Use of the MS Flight Simulator in the teaching of the
Introduction to avionics course

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Introduction

The course Introduction to avionics GPA-745 is an optional course in the Aerospace program given in the Department of Automated Production Engineering at École de technologie supérieure in Montreal, Canada. The main objectif of this course is the study of electronic avionics instrumentation installed in aircraft. In this course, the following chapters are presented: History of avionics, Methods of navigation and orientation, Pilot cockpit and board instrumentation, Communication systems, Radio-navigation systems, Landing systems, Engine signalization instruments, Central alarm systems, Maintenance systems and Warning systems.

The presentation of the course in the class to the students is shown on PowerPoint slides and videos on modern aircraft such as Airbus and Boeing. Also, regarding the pilot induced oscillations a video film is provided from Bombardier Aerospace. However, the presentation of the course in the class may be improved and become more efficient grace to the use of MS Flight Simulator.

The main idea of this paper is to show how the participation of the students in the class will be increased by use of the MS Flight Simulator. The use of the systems and the electronic board instrumentation will be shown with the help of the new flight simulations modules realized within the MS Flight Simulator. For each instrument, one module will be created and presented in the class, which will result in a more interesting course presentation, stimulating and dynamical from pedagogical point of view, than the theory of the course by use of PowerPoint. In these modules, the use of:

- Flight instruments for the aircraft control
- Radio-navigation systems for landing such as ILS and MLS
- Board instrumentation and radio-navigation systems such as VOR and ADF

will be analyzed for the flight main phases: take-off, climb, horizontal flight, descent, landing, and turns.
Methodology

The functioning and use of the navigation instrumentation\(^1\) will be described in detail from the two points of view: engineering and pilot. Each instrument will be described firstly in the course from engineering point of view by use of the course notes, and secondly from pilot point of view based on MS Flight Simulator manuals.

In order to explain very well the use of the flight instruments, new flight modules will be created in order to be presented separately or simultaneously in the class, for each session. These new modules will illustrate the main flight phases with their corresponding instrumentation use.

The methodology will be mainly divided into three parts:

1) The realization of various modules in Flight Simulator for their use in the class as a pedagogical tool.
2) These modules are also used in the laboratories of the students. Thus, a continuous interaction will exist between the knowledge acquired in the class and the knowledge acquired in the laboratories.
3) A user manual for the modules is realized and is useful to well prepare the student for the aeronautical industry needs.

An example for use of the MS Flight Simulator\(^2\) in the class will further be explained in the paper by an example, and this explanation will be given in accordance with the description of board instrumentation.

Example

In this chapter, we are firstly going to introduce the avionics instrumentation. Then, for each flight phase, the instruments functioning is described.

Description of the primary board instruments

There are the primary instruments in the cockpit which give the most important information regarding the aircraft behaviour: the heading indicator, the attitude indicator, altimeter, turn rate indicator, airspeed indicator, and vertical speed indicator. Before explaining these instruments, the aircraft movements around its axes X, Y, and Z will be defined. The movement of an aircraft around its vertical Z axis is called yaw. The yaw is equivalent to the aircraft nose turning to the right or left, and is controlled by the rudder. The movement of an aircraft around its lateral Y axis is called pitch. The pitch is equivalent to the aircraft nose pointing up or down. The turning of an aircraft around its longitudinal X axis is called roll. The roll is equivalent to the aircraft turn to the left or right. Each of these instruments will be explained in detail in the next paragraphs.

- The attitude indicator (artificial horizon)

This indicator shows if the aircraft nose is raised or lowered, and also if the wings are level with the horizon. The top half of the instrument is painted blue and the bottom half is brown. The earth’s horizon is the division line between the two colours top/bottom. This division line is the earth’s
horizon, also named artificial horizon. In level flight, on this indicator a set of wings or a small depiction of an airplane overlaying the artificial horizon line.

- **Turn rate indicators**

  The turn rate efficiency of the aircraft nose around the vertical Z axis is measured by compass degrees traveled per second. The instruments displaying turn rates are the *turn indicator* and the *turn coordinator*. The turn indicator measures rate of turn as a change of compass heading over time. The turn coordinator factors in the roll rate of the banked wing. Thus, when the wings are first banked, the nose of the aircraft may not start to change headings immediately. Therefore, the turn coordinator may register the roll or bank before the turn indicator reflects the progress of the turn in degrees of change. At the bottom of the turn coordinator and turn indicator is the *inclinometer* or the slip/skid indicator or the ball, which shows the balance of forces at work in a turn.

  When the aircraft nose turn to the left or right, the a straight needle on the turn indicator deviates also to the left or right. The turn coordinator uses miniature aircraft wings to show the turn. The wings turn in the same direction as the turn. When the ball rolls toward the inside of the turn we obtain a slipping turn. When the ball moves toward the outside of a turn, skidding turn is obtained. When the ball remains in the centre, then a coordinated turn is obtained.

- **Airspeed Indicator**

  This indicator shows the speed of the aircraft relative to the air, which is actually the indicated speed, but not the speed of the aircraft relative to the ground. Airspeed is always measured in knots or nautical miles per hour.

  The airspeed needle points to the aircraft’s indicated airspeed in knots. The indicated airspeed is used mostly for takeoff and landing. This read value of the indicated airspeed is not exact because of the variation in the atmosphere and also because of the position of the probe installation. The true airspeed is the speed the aircraft really moves through the space, and it reflects the ground speed. This speed is used to compute navigation and travel time, such as the arrival time at the final destination airport. The true airspeed is calculated by multiplying the indicated airspeed shown on the airspeed indicator by double the altitude where aircraft is in cruise mode.

- **Vertical Speed Indicator**

  This indicator shows how fast the aircraft is climbing or descending and the rate of climb or descent is given in feet / minute. The differences in rates of climb and descent are measured by the direct and immediate change in case pressure.

- **Altimeter**

  This instrument shows the altitude at which the aircraft flies above the mean sea level, and not the height above ground level. If the ground elevation is above sea level, the aircraft will be closer to the ground. The height above the ground is found by subtracting the elevation of terrain below the indicated altitude above sea level.
- **The heading indicator**

  This indicator is also called directional gyro and shows which compass heading the aircraft is tracking. The compass is difficult to read during flight. This instrument is initially set to agree with the compass heading.

**Flight conditions**

**Preparation for take-off**

We have chosen the Boeing 737-400 with the following characteristics:

We are now on the landing track and we are ready for the take-off:

We can see to the right of the instrumentation panel - down the gas, in the middle the landing gear and up the flaps. Here only the flight phases are described.

1) The flight controls are verified.
2) The flaps are deflected with angles of $5^0$ in order to obtain the maximal speed.
3) We increase progressively the thrust
4) We release the breaks
5) At approximately 150 knots, we pull out softly the joystick
6) We adjust the angle of inclination to lift the nose to $15^\circ$
7) We retract the landing gear
8) At 175 knots, we enter the flaps and at 250 knots we accelerate.

We may see that the take-off is very well done. We climb gradually at $15^0$ with a slight turn to the left.

**The uniform flight**

Now that we entered the landing gear, reduce the gas, and entered the flaps, then we are going to stabilize the aircraft. We are ready to pass into the mode of uniform flight.
We are going to stabilize the level flight and reduce the gas in the aim to obtain a Mach number equal to 0.74.

Now that everything is under control, we can inform the control tower that the take-off is successful. It is important to avoid the abrupt movements and use as least as possible the joystick to straighten up the aircraft. We play with the gas and flaps to stabilize rapidly the aircraft.

**Turn to begin the descent**

We are going to realize a turn of $15^0$ in order to align on the landing track and to begin the descent.

![Image of airplane cockpit](image_url)

**The descent**

We are going now to begin the descent. We are going to reduce slowly the gas. The airplane will start to descent. If we wish to straighten up again the aircraft, the gas will increase by 65%.
We can realize that the altitude and the speed are lower, and we keep the airplane stable which is excellent.

**Approach and landing**

We will prepare now for the approach. The airplane will stabilize in level flight at 210 knots. We deflect the flaps at 1 degree and we stabilize the airplane at 190 knots. We turn to the track, we deflect the flaps at $5^0$ and we slow down at 170 knots.

Regarding the landing, we will take out the flaps at $15^0$ and verify that the landing gear is out. We deflect the flaps at $30^0$ and we reduce the speed at 140 knots. We maintain the aircraft calibrated. We reduce the gas at minimum. Once the aircraft touches the track, we can put the aero-breaks and we inverse the thrust by putting the reverse. At 60 knots, we will put back the gas and we succeeded.

**Introduction to radio-navigation systems ADF and VOR**

Direction finding represent an important task for a pilot. In order to obtain accuracy, quite elaborate receiving equipments must be used. Direction finding equipments can be divided in two classes:

- Ground-based direction-finders
- Airborne direction-finders
The most commonly used equipment is the VOR (Very high frequency omni-directional range) and the ADF (Automatic Direction Finder).

**The VHF Omnidirectional Range (VOR)**

The VOR operates between 108 and 118 MHz with an increment of 100 KHz. The ground station emits an omni-directional signal which is frequency modulated with a fixed 30-Hz reference tone. The phase difference between the 30-Hz tone varies directly with the bearing of the aircraft. It also emits a cardioid pattern that rotates with 30 rps, generating a 30 Hz sinus wave at the airplane’s receiver. The only limitations are due to propagation effects and instrument errors.

The VOR can be used to find an airport, join a pre-established path. The VOR may have to be readjusted several times during a flight because of the spatial limitation (70 to 90 NM in the simulator) in propagation of the waves. The VOR’s can be set on the ground and during the flight.

The onboard VOR equipment consist of a reception antenna, a short-wave receiver NAV and the display. The VOR is composed of the CDI (Course Deviation Indicator) and the OBS (Omni Bearing Selector).

To navigate using the VOR one must:

- Set the VOR to the proper frequency (The VOR’s frequencies are found in tables and on navigation maps).
- Turn the OBS until the CDI is in the middle of the display pointing straight ahead. This gives the course to be taken.
The Automatic Direction Finder

This is a receiver which uses non-directional beacons which radiates in the long and medium frequency band. It can help define (mark out) a route, delimitate the approach of important airports, to make the approach easier when used in conjunction with the ILS. In order to use the ADF the proper frequency of the beacon must be set (here it is 379). The simplest exercise of flight using the ADF is to fly directly on the beacon. Here we present the approach of the 28L runway in San Francisco. The ADF is set on the locator beacon BRIJJ which emits on a frequency of 379 KHz.

The Instrument Landing System (ILS)

The ILS is a collection of radio transmitting stations used to guide aircraft to a specific landing track. This is very useful when the visibility is limited. The ILS includes the localizer, the glide slope, marker beacons. Each device (localizer, glide slope, marker beacons) receives a signal in a specific frequency band.

The localizer provides a measure of the lateral deviation of an airplane from the vertical plane containing the centre line of the landing track. The glide slope indicates if the approach is good in terms of altitude. The marker beacons provide an indication of the position to the pilot. The major limitation of the ILS is its sensitivity to the environment. There are accuracy degradations due to the reflection from buildings, terrain and other airborne airplanes.
The ILS landing of a Boeing on the 28L San Francisco runway is presented in the course. The ILS is set on 109.55 the frequency of the landing track just mentioned. The red squares represent the correct approach of the plane. We see the glide slope GS (in yellow).

**The Microwave-Landing System (MLS)**

The sensitivity of the ILS to the environment can be eliminated by using microwave frequencies. The ILS uses the MHz frequency band. This is a strong impediment in metropolitan areas where the available channels in this frequency band is limited. The MLS does not have this limitation. The MLS consists of azimuth and elevation ground stations and a DME (Distance Measuring Equipment) for 3D positioning.

**Conclusion**

The use of the MS Flight Simulator has been seen to substantially improve the understanding of difficult theoretical concepts for students taking the *Introduction to Avionics* course. The presentation of the course is more dynamic and there is more feedback from the students.

Few examples have been shown in this paper in order to well understand the way of use of the MS Flight Simulator in the course. Actually the functioning of the board instrumentation and of the radio-navigation systems have been here explained.
Bibliographic information