend a presentation via a virtual world from home or from their workplace, can help the user to be more at ease and comfortable. The flexibility of virtual worlds has greatly improved the options for student study and business collaboration. On the contrary, although virtual worlds are a good way of communicating and interacting between students and teachers, this is not a substitute for actual face-to-face meetings. When using virtual worlds, there are the downsides in that you lose the body language and other more personal aspects.

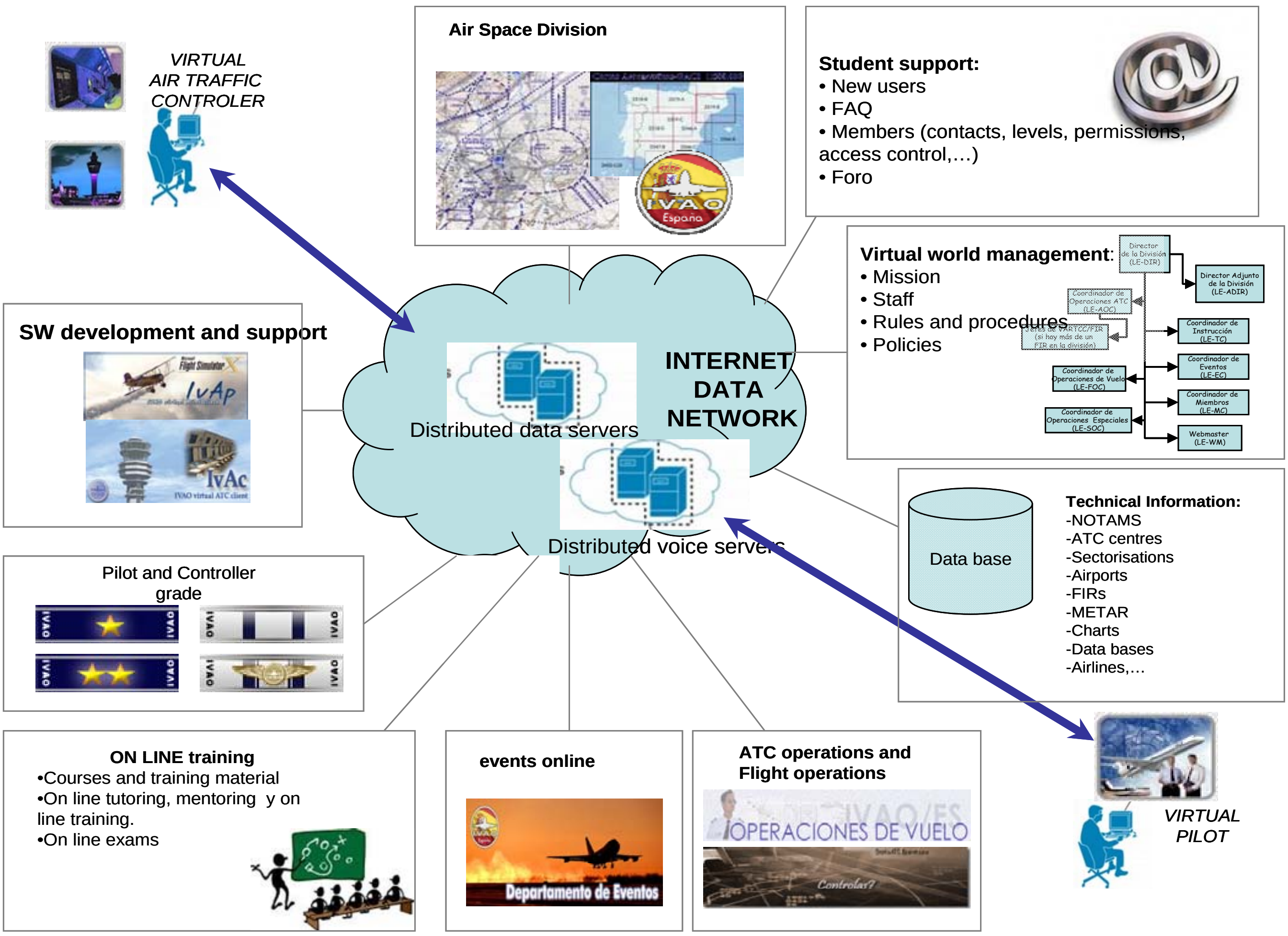

Figure 3. Flight virtual world components.

VI. EDUCATIONAL SIMULATION FOR AIRSPACE STRUCTURES AND INSTRUMENT FLIGHT PROCEDURES DESIGN.

Besides the technological platforms used, a fundamental element of this project is the set of educational simulations developed to master the knowledge required for airspace structures and instrument flight procedures design.

The main objective of these practices is that students assimilate the basic concepts of the air navigation. This means that:

- the students understand and internalize the principles of flight and air navigation;
- they check, from the point of view of the pilot, the operational use of the various systems explained during the course (radio air navigation aids, communications and surveillance systems), and
- they work with different airspace structures and instrument flight procedures.

To achieve this goal the professors have organised a set of flight instruction exercises that allow the students to experience the principles of flight in a realistic environment. The program includes four two-hour practices each, aimed to assimilate the concepts related to flying and more specifically with the instrumental flight, including: basic flight manoeuvres, aircraft instruments, air navigation instruments, flight procedures, etc ...

The first of these practices is an introduction to basic flight and to VOR (Very high frequency Omnidirectional Range) and ILS(Instrument Landing System) air navigation. This practice is a first contact with the simulator and is designed to familiarize students with the basic flight manoeuvres, straight and levelled flight, coordinated turns, fly a heading, etc ... It also serves as making contact with the VOR air navigation principles and the ILS instrument approach landing procedures.

The second practice is to reinforce the concepts learned in the previous one. To this end, the following manoeuvres are exercised: flying an inbound or outbound VOR radial (TO-FROM a VOR station), intercepting an inbound/outbound VOR radial, radio interception, defining a waypoint as a DME distance along a VOR radial, flying an instrument approach procedure based upon an ILS approach. It will also include flying inbound / outbound ADF tracks.

The third practice is based primarily on the techniques for flying a holding pattern, the execution of the various holding pattern entry procedures (direct, parallel and teardrop) and the execution of procedure turns (a manoeuvre prescribed when it is necessary to perform a course reversal to establish the aircraft inbound on an intermediate or final approach course), etc…

The last practice is a full flight of about an hour between two nearby airports. The simulated flight consists of all the typical phases of any instrument flight: standard instrument departures (SID), en-route, standard instrument arrival (STAR), instrument approach and landing at the aerodrome of destination. During the flight all the air navigation concepts practised earlier are exercised. The students work with the actual air navigation charts, so they can identify, among other data, communication frequencies and air navigation aids, the different procedures of departure, arrival and approach transition altitude, etc ...

It is very important that, before affording this practice, the students are thoroughly familiar with the flight to be undertaken, since the high workload for the pilot, students in this case, is a feature of all IFR flight. In this case also the inexperience is an aggravating factor.

The practices are organized to facilitate an introduction and progressive mastery of flight techniques. All of them include a guide that the student should work before the execution. This guide includes some exercises, usually on calculations related to the flight, that the student must do in advance to verify that he has understood and assimilated the basic concepts to be exercised during the simulated flight. The guide also includes exercises that the student must complete once they have done the practice. Due to limited time available to complete the practices, it is vital that students prepare thoroughly the practices prior its execution. An understanding of the practice and implementation of previous exercises will optimize the use of the simulator and student learning. Additionally the student is provided with a detailed description of the flight simulator and its operation, and he will receive instruction about flight theory in the context of the simulator to be used. The practices are carried out individually by each student, which will be helped and supervised by professor throughout the complete duration of the practice.

Additionally to complement the course, students design instrument flight procedures that they flown later on in the simulator, with the help and guidance of teachers. Through these exercises the student verifies that the procedure outlined is correct, the calculations are well made and the procedure can be flown. Moreover, this process allows engineers to see what a pilot will experience when flying the procedure. Additionally, as part of this exercise, students assimilate and internalize in a natural way the essential concepts of air navigation, air traffic control organization and structuring of airspace have been provided along this and other related subjects

This experience offers students the opportunity to grasp the essential concepts of air navigation and air traffic controllers or pilots practicing for the air traffic in a controlled and realistic. It will be difficult to find people who would prefer a traditional theoretical exposition. This confirms to us that we all like to experiment with what we have to learn. Probably our experience tells us that everything we've been taught but not practiced we have not learned properly.

VII. ELEMENTS OF A SUCCESSFUL EDUCATIONAL SIMULATION.

On this experience the three essential elements that, according to Aldrich [31], can be used to create successful educational experiences, are included: simulation, game and pedagogical elements. Simulation elements enable discovery, experimentation, practice, and active construction of systems, cyclical, and linear content. Game elements provide familiar and entertaining interactions that drive up the time spent by the student within the educational experience. Although they do not directly support the learning objectives, they are, as Aldrich says, the "spoonful of sugar that helps the medicine go down." Finally the pedagogical elements are the background material that supports the content. These elements are the more important. They should drive the learning experience and organize the other elements around it.

Additionally, based on the previously described work, the following points have been identified as key issues for developing a successful educational simulation program. First of all, simulations should be real or virtually real; that means that they must simulate the core part of the activity well enough that real learning could take place. This concept of simulating reality is key for educational purposes as introduced by Rheingold [32] in its book Virtual Reality where he deals with the technology that "...creates the completely convincing illusion that one is immersed in a world that exists only inside a computer". Luckily the sophistication of modern PC flight simulators is so high that the ground school portions of what is required for a beginner's pilot license can be learn on the computer[1]. In this case the PCs slight simulator has been integrated in a physical mock-up of an aircraft cockpit with real instruments providing an even more realistic environment.

The second crucial element is the proper plan of the simulation exercises [33,34]. A very important factor for success is to define clear objectives for each exercise developing a clear picture and understanding of what students are expected to learn. It is useful to prepare the exercise with the student on a briefing session where the purpose of the simulation should be clearly explained. Exercises should be designed in a way that facilitates the students to become participants, not just listeners or observers. Exercises should also be motivators and get the student involvement in the activity. Fortunately, current flight PC simulators are conceived like video games so the player becomes the centre of the activity. More over, besides the complex graphics and technical performance of simulators, they are fairly easy to use even for those that have never played before. Only little training on the features of the simulator is required to get the student prepared to execute the educational simulation exercises.

The third important element is the teacher [35]. The use of simulations puts the teacher into a new role. Its role in this educational experience is no longer that of a presenter of information but is that of a guider or coacher, that help the student in the learning process. This function is the inevitable result of the evolution of the role of the teacher in education. With the use of this kind of simulations the teacher moves to its new part naturally. In that sense this experience is also very interesting and useful for teachers and constitutes a learning experience for them. Each successful simulation should also include a "coaching guidance" component, to help the learner through the tasks and to provide advice at various levels of detail along the way, and a feedback component, that provides the learner with information on how well he or she performed the task [36]. These new roles have to be played by the teacher in this new experience.

[1] *X-Plane* is also used in non-motion and full-motion flight simulators for flight training. Some of these implementations have been certified by the FAA for authorized flight instruction such as Flight Level Aviation and Simtrain.

VIII. CONCLUSIONS

The technology of current home PC flight simulators and virtual worlds, specially its powerful graphics and the simulator physics models, makes them a useful resource for training and education.

Although it its necessary that the teacher assists the student in understanding the simulator weak areas, so as to avoid picking up misconceptions, fight simulators are being more and more used as training tool in aeronautics disciplines such as engineering.

One of the values of a good simulation is its ability to develop concepts and conceptualization. Properly designed educational simulations are a kind of event that allows students to internalize major concepts. Simulations can provide effective learning; allowing learners to practice skills in a realistic environment.

Nevertheless the success of an educational simulation requires an emphasis on the educational components rather than just the simulation aspect. The goals of educational simulations must be not only to provide a practice environment, but to provide a specific learning environment (with some type of guidance and feedback for the teacher).

A powerful educational experience focuses on the learning objectives and frames other elements around it. It can not be decided what to model (simulation elements) or what to reward (game elements) until the learning objectives and the pedagogical elements have been established. Additionally the use of coaching guidance and feedback, in each of the simulation-based learning programs has to be carefully designed to suit the students and the skills being taught.

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