

Development and Application of a Reconfigurable Engineering Flight Simulator at Ryerson University

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Abstract—Flight simulators can recreate aircraft flights for flight training and aircraft design. This paper reviews existing engineering flight simulators and introduces the development of a multi-purpose reconfigurable engineering flight simulator at Ryerson University. The multi-purpose engineering flight simulator named the Ryerson Fixed Base Simulator (RFBS) has been designed and built to teach and initiate research projects in the area of aircraft design, flight simulation, pilot training, and flight data analysis. It consists of three 46 inch high definition screens and six 22 inch touch screen panels to represent the instrument panel, the centre console, and the overhead panels of an actual aircraft flight deck. Several low-cost commercial flight simulation softwares were tested, and X-Plane was selected as the main flight simulation tool. This paper also introduces research that utilizes the RFBS and commercial flight analysis software. The objective of the research was to develop methodology for flight data conversion. A case study was commenced to verify the work flow of flight data generation and analysis with an example of hard-landing analysis.

Keywords—Fixed based flight simulator, flight data generation, flight data analysis, flight test.

I. INTRODUCTION

FLIGHT simulation has a fairly long history when it started as a training device in the early 1900s. In the modern era, it has become an essential tool for aerospace system design [1].

Modern flight simulators are composed of computation units and human interface units. The computational units involve mathematical models and equations of motions. The human interface units involve the control input and feedback system [2]. The typical composition of a flight simulation system can be seen on **Figure 1**. This simulation system was set decades ago, but it is still the foundation of modern flight simulators.

Several academic institutes around the world installed high fidelity simulators for multiple purposes. Some of these simulators utilize in-house mathematical models and equations. They are used as a tool for various studies such as developing new software architecture [3] and solving time delays in visually coupled systems during simulation [4].

Literature survey revealed that researchers from different institutes developed various flight simulators to be used as engineering tools and as training tools for pilots and engineers

[5],[6]. These simulators are relatively low-cost compared to the above mentioned simulators. The University of Illinois at Urbana-Champaign developed ‘The Icing Encounter Flight Simulator’ (IEFS) as part of the Smart Icing Systems studies [7] while Pennsylvania State University developed a low-cost rotorcraft simulation facility [8]. However, both simulators were developed for specific purposes that focused heavily on developing the suitable model and flight control; neither focused on handling qualities or pilot training.

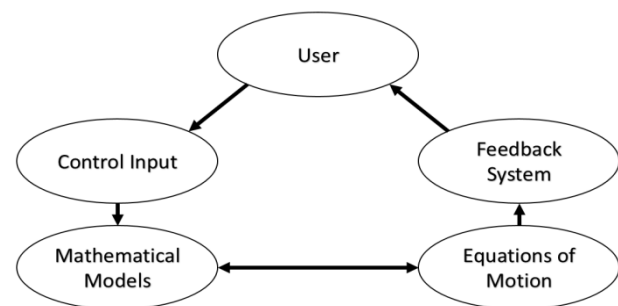


Figure 1 Typical composition of a flight simulation system

The Air Force Research Laboratory at Wright-Patterson Air Force Base developed the Modeling and Simulation Familiarization Tool (MSFT). Its main purpose was to educate engineers from different disciplines who lack knowledge of a specific discipline in a flight simulator system [9]. The MSFT is a very useful engineering training tool but it can only accommodate one type of aircraft: the F16.

Researchers at the University of Alabama in Huntsville developed a flight simulation environment with multiple flight simulators. Each system was designated for a specific purpose such as helicopters, aircraft, and UAVs [10]. Similar attempts were done by the Test and Evaluation Modeling and Simulation (TEMS) facility at the Air Force Flight Test Center (AFFTC) Edwards Air Force Base [11]. They developed flight simulators with realistic cockpits and studied the relation between the reconfigurability and fidelity and concluded that as the fidelity of the simulator increased, the reconfigurability of the simulator decreased. As a result, high fidelity hardware was chosen to represent the instrument panel, sacrificing the reconfigurability of the simulator.

For Ryerson University, the necessity of the flight simulator arose from gathering flight data for multiple purposes. Flight data analysis occurs in various sectors within the aerospace

industry. However, flight data is proprietary information from an airline or a manufacturing company, thereby making it hard and expensive to acquire for academic purposes. Flight simulation integrated with data generation solves this problem. Flight simulation allows the recreation of any flight situation. It can be used for teaching purposes as well as aircraft design studies, coupled with the careful assessment of simulation accuracy. In addition to the data generation and analysis features, training and educating pilots and engineers is another important role of a flight simulator. To properly train the pilots and engineers, it is necessary for the simulator to replicate the cockpit environment and avionics as much as possible.

The Mixed-reality Immersive Motion Simulator (MIMS) Laboratory is the newest addition to the Aerospace Engineering Department at Ryerson University. It consists of the Ryerson Fixed-Base Simulator (RFBS) and Ryerson's Full-Motion Simulator (RFMS). It was envisioned to generate opportunities for students and faculty alike to conduct studies in various disciplines such as aircraft stability and controls, aircraft simulation, human factors, data analysis, and more. The RFBS is focused on the cockpit representation and accurate data generation allowing for studies on flight data analysis and computer based training.

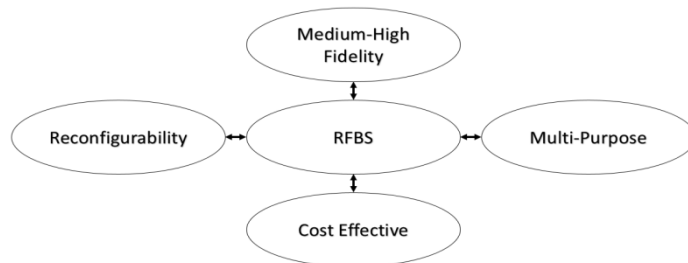


Figure 2 Integration of important aspects in a single flight simulator

During the development of the RFBS, the focus was on combining all the positive factors while minimizing the negative factors of existing flight simulators, as seen on **Figure 2**. Many previous engineering flight simulators are rather more focused on computation and data communication than the cockpit environment. The RFBS integrates all aspects of flight simulation, flight data generation, and the data analysis system, making it a true multi-purpose simulator. A multi-purpose simulator is also very cost-effective as the school cannot afford to purchase multiple simulators for different purposes. Advancement in computing power also allows the integration of multiple simulation features into one system. Academically, multi-purpose simulators can be used not only for research but to educate the students about avionics and flight dynamics. The main advantage of the RFBS is its reconfigurability. By replacing hardware buttons with touch screens, it can virtually simulate any aircraft.

This paper thoroughly explains how the RFBS was conceptualized, refined, and built. Two key projects were successfully completed following its construction to demonstrate the data generation and analysis capability as well

as highlight the reconfiguration capability of the simulator. This paper will go in-depth into the development of a flight data conversion methodology and some examples of flight testing and analysis case utilizing the RFBS and the Data Converter Program.

II. DESIGN AND BUILD OF THE SIMULATOR

A. Hardware Selection

The main parts of a flight simulator can be categorized into one of five sections: visual, audio, instruments, control, or motion components [12]. Visual and audio are in the form of feedback for a pilot from the simulator, while controls are inputs into the simulator. Instruments serve as both feedback and input – the pilot is required to see the status of the aircraft as well as input commands such as GPS settings. Motion provides the pilot with a more realistic feel; however, since the RFBS is a fixed-base simulator, motion is disregarded. Hardware choices were studied in parallel throughout the design of the simulator.

1) Visual

Since the RFBS is a multi-purpose simulator, the visual feedback was as important as the computation system. As a result, a study for suitable visual feedback was needed. There are two types of visual feedback: Projector and Display panel types. A projector projects an image onto a surface which is generally smooth and white. With various combinations of projectors, projection surfaces, and mounting positions, there are an infinite number of ways to represent an image. As a result, it is used in high fidelity pilot training simulators such as the CAE 7000XR [13]. However, projectors are heavily affected by the environment – especially by lighting. To get the best results from a projector, the ambient lighting must be at a minimum. Modern projectors that overcome these factors are available but are much more costly. Display panels however, are less affected by the environment and will always generate high definition images on the panel regardless of positioning. Despite being confined to one form, they come in different sizes, providing for a vast range of choices.

For the RFBS, three 46 inch High Definition LCD screens were selected and were positioned side by side to recreate an immersive environment of the outside view from the cockpit. Projectors were not used mainly because of the uncertainty of the laboratory environment and potential installation difficulties.

2) Instruments

High-end flight simulators built for specific aircraft represent an exact mock-up of the cockpit. However, because they are so specific, they cannot be used for other aircraft unless they undergo a complete overhaul of replacing the interior of the simulator. The RFBS overcomes this problem with touch screens. As previously mentioned, aircraft instruments have both aspects of visual output and command input – a touch

screen is capable of fulfilling both requirements. Additionally, the reconfigurability of the touch screen is a tremendous asset because the instrument panel can be redesigned for the aircraft currently being simulated.

3) Controls

Conventional fixed wing aircrafts have two configurations of controls: Yoke and joystick. The RFBS is equipped with both: there is a yoke on the captain's seat and a joystick on the co-pilot's seat. Both seats are equipped with spring loaded rudder pedals and share a throttle quadrant placed between them. Both types of controls are used to accommodate various types of aircrafts. Since they are installed at the same time, swapping of equipment is unnecessary.

There are two types of yoke in the flight simulation market: column and desktop type. The desktop yoke is smaller in overall size and depending on the manufacturer, can be considerably cheaper. However, it is hard to install a desktop yoke without a desk or any kind of stand. Yokes also require a large amount of depth to accommodate the control rod, which sticks out even further when pushed in fully. The column yoke however, sticks up from the floor, thus no desk or stand is necessary. In addition, the push-pull movement of the yoke does not require much space compared to the desktop yoke. The downside of a column yoke is that they are very expensive.

As previously explained the RFBS has touch screen monitors serving as an instrument panel and is ergonomically positioned so it is easy for the pilot or co-pilot to reach, minimizing unnecessary movement. If the desktop yoke was chosen, it would require a stand in between the pilot and the instrument. Also, because of the large depth required, the gap would increase even further. When the column yoke was used, it minimized this gap, enabling the pilot to engage with the instrument panel much easier. For this reason, Precision Flight Controls Inc.'s Jetliner column yoke and Thrustmaster's HOTAS Warthog™ were chosen as the main controls of the simulator.

4) Audio

A conventional 2.1 channel speaker is used to generate the cockpit environment's sounds. Upgrading the sound system was considered but we concluded it was unnecessary as the current speaker system performed well with warning and caution alarms as well as general environmental sounds.

B. Initial Designs

While in the conceptual design phase of the simulator, the search for adequate laboratory space was still on going and it was necessary to have as many design concepts as possible due to the uncertainty of the size, layout, and environment of the lab. On a conceptual level, the RFBS focused on smaller, general aviation aircraft such as the Cessna 172. Thus, the hardware combination was chosen to fit the design of smaller aircraft rather than larger commercial aircrafts. Most small aircrafts have all their instruments positioned in front of the pilot and co-pilot.

To accommodate the reconfigurability of the RFBS for these smaller aircraft, a 46 inch HD touch screen monitor was selected to represent the instrument panels. With a general idea of what hardware was going to be used, three concepts were proposed: wall mounts concept, stands concept and rig concept.

C. Design Phase

The purpose of the RFBS was to integrate flight simulation, data generation, and data analysis into a single system. Although the stand configuration provided for the most reconfigurability, its modular design did not fit with the objective of the simulator, thus it was eliminated. The wall mount configuration had too much uncertainty and it was heavily dependent on the physical space of the laboratory, thus it was eliminated. The rig configuration was chosen, and following several design phases shown on **Figure 3**, it was optimized to meet the objectives.

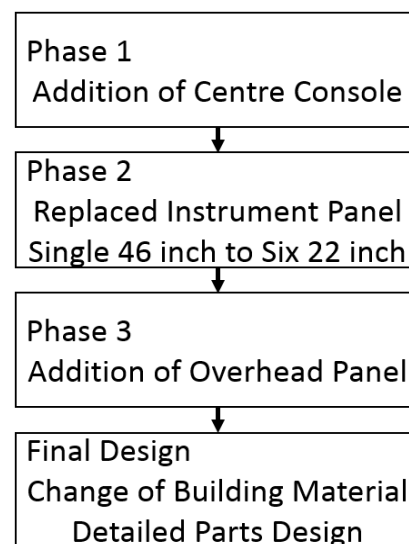


Figure 3 Design phases of the simulator

D. Building the simulator

Once the final design was confirmed, materials needed for the construction were put on order. The main material used to build the simulator was aluminum extrusions. To optimize the manufacturing time and material cost, careful planning of the materials to be purchased was needed. For most parts, it was found that it was much cost effective to cut longer extrusions into many shorter pieces. For some short parts however, it was found that purchasing pre-cut extrusions were more appropriate, because it required higher accuracy and uniformity of the parts. Such parts include the support feet of the base of the simulator. After planning, exact amount of material needed was calculated, and then purchased with a few backup pieces just in case of any unforeseen mistakes.

The RFBS was built with a modular method. The base, the stand, the screen mount, the overhead support and the centre console were made separately, and then assembled in order. During the building process, slight changes to the design were made. One of the main changes was the addition of support beams and support cables. When the base, the stand and the screen mount were assembled, the entire structure vibrated with

little disturbance. To reduce the vibration, four additional supports were added from the rig floor to the stand. Also, the overhead support and side screen mount started to deflect slightly with weights applied. The deflection of the overhead support was negligible, but the deflection of the side screen mount was more than expected. This is not just bad for the structure; it is also bad for the quality of the simulation experience. Once the side screens deflect, there will be a gap between the screens, disturbing the immersive experience of the pilot and the co-pilot.

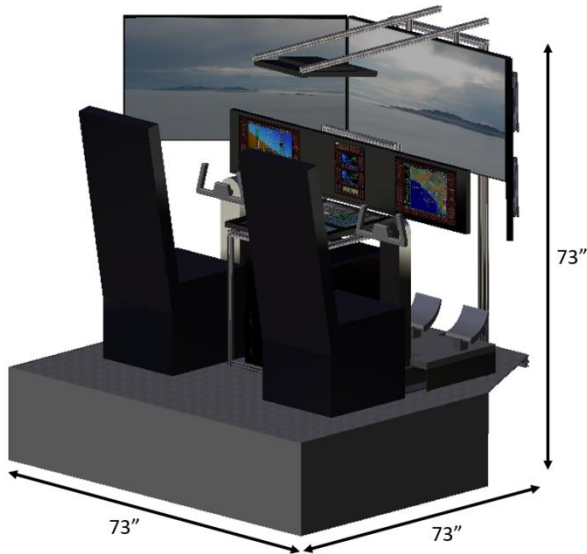


Figure 4 Final design CAD model



Figure 5 Pilot seat with the column yoke, co-pilot seat with the joystick



Figure 6 Front view of the complete simulator

E. The final product

Once the rig was complete, electronics and other hardware were installed. Slight changes were made during this time, including relocating one of the touch screens from the centre console to overhead, resulting in two overhead displays in the overhead panel, and the installation of a throttle quadrant. We conducted an analysis on whether a simulated throttle quadrant or a physical throttle quadrant was a better choice. It was decided that the physical throttle quadrant was a better choice because it allows the user to control the throttle more precisely.

III. SYSTEM AND SOFTWARE

A. System configuration

1) System Architecture

The RFBS utilizes two computer systems and in order for it to reach its full capability, both computers must be operational. The first computer handles flight simulation and data generation while the second computer handles the instrument panel and control inputs. The computers are connected with a local area network (LAN) data cable, allowing for real time communication. This system architecture is shown in Figure 7. Hardware configurations for each computer are listed in TABLE I.

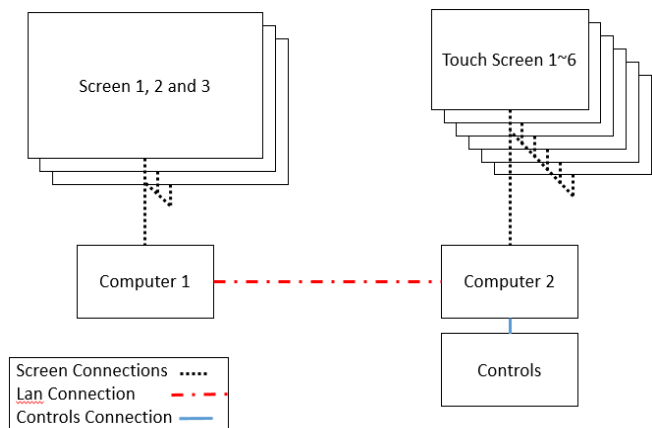


Figure 7 RFBS system architecture

TABLE I COMPUTER CONFIGURATION

	Computer 1 Simulation	Computer 2 Instruments & controls
Operation System	Windows 7 Professional	Windows 7 Professional
CPU	Intel i7-4770K	Intel i7-3770K
RAM	32 GB	16GB
Graphics card	GTX 760	Two GTX 670s in SLI
HDD	256 GB SSD	1TB HDD

2) Transport Delay

Transport delay is a critical issue in flight simulation: it is so critical, there was specific research done for this matter [4]. A transport delay is often described as a “lag” or the time elapsed between the user input and the response of the associated hardware and software [20]. In modern flight simulation, the lag occurs when the visual and motion cues are not synchronized [21]. The RFBS is a fixed base flight simulator so motion synchronization is not a problem. However, efforts had been done to find other possible sources of a transport delay. Referring to **Figure 7**, a transport delay could occur in four different locations: between the computers and the displays, between the two computers, between computer 1 and the control devices, and finally processing delays in each computer. Delays between the computers, the displays and the control devices can be ignored because they use high speed data ports. The specific data transfer rate is tabulated in **TABLE II** below.

TABLE II INTERFACE SPEED

Interface	Port Type	Bitrate (maximum)
Instrument displays	Digital Visual Interface (DVI)	7.92 Gbit/s
Out-the-window displays	High-Definition Multimedia Interface (HDMI)	18 Gbit/s
Control devices	USB 2.0	480 Mbit/s

As explained above, two computers are used to disperse the workload. Each computer is equipped with a high end CPU and graphic processor, and the setting of the simulation software was optimized to produce no lag so that there are no processing delays in each computer. A remaining possible source of transport delay is the connection between the two computers. As explained in section *System Architecture*, the two computers are connected with category 6 LAN cables which have a speed of 1 Gbit/s. To confirm that the network delay is insignificant, the “ping” between the two computers was found to be less than 1ms. This is insignificant because the simulation is running at 240Hz [21].

B. Software

1) Flight Simulator Software

The main flight simulation software used with the RFBS for this research is Laminar Research’s X-Plane. It is the only flight simulation software that utilizes blade element theory [15]. Other simulation software uses pre-determined flight models to simulate the motion of an aircraft. These include Lockheed Martin’s Prepar3d, Microsoft Flight Simulator X, and FlightGear, an open source flight simulator compatible with MATLAB. The MIMS lab has access to all the above software, in addition to FlightSIM from PRESAGIS. FlightSIM is high fidelity fixed wing flight simulation program that utilizes aircraft stability characteristics to simulate aircraft dynamics [19]. However, it was not chosen to be the simulation software for this research because the focus of the research was not just flight data generation, but flight data generation in an affordable method.

X-Plane calculates aerodynamic forces in terms of the shape of the aircraft flown. Usually, when a new aircraft is developed, it needs to undergo various tests to define its flight model and characteristics. This data must then be tabulated correctly in order to fly in the simulator. However, X-Plane does not require this process and can generate the aircraft’s flight model in real time using the geometry of the aircraft. Also, it is very easy to save flight data with X-Plane, as it provides an in-house feature for it. The user can save hundreds of simulation parameters with a desired rate. Finally, it provides good graphics. With some additional scenery add-ons, it is one of the best looking flight simulators on the market.

2) Instrument

Because of the RFBS’s unique system architecture, it is not possible to use generic instrument panels generated by the flight simulation software – SimAVIO by FlyThisSim solves this problem. SimAVIO is avionics software which simulates the instrument panel of an aircraft. It receives flight data from X-Plane through the LAN network in UDP packet format. The flight data is then visualized using SimAVIO’s own visualization method. FlyThisSim also provides Instrument Builder, allowing the user to design any type of instrument needed. The graphical part of the instrument is designed using a 3D drawing program called AC3D. The drawback of SimAVIO is that the functions of the software are limited and it is only compatible with X-Plane.

The MIMS lab also has VAPS XT from PRESAGIS. VAPS XT is an instrument builder which works in parallel with FlightSIM. The combination of FlightSIM and VAPS XT is superior to both X-Plane and SimAVIO in terms of fidelity and content creation, as they can provide more realistic data and instrument panel representation within the simulation. However due to the scope of the research, VAPS XT was not used for this research.



Figure 8 Flight data analysis software [16, 17, 18]

3) Data Analysis

For in-depth data analysis there are many commercial software solutions available including CAE Flightscap^e's InsightTM [16], Applied Informatics and Research Inc.'s FASET [17], CEFA Aviation's CEFA FAS System [18] and more.

The RFBS is equipped with some of this commercial flight data analysis software. The application of the RFBS and utilization of its installed software focused on easy data generation and extraction.

IV. APPLICATIONS

Once the simulator was complete, we started to develop the flight data conversion methodology which utilized the simulators flight data generation capabilities. Commercial flight data analysis program must have some flight data to analyze and animate; without flight data, the software is powerless. The development of the methodology and the data converter allowed the flight data generated by X-Plane to be imported into the commercial flight data analysis software. The data converter was coded in MATLAB and formed into an executable program with a graphic user interface (GUI) with MATLAB GUIDE. Once the software was completed, a test flight was flown with the RFBS to ensure it worked.

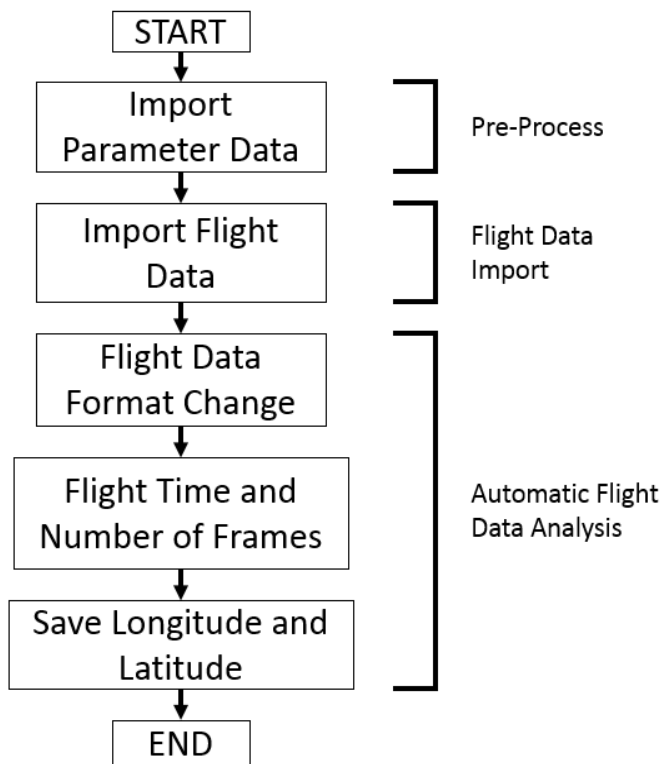


Figure 9 Flowchart of data importation to the data converter

A. X-Plane Data Output

X-Plane provides in-program feature for exporting flight data in real time. A user can select different parameters to

output by simply selecting the box from the 'Data Input & Output' option. The user must be careful with which parameters to output, because some of the parameter holds the information about the X-Plane program itself such as video frame-rate. Also, it has some parameters that hold the values of the aircraft traffic which is unnecessary. The data record frequency can be defined by the user also, starting from as low as 1Hz to as high as 60Hz or more, depending on the user's computer specification.

B. Data Importation to the Data Converter

1) Pre-Process

The flight data generated by X-Plane uses its own naming convention to fit the data within its fixed width variable format. As seen on **Figure 10**, each column is composed of 14 characters. To overcome this, a database that holds both the abbreviation and common names used in aviation industry was created. The database also holds the unit of the numerical parameters and the type of the parameter. When the Data Converter starts, the first task it goes through is calling in the parameter data.

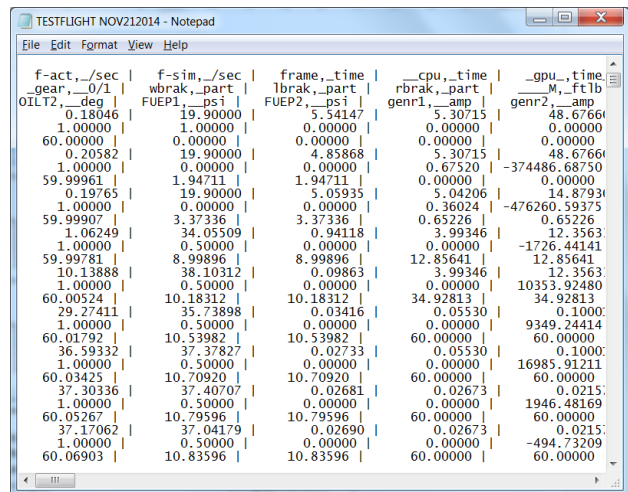


Figure 10 Typical data output from X-Plane

Matrix I				
__VVI, __fpm	Vertical speed	(fpm)	Number	Speed
Gload,norml	G-load across aircraft	(G)	Number	G Load
Matrix O				
__VVI, __fpm	Vertical speed	(fpm)	Number	Speed
Gload,norml	G-load across aircraft	(G)	Number	G Load

Figure 11 Example of matrices 'I' and 'O'

The final step of the data analysis is saving latitude and longitude coordinates for path plot interface of the program. Once this is done, the data import and analysis sequence is complete.

C. Data Conversion and Data Save

Data conversion process converts the imported data into a format that can be directly used in common flight analysis software. During this process, all the parameter names are switched to standard names accepted by the flight analysis software. Also, three new rows of data are created right below the parameter names, holding unit, format and type information of the corresponding parameter. This information is uploaded, during the pre-process phase of the program. Finally, conversion is made for GMT time and local time. These parameters are represented in hours, however it is mandatory for these parameter to have standard time format: HH:MM:SS.

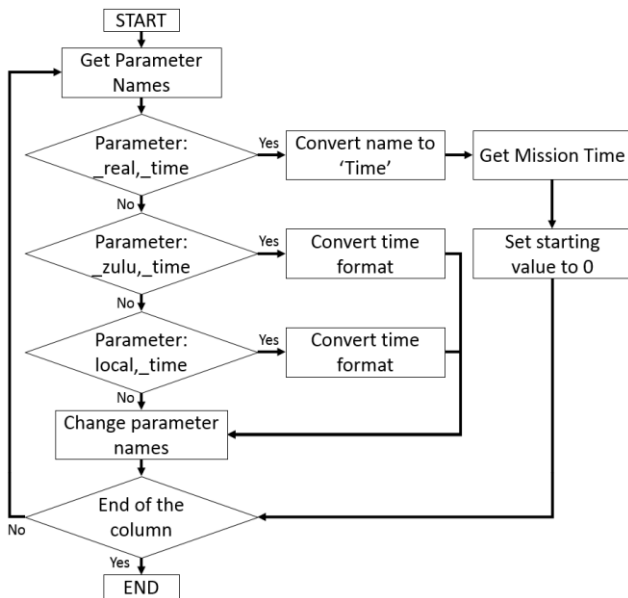


Figure 14 Flowchart of the conversion process

The final process is to save the converted data. The program uses cell to csv function to save the converted data into a csv format as typical flight analysis software can import csv data file.

D. Case Study

A case study was performed to verify data generation and analysis process. Two students were involved in this study, one with flight simulator experience, and the other with minimal experience. For convenience, the experienced participant will be called participant A and the inexperienced participant will be participant B. Neither participant had actual pilot experience so they flew “as best as they could” on the simulator during this study. Note that this case study was done with the sole purpose of demonstrating the use of the flight simulator and the data conversion program.

1) Preparation and the flight

The aircraft used for this study was Airbus A320, developed by QPAC specifically for the X-Plane. The flight test location was at CYYZ, Toronto Pearson International Airport. Before the two participants took over the controls, the aircraft was prepared for take-off conditions and aligned on the runway by more experienced user. The weather was set to clear, with minimal wind and disturbance and no precipitation. Finally, all of the air traffic was removed.

The flight plan was to take off from runway 15L, circle around Lake Ontario and land on 06L. Since the aircraft was aligned and ready to fly, there were no problems with takeoff for both participants. However when it came to land the aircraft, participant A had no problem lining up with 06L, but participant B circled too wide, ending up landing on 05. Both participants’ flight data was analyzed to compare landing skills between the two participants.

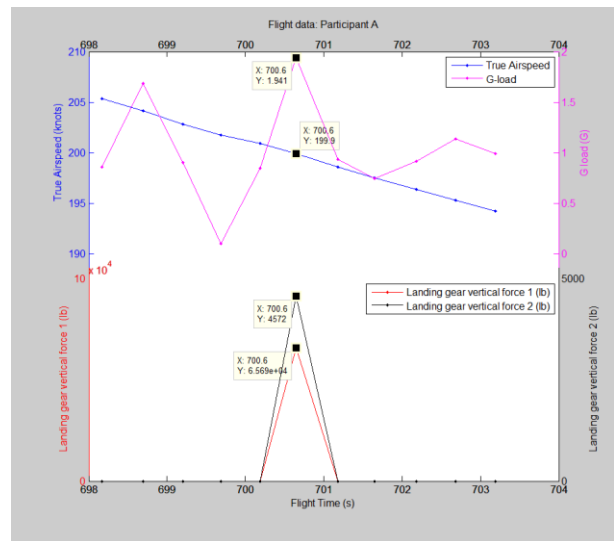


Figure 15 Touchdown of participant A

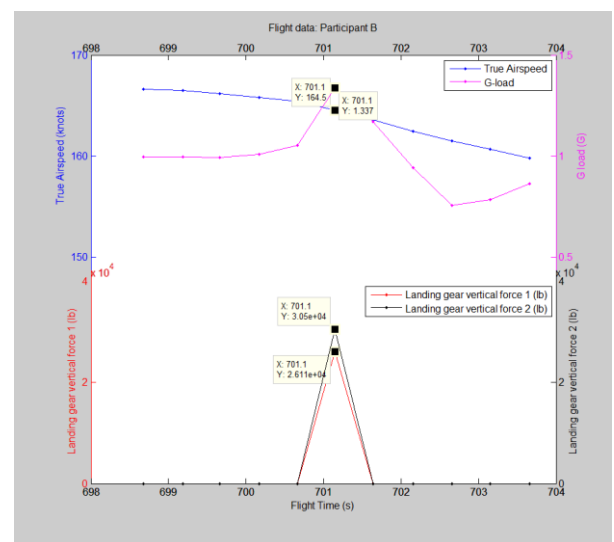


Figure 16 Touchdown of participant B

2) Flight Data Analysis

The flight data was converted using the data converter program then plotted for analysis. **Figure 15** and **Figure 16** show the plots of selected parameters, at the exact moment when the main landing gears touched the runway. **Figure 15** is the plot of participant A and **Figure 16** is the plot of participant B.

One can clearly see that participant A landed the aircraft better than participant B. The first parameter to be compared is the approach speed. The inexperienced participant approached the runway with an excessive speed of 200.9 knots, way over the reference speed of 140 knots. The second parameter to compare is the G-load. Participant A's aircraft went through about 1.33G at the moment of touch down where participant B's suffered about 1.94G. There are no specified definitions for hard landings in terms of regulations. However, aircraft manufacturers set threshold for vertical accelerations. For example, A340 has the threshold of 1.75G, 1.8G for the B747 and 2.2G for the B737 [14]. Although participant B's G loading did not exceed the 2.2G of the B737, it was fairly close enough to say that it was hard landing. The vertical forces on the landing gear were also examined. The landing gear vertical force parameter is numbered 2 and 3 for the left and right main landing gear respectively. The force difference on participant A's landing gear was about 4400lb. The force difference on participant B's landing gear was about 61000lb. This difference is too great, if it was a real life situation, the left main landing gear could have suffered damage due to hard landing. Finally both participants bounced off the runway once before coming to full contact with the runway.

V. CONCLUDING REMARKS

The RFBS was developed as a multi-purpose engineering simulator. After multiple phases, the rig with six touch-screen instrument panels was selected as the final design. The design was further revised when construction began. Once the RFBS was finished, two projects focusing on demonstrating two major capabilities of the RFBS were completed: Data generation and the advantages of having a reconfigurable instrument panel. With the development of the data converter program, the gap between data generation and data analysis was resolved. A case study was commenced to demonstrate how the data generation and analysis could be done by using the RFBS, the data conversion program and finally analyzing the result from the conversion program.

In the near future, Ryerson will develop an inter-link between the RFBS and the RFMS. Both machines will be upgraded to high fidelity simulators for accurate data generation. The RFMS will be used to recreate the motion of flight and this data will be further used for human factor studies. The RFBS will be kept up to date with the most recent technology and software in order to meet industry standards.

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REFERENCES

- [1] David Allerton, *Principles of Flight Simulation*, Chichester: Wiley, 2009. [CrossRef](#)
- [2] Max Baarspul, "A Review of Flight Simulation Techniques" in *Progress in Aerospace Sciences*, Vol. 27, pp. 1-120, 1990. [CrossRef](#)
- [3] C.A. Ippolito and A.R. Pritchett, "Software Architecture for a Reconfigurable Flight Simulator" in *Proc. AIAA Modeling and Simulation Technologies Conference and Exhibit*, Denver, Colorado, August 14-17, 2000. [CrossRef](#)
- [4] Sion Jennings, L. D. Reid and R. V. Kruk, "Time Delays in Visually Coupled Systems During Flight Test and Simulation" in *Journal of Aircraft*, Vol. 41, No. 6, November 2004.
- [5] Lung-Nan Wu and Yun-Ping Sun, "Development of a Low-Cost Flight Simulation Training Device for Research and Education" in *Proc. 2nd International Conference on Intelligent Technologies and Engineering Systems*, Kaohsiung, Taiwan, December 12-14, 2013.
- [6] F. Holzapfel, I. Sturhan and G. Sachs, "Low-Cost PC Based Flight Simulator for Education and Research" in *Proc. AIAA Modeling and Simulation Technologies Conference and Exhibit*, Monterey, California, August 5-8, 2002. [CrossRef](#)
- [7] Robert W. Deters, Glen A. Dimock and Michael S. Selig, "Icing Encounter Flight Simulator" in *Journal of Aircraft*, Vol. 43, No. 5, September 2006. [CrossRef](#)
- [8] Joseph F. Horn, Derek O. Bridges, Leonard V. Lopes and Kenneth S. Brentner, "Development of a Low-Cost, Multi-Disciplinary Rotorcraft Simulation Facility" in *Journal of Aerospace Computing, Information and Communication*, Vol. 2, July 2005.
- [9] R. Scott Burns, Matthew M. Duquette, Joseph B. Howerton, Richard J. Simko, "Development of a Low-cost Simulator for Demonstration and Engineer Training" in *Proc. AIAA Modeling and Simulation Technologies Conference and Exhibit*, Austin, Texas, August 11-14, 2003.
- [10] Thammanit Piputsitee and D. Brian Landrum, "UA-Huntsville Flight Simulation Development" in *Proc. ECTC ASME Career Technical Conference*, Miami, October 3-4, 2008.
- [11] Guy Williams, Ken Lawrence and Richard Weeks, "Modeling and Simulation Technologies: Reconfigurable Flight Simulators in Modeling and Simulation", in *Proc. AIAA Modeling and Simulation Technologies Conference and Exhibit*, Providence, August 16-19, 2004.
- [12] Lawrence C. Boyer, "Introducing Parks College Reconfigurable Engineering Simulator" in *Proc. AIAA Flight Simulation Technologies Conference*, San Diego, July 29-31, 1996 pp. 565-572.
- [13] CAE Display Systems, 2014. [VIEW](#)
- [14] Roger Rozelle, "Stabilized Approach and Flare are Keys to Avoiding Hard Landings" in *Flight Safety Digest*, Vol 23, No. 8, August 2004.
- [15] How X-Plane Works, Laminar Research, 2014. [VIEW](#)
- [16] CAE Flightscape, 2014. [VIEW](#)
- [17] Applied Informatics and Research Inc., 2015. [VIEW](#)
- [18] CEFA Aviation, 2015. [VIEW](#)
- [19] PRESAGIS, 2014. [VIEW](#)
- [20] R. Marshall Smith, "A Method for Determining Transport Delays in the Flight Simulation Environment" in *AIAA Flight Simulation Technologies Conference*, New Orleans, Louisiana, August 12-14, 1991.
- [21] R. Rivera and D. Biezad, "Cal Poly's Motion Flight Simulator and Motion Algorithms" in *AIAA Modelling and Simulation Technologies Conference and Exhibit*, Honolulu, Hawaii, August 18-21, 2008.