Development of a low cost flight simulator to enhance students' learning of technical and non-technical flight skills

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ABSTRACT: Previous research by the author has shown that the use of a simulator for preliminary technical flight skills training has led to improved student performance in flight training. The author has also espoused the use of a simulator for the training of non-technical flight skills, in addition to the training of technical flight skills. The unique property of this flight simulator is the ability to view and export flight data from the device. This is important because it will enable analysis of pilot, or student pilot, to determine whether the flight is safe or unsafe, or student performance is satisfactory or unsatisfactory. The ability to access flight performance data will increase the effectiveness of students' experiential learning and will greatly assist current research projects under way in the AERO Lab. In this paper, the author describes this relatively low cost flight training device.

INTRODUCTION

Since the first flight of a powered heavier than air vehicle, roughly a century ago, air travel has become progressively safer and safer. The Aviation Industry and the flying public regard air travel as the safest form of transportation. There is general agreement that air travel is extremely safe. Accident statistics show that since 1970, after the worldwide introduction of the jumbo jet, the number of aircraft accidents per year has been steadily reducing [1]. In fact, 2007 was a particularly safe year, being the second safest year on record. This decreasing trend in aircraft accidents is despite the increase in flights and the corresponding increase in passenger miles. The growth of the Aviation Industry is estimated to be some 3-5% per year [2]. This downwards trend has been largely attributed to the increased mechanical reliability of the turbo jet engine, coupled with the increased use and reliability of on board automated systems, and the wide spread development and implementation of flight crew training in non-technical flight skills such as leadership, communication, team management and group effectiveness.

However, despite all these advances, there appears to be a residual number of accidents that continue to occur, albeit in decreasing numbers. Of all the types of aircraft accident, perhaps the one that is of particular concern is the controlled flight into terrain (CFIT) accident or approach and landing accident (ALA). In this classification of accident the aircraft is perfectly serviceable at the time of the accident and under the direct control of the flight crew when it unintentionally impacts the ground. These accidents are of major concern because of the large number of fatalities attributed to these types of accident. In 1998, Ashford conducted a study of fatal CFIT/ALA accidents worldwide from 1980-1996 inclusive [3]. The study sample included 287 fatal accidents involving 7,185 fatalities to passengers and crew members, and was based on the UK Civil Aviation Authority database for its Global Fatal Accident Review. A graph of Fatal Approach and Landing Accidents (ALA's) Worldwide, by Year 1980-1996, for aircraft with a maximum takeoff weight greater than 5,700 kg can be seen in Figure 1 [3].

This statistic shocked the industry and led to the introduction of Terrain Awareness Warning Systems (TAWS) or Ground Proximity Warning Systems (GPWS) in 1974 and the mandatory ruling by the International Civil Aviation Organisation's (ICAO) for the fitting of GPWS to aircraft in 1978 [4]. Later in 1998 ICAO amended the requirement to fit GPWS to all aircraft with a take-off weight greater than 5,600 kg or authorised to carry nine or more passengers [4].

Ashford's study also lead to the setting up of the Flight Safety Foundation's (FSF) Approach and Landing Accident Reduction task Force to further analyse the causal factors associated with CFIT accidents [5]. A causal factor is an event, action or item that is deemed to be directly instrumental in the causes of an accident. This study by Khatwa, Collins and Helmreich in 1989-1990 determined that the causal factors in an accident ranged from 1 to 10 and were ranked as follows [5]:

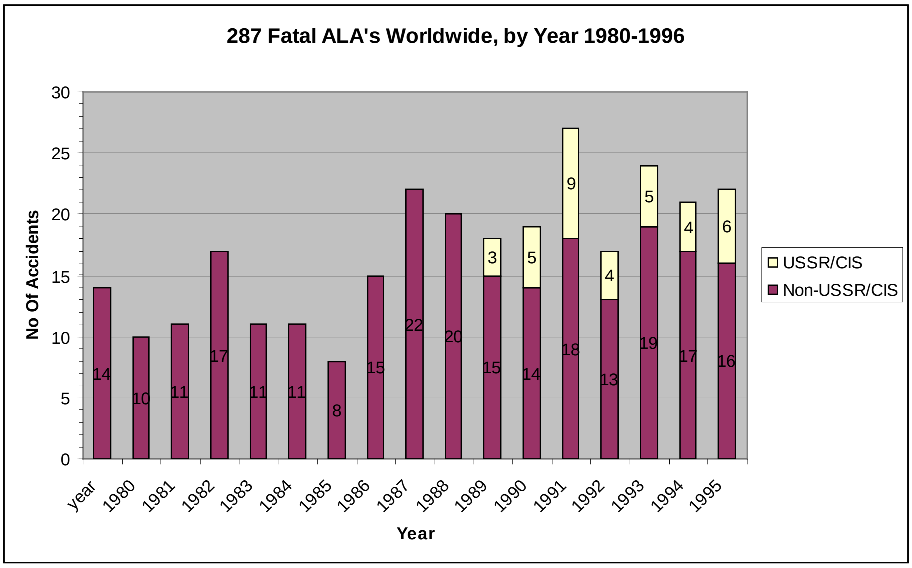

Figure 1: Fatal Approach and Landing Accidents (ALA's) Worldwide, by Year 1980-1996, for aircraft with a maximum takeoff weight greater than 5,700 kg. USSR – Union of Soviet Socialist Republics, CIS – Commonwealth of Independent States.

1.	Omission of action/inappropriate action	24.7%
2.	Lack of positional awareness in the air	18.8%
3.	Flight handling	12.2%
4.	Press-on-itis	11.1%
5.	Poor professional judgement/airmanship	4.3%
6.	Deliberate non-adherence to procedures	2.9%
7.	Windshear/turbulence	2.2%
8.	Failure in CRM	1.8%
9.	Icing	1.4%
10.	Systems failure	1.4%

Further analysis revealed that *Lack of positional awareness in the air* occurred in 47.3% of accidents, *Omission of action/inappropriate action* occurred in 43.7% of accidents and *Too low or too slow on approach* occurred in 39.1% of accidents [5].

CURRENT SOLUTIONS

The Aviation Industry's response to the FSF Task Force's report has been to prevent the causal factors from occurring. This has been relatively successfully achieved using two very different approaches.

One approach has been to increase the level of automation in the cockpit through the use of GPWS's and Global Positioning Systems (GPS). This has been largely successful because it is widely recognised that at least 70% of aircraft accidents are caused by human error [6]. This is largely attributed to the flight crew in terms of lack of leadership, lack of communication skills and deficiencies in team management, with the resulting lack in group effectiveness. The flight crew are also prone to forgetting to perform a vital action or performing an action that was inappropriate or becoming unaware of where the aircraft is (lack of situation awareness).

The GPWS and the more advance Enhanced GPWS (EGPWS) is explained in detail in Honeywell's Pilot's Guide to the EGPWS [7]. However, this approach has the potential to introduce new errors. Most of these errors can be classified as *out of the loop* errors because the flight crew are not aware of what the aircraft is doing. One example is the accident at Phuket in 2008. The pilots executed a go-around because of bad weather but didn't press the go around button; causing the aircraft to fly itself into the ground. Another problem is that pilots can effectively program the aircraft to fit their understanding of the situation rather than the real situation. This can cause the aircraft to become *lost* with the potential to impact with terrain.

The other approach is to tailor a pilot's education to try and eliminate error. This is achieved by increasing the level of training that flight crews receive, especially in the area of non-technical flight skills. To this end Crew Resource Management (CRM) has been widely introduced into airline training syllabuses. The training is undertaken in full scenario simulator sessions or Line Oriented Flight Training (LOFT) sessions [8]. The effectiveness of this training is regularly assessed by trained evaluators in both the simulator during recurrent training, and on line in actual flight situations through line operations safety audits [9].

NOVEL SOLUTIONS

The author has long maintained that each of these approaches, both the technological and the educational, could be improved with the use of intelligent agent methodology [10-14]. The author has argued that the implementation of non-technical flight skills training at the early part of a pilot's training would allow the non-technical flight skills to become well imbedded in a pilot's behavioural repertoire in a similar way that technical flight skills are [15].

Thatcher, Fyfe, Jones and Ong-Aree have shown that the use of a simulator in the very beginning of a pilot's flight training enhances the learning experience and improves outcomes [16]. However, the development and use of intelligent agent technology in the education of pilots has been hindered because of a lack of a suitable simulator. Thatcher, Fyfe, Jones and Ong-Aree [16] and Thatcher [13][14] have used a $120,000 simulator and a smaller $10,000 to some effect but the ability to retrieve usable data from the simulator has halted any further advance in this area.

Recently, the author has commenced the development of a specialised simulator, which will allow the easy extraction of flight data. This simulator, situated in the AERO Lab, is presented in its development stage in Figure 2. The flight parameters and variables that can be extracted are presented as a screen dump in Figure 3.

Figure 2: Simulator being developed in the AERO Lab.

The simulator is base around 4 to 5 computers, one controlling each screen. The centre computer controls the instrument display and the other computers control the centre screen on the over head and the two side screens. A fifth computer can be used as a controller for the instructor station, where different weather and flight scenarios can be programmed. These are networked together to synchronise the displays on each screen.

As can be seen from Figure 3 a large array of flight performance and student performance data can be accessed and saved to the hard drive. This can later be accessed to analyse the student's performance during the flight. The type of data that can be accessed includes, aircraft position, height, airspeed, ground speed, aircraft flight controls position, landing gear and flap position, weather information, engine parameters, etc. Depending on the experimental design, a given number of these variables will be selected to generate an n- dimensional vector of aircraft/student performance data as a function of aircraft position and height; or bearing, distance and height from the aerodrome.

Once collected, this data will be analysed using clustering algorithms to determine if there are any patterns in the flight data. These patterns will be assessed to see if they promote good or bad student learning. These will then be used to generate a data base of *good* and *bad* student performances on that particular flight scenario or lesson. The agent will then be able to classify a student flight as satisfactory (or perhaps safe) or unsatisfactory (or perhaps unsafe). These will then be assessed by an instructor to update the data base using a strategy of *assisted learning by domain experts*. Once the database has reached a critical size, the agent can be used as an instructor to assist the student in the learning process.

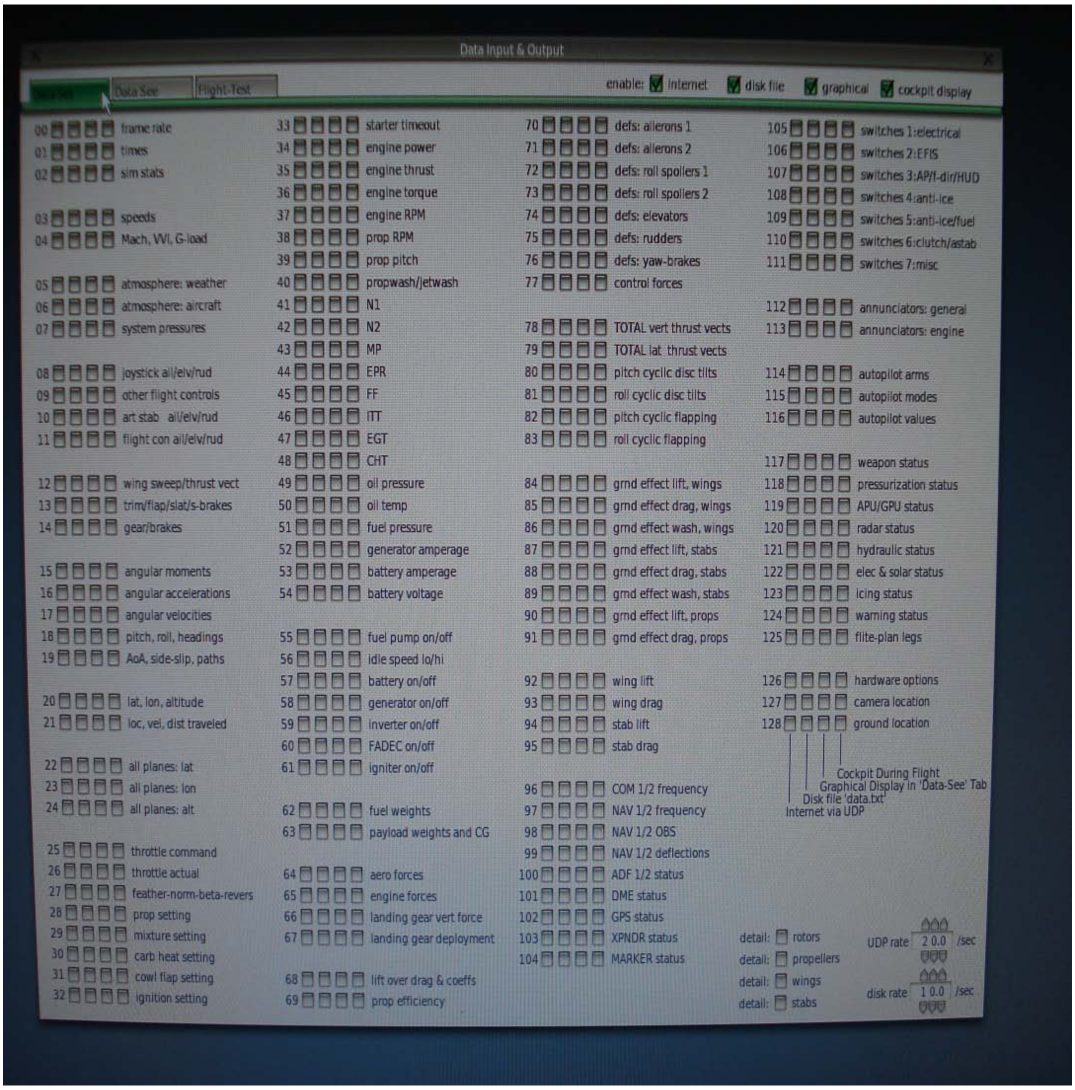

Figure 3: Screen capture showing aircraft parameter and performance data.

SUMMARY

Even though the airliner accident rate is decreasing, there is still concern in the Aviation Industry regarding the small number of accidents that occur due to CFIT. This is because of the high number of fatalities associated with these types of accidents. CFIT accidents are more likely to occur due to flight crew error than malfunction of aircraft equipment. The Industry has tackled the problem using two different strategies; increase in automation on the flight deck and increase in flight crew training in non-technical flight skills. These strategies have been relatively successful but still accidents occur. The author has suggested extending each of the strategies by using intelligent agent software programs.

The paper describes the use of a relatively inexpensive simulator, which will allow flight crew and aircraft data to be extracted and used by the agents to assess whether the student is learning the flight lessons in an effective or safe way. The software agents will use clustering algorithms to ascertain if patterns exist in the output data that can determine effective or ineffective student learning, or safe or unsafe flight patterns. These patterns will form a database of flight performance parameters which the agent can use to facilitate a students learning. In this way a student can maximise the benefits from their experiential learning without the need for an instructor.

REFERENCES

1. Safety 2007. *Air Transport New*, 31 January (2007).
2. Lee, D.S., Lim, L.L. and Raper, S.C.B., The role of aviation emissions in climate stabilization scenarios, *Proc. of Avoiding Dangerous Climate Change Symposium*, Exeter, UK, 1-3 (2005).
3. Ashford, R., A study of fatal approach-and-landing accidents worldwide. 19801996, *Flight Safety Digest*, 17, **2-3**, 1-41 (1998).
4. Khatwa, R. and Roelem, A.L.C., An analysis of controlled-flight-into-terrain accidents of commercial operators, 1988 through 1994 (1996). *Flight Safety Digest*, 15, **4-5**, April-May 1996, http://www.flightsafety.org/fsd/fsd_apr_may96.pdf

5. Khatwa, R. and Helmreich, R. L., Data acquisition and analysis working group final reports, Analysis of critical factors during approach and landing in accidents and normal flight. *Flight Safety Digest*, 17, **11-12**; 18, **1-2**, 1-77 (1999).
6. Helmreich, R. L. and Foushee, H.C., *Why Crew Resource Management*? In: Weiner, E.L., Kanki, B.G. and Helmreich, R.L. (Eds), Cockpit Resource Management. San Diego: Academic Press (1993).
7. Honeywell, MK VI and MK VIII Enhanced Ground Proximity Warning System (EGPWS) Pilot's Guide. 060-4314-000 Rev. C - May (2004), http://www51.honeywell.com/aero/common/.../Mk_V_VIII_EGPWS.pdf.
8. Johnston, N., The development and use of a generic non-normal checklist with applications in Ab Initio and Introductory AQP programs. *Inter. J. of Aviation Psychology*, 2, **4** (1992).
9. Klinect, J.R., Wilhelm, J.A. and Helmreich, R.L., Threat and error management: Data from line operations safety audits. *Proc. 10th Inter. Symposium on Aviation Psychology*, Ohio State University, Columbus, Ohio, 683-688 (1999).
10. Thatcher, S.J., Jain, L.C. and Fyfe, C., An intelligent aircraft landing support system: Lecture notes in computer science. *Proc. 8th Inter. Conf. on Knowledge-based Intelligent Information & Engng.*, Berlin: Springer-Verlag (2004).
11. Thatcher, J., Jain, L.C. and Fyfe, C., Theoretical framework for a knowledge-based intelligent enhancement to an aircraft ground proximity warning system. In: Negnevitsky, M. (Ed), *Proc. 2nd Inter. Conf. on Artificial Intelligence in Science and Technol. (AISAT'2004)*, University of Tasmania (2004).
12. Thatcher, S.J., Jain, L. and Fyfe, C., An intelligent aircraft landing support paradigm. *Proc. 13th Inter. Symposium on Aviation Psychology*, Oklahoma City, Oklahoma, 741-746 (2005).
13. Thatcher, S., The use of advanced simulator technology in aviation education. *Proc. 9th IASTED Inter. Conf. on Computers and Advanced Technol. in Educ.*, Lima, Peru, 316-320 (2006).
14. Thatcher, S., Experiential learning and classification of team skills in pilot education. *World Transactions on Engng. and Technol. Educ.*, 6, **2**, 271-274 (2007).
15. Thatcher, S. J., Crew-centred flight training: a methodology for improving technical flight training. *Proc. 4th Asia-Pacific Forum on Engng. and Technol. Educ.*, Bangkok, Thailand, 169-172 (2005).
16. Thatcher, S.J., Fyfe, A., Jones, C. and Ong-Aree, J., Preliminary investigation of education transfer from simulator to aircraft. *World Transactions on Engng. and Technol. Educ.*, 5, **1**, 83-86 (2006).