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Simulation Mechanism with 2 Degrees of Freedom

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Abstract ***— This article discusses the historical analysis of the development of simulators applied to aviation. From the development with the application of the first necessity, at the beginning of the 20th century, to the nowadays technology. Today the technology is used in several fields, justifying the increasing business investment destined to the sector, such as training, recycling, development and entertainment. Its advantage, compared to the real model, is the lower cost and greater security. Some simulator mechanisms were studied in order to select one that meets practical usage demands, and, in the end, a mechanism design is presented, aiming at the future construction and*** study of the different systems of a simulator in practice.

Keywords — Aircraft, Simulators, Design, 2DoF.

I. INTRODUCTION

The advent of aviation brought the need to introduce practical and theoretical concepts for the future pilots. At first, those theoretical knowledges were developed in classrooms, with the complement of the practical part realized in real structures, susceptible to the risks and with high expenses.

The development of simulators, in order to replicate the actual conditions, came to supply this market demand. Capable of simulating not only everyday situations but also the most dangerous ones, avoiding the inherent risk and reducing costs.

Over the years the simulators have had their functions expanded and improved, movements have been linked, insertion of images and sensations, all in view of increased realism of the simulator.

And, even if it was developed with professional bias, today we have simulators on the market to meet the diverse ranges, from research and development to future aircraft, to the training and recycling of pilots and crew and even for the entertainment industry, being used for leisure.

The **Fig.1:** *Current simulators with cab replication* shows the appearance of current simulators, where it is replicated to the aircraft cockpit.[1]

Fig.1: Current simulators with cab replication

Thus, this article is divided into 8 chapters, which will be presented, after a brief introduction, a history on flight

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simulators, aircraft main movements, types of systems and platforms, and a project, aiming to develop future drafting work of a complete simulator with all operating systems, with lower costs and safety.

II. HISTORY OF SIMULATORS

Simulators are systems capable of simulating the behavior of some situation. Reproducing from physical sensations, to the output response, without the need for total element construction. Some aspects, however, require external components, such as those that respond by movement and perform speed sensations, or screens that copy visual stimuli.

In the specific field, aeronautical simulators are used since the first models for the training of pilots, however infidel the real conditions, as shown **Fig.2**, below. One of the first mechanisms developed was the Billing type, created in England in 1910, which was an airplane fixed on a universal joint, attached to the ground, and used for students to replicate the necessary movements and maintain balance in flight.[2]

Fig.2: Antoinette type simulator

Until the First World War, advances were restricted to mechanical components, which sought to replicate more flight situations, without the need for external factors, or help from other individuals. With the simulator, developed by Ruggles, as shown in **Fig.3**, which consisted of a ring-mounted seat that allowed the total rotation of the student on the three axes, besides vertical movement, produced in response to the user's movement through electric motors, this structure already allowed the simulation of aerial combat situations.[2],[5]

During World War II, the computer simulation had its great leap, both with the American Navy, with the *Mark I*, as with the army, with the *ENIAC*, using the computers, which were large and slow, of the time for simulation of missile launches.[3]

Simulators with visual systems date back to the late 1950s, where they used the cinema projection system, or closed-circuit television, with images recorded from a real airplane. Even special instruments were used at the time in order to map the land, but the approach was not very practical and rather limited.[4]

Until the 1970s the production of simulators was extremely expensive, limited to large corporations and universities. The simulators of the time were limited not only by technology, but also by the workforce. Those responsible for develop, operate and maintain should possess thorough knowledge, which further becoming more expensive the project.[3]

Finally, in the 1970s, CGI (*Computer-Generated Imagery*) system began to replace the recorded images, but still in a very simplified and limited way by the processing of the computers of the time. Due to military necessity, which required more complex simulations, such as high-speed flights, attack situations and agile maneuvers, the CGI was further stimulated.[4]

Fig.3: Ruggles Advisor Simulator

In the 1990s, with the reduction of the equipment costs, increasing the processing capacity and simplifying the tools used in the development, the use of the simulators became more intense, being used as an efficient means to elaborate the projects, animations and research.[4]

The future will tend to raise the levels of complexity of the simulation, being even more flexible to deal with varied situations and not presenting problems to the user's decision, which would render their main function unfeasible: to replace, in the most realistic way, the real system.[3] The **Fig.4** presents a modern simulator, possessing total freedom of movement and visual system totally immersive.[6]

Fig.4: Modern simulator, with total freedom of movement

III. AIRCRAFT MOVEMENTS

Any aircraft will rotate around its center of gravity on a flight and may therefore define the orientation of the aircraft by the amount of rotation along its three main axes, the **Fig.5**: *Aircraft Rotation Movements* below shows the movements of the aircraft.[7]

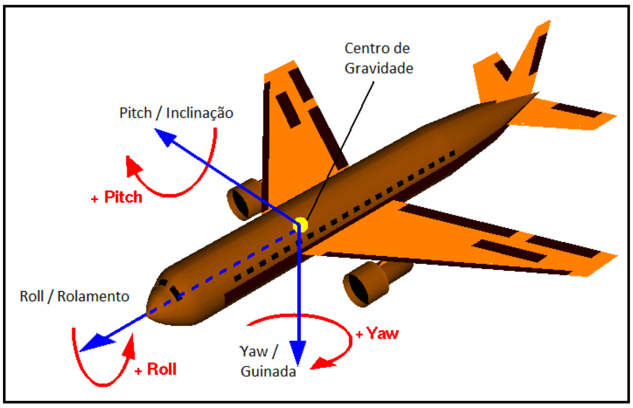

Fig.5: Aircraft Rotation Movements

The main movements are:[7]

- *Pitch*: is the movement around the transverse axis, which moves up, or down the aircraft;
- *Roll*: is the rotational movement around the longitudinal axis of the engine;
- *Yaw*: is the rotation movement around the vertical axis.

IV. CLASSIFICATION FOR USE

The simulators are used in several segments, such as the design of new aircraft construction, civil and military training and, more recently, for the entertainment industry. The classification of the simulators is made considering: the subject, or the object to be analyzed; the simulation itself; or pilot-focused.[8]

- Research and Development: the simulators are used to determine the real perception of the reality that the system passes, seeking the improvement of the same. Branch that provides innovations to the area to search for the faithful representation of reality.
- Engineering use: the use in this field involves the development, or improvement, of an aircraft, using the simulator to analyze the behavior of the design phase from the idea to the production.
- Use for training: simulators used in training and retraining of pilots and teams.

1. SIMULATOR SYSTEMS

It is the various items that can compose a simulation mechanism, the greater the complexity, the greater the cost and the greater the reproduction of real conditions found.

1.1. Audio-visual system

A fundamental part for the user interaction with the simulator, composed of one or more image sources, sound system and flight replication software. **Fig.6** presents the interface of one of the most used software developed by Microsoft.

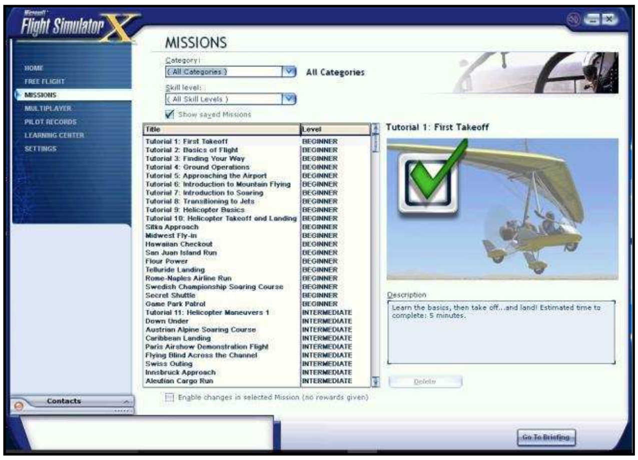

Fig.6: Flight Simulator-X Interface

1.2. Interface Systems

Performs the communication between the visual system and platform controllers. There are several programs that stand out in this functionality, the most used are *Link2FS* and *ArdSim*. **Fig.7**, below, presents the *Link2FS* settings screen.

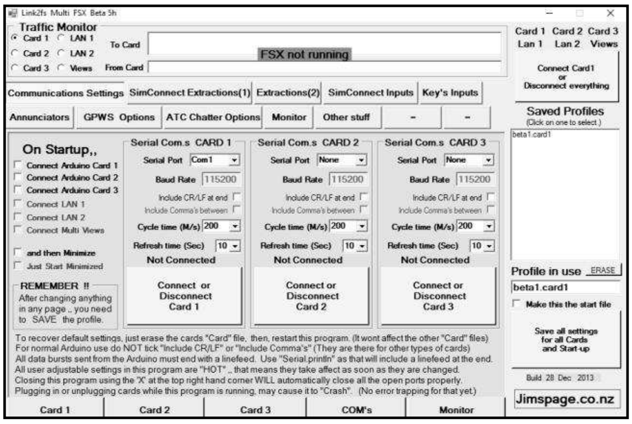

Fig.7: Link2FS Configuration Panel

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1.3. Activation System

They are responsible for promoting the movement of the mechanism, responding to the user's command and replicating it.

1.4. Control system

They realize, through sensors and controllers, the movement of the activation system, in accordance with the command given by the user.

1.5. *Structural* System

They are the components that must withstand the design efforts, from applied loads, to the torque of the movement.

2. MECHANICAL SYSTEM

Some of the platforms on the market are presented in the topics below.

2.1 DIY Mini-Motion Platform

Fig.8 shows the first model evaluated. It has 3 degrees of freedom: with pitch, roll and vertical translation.[9]

Mechanism consisting of a movable part, supported by a joint positioned in the center of gravity.

The translatory movement, obtained through the telescopic support, allows 85mm of total displacement, while the pivoting movements allow an angle variation between ±9° for the pitch of ±13° for the roll.[9]

This platform has its project totally available for construction, accessible through the internet.[9] However, details of ergonomics and reduction of expenditures with materials are the disadvantages seen in the mechanism.

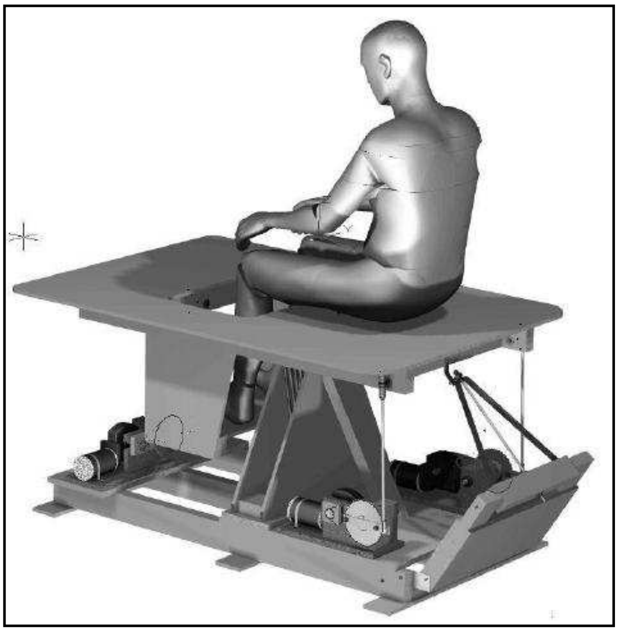

Fig.8: Simulation platform with 3DoF

1.6. Camps Party Platform

The simulator, shown in **Fig.9***: Model in X, presented in the CPBr5*, presents the model seen in the Brazilian technological event, called the Campus Party edition number 5. This platform has 2DoF, making the movement of *pitch* and *roll*, with complete freedom of rotation with 360° turns in both cases. The load is supported by the shafts, which also transmit the torque from the drive.[10]

The major drawback of this simulator is the necessity that the components are fixed in structure and can be subjected to vibrations mechanism.[10]

Fig.9: Model in X, presented in the CPBr5

3. DEVELOPED MODEL

Considering the elaboration of a platform with cost-benefit and safety and the analysis of some existing models, a model was proposed, in order to be used later in a mechanism with the other systems.

The model of **Fig.10**, was designed in SolidWorks in order to lower expenses with materials and maintaining the freedom for the simulation.

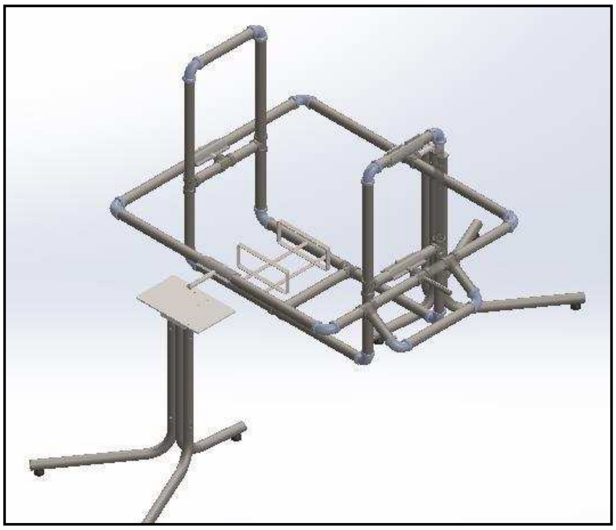

Fig.10: Platform with rings proposed

Based on a commercial ASTM A-36 steel frame, 2" and schedule 80. This choice was due to the structural aspect, visual and ease of assembly of these components from their own connections, which would be connected through welding, or threaded.

National manufacturers' catalogs were used, in the case selected Comforja, both for dimensioning the tubes, from measures already established in the initial design, and for the dimensioning of the connections used.

It was used the standards ANSI B 36.10 for tubing thickness and external diameters and ANSI B 16.9 for the connections.[11]

There are 3 main parts, divided into:

- Support: promoting the support of the mechanism, with two tripods;
- External Ring: generates the rotation movement, around the axis, and simulates the pitch movement of the mechanism;
- Internal ring: generates the rotation, around the axis, and simulates the roll movement of the engine. It also supports the user and the audiovisual system.

The movements were limited mechanically ±40° for *pitch* and *roll* as a safety measure and would already serve several real flight situations.

With a total of 3.5m wide, 2m long and 2 meters high. And it was designed for a user up to 1.80m in height and 150kg in mass.

It has the advantage, comparing that to the model of **Fig.9***: Model in X, presented in the CPBr5* the fact of having its load carrier divided in 2 shafts, dividing efforts, in addition to a lower risk of tipping.

V. CONCLUSION

The overall objective of the article was reached, where the platform, which will serve as the base of the simulator, was.

The mechanism was based on previous studies of other simulators, with the intention of producing one that is cheaper, safer and provides physical sensations in response to a visual system.

The further work should include the choices for the other constituent systems (visual, drive, control and interface), and numerical analysis to validate the effects of the loads imposed on the structural system.

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