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UA-HUNTSVILLE FLIGHT SIMULATION DEVELOPMENT

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ABSTRACT

To the general public flight simulation implies computer games or pilot training. However, this discipline has evolved to include aerospace vehicle design, collaborative vehicle interactions and human/machine interfaces. Personnel at the University of Alabama in Huntsville have developed a flight simulation environment combining the inexpensive X-Plane® software with moderate capability PC hardware to provide an affordable desktop flight simulation capability. This capability is being used in research studies of helicopters and unmanned aerial vehicles, and in the aerodynamics and flight dynamics curriculum. This paper describes the development of the university's simulation capabilities and presents selected examples of its versatility.

ACADEMIC FLIGHT SIMULATION

In addition to an ongoing role in vehicle operations, simulation has become an integral part of all phases of aerospace system design. This includes expanded research emphases in optimization of the human/machine interface to accurately present visual and vestibular cues to a pilot or operator. A concurrent effort is being made to reduce the cost of high-fidelity simulation through the use of low-cost components such as personal computers and commercial-off-the-shelf visualization systems.

A number of universities have developed flight simulation environments that integrate academic studies and research. The University of Illinois at Urbana-Champaign aerospace engineering department developed a flight simulation lab to teach undergraduates aircraft flight mechanics and control systems. This includes an innovative "icing encounter" flight simulator used in research projects [1].

Researchers at Pennsylvania State University developed a low-cost rotorcraft simulation facility constructed entirely from commercially available hardware [2]. A "graphical cluster" was constructed by linking several PC computers to provide multiple interactive displays. Graphics are generated by free, open-source FlightGear code [3]. Vehicle flight dynamics are generated by the U. S. Army / NASA GENHEL code [4]. The system is being used to support research in flight control design, rotorcraft flight dynamics modeling, and near real-time acoustics modeling. Issues related to control feel and latencies were considered to be minor weaknesses in relation to the flexibility and cost effectiveness of this facility approach.

The University of North Dakota flight operations department produces *AeroCast* [5]. This free video podcast teaches flight principles and the use of aircraft instrumentation. Each episode includes simulations generated with the commercially available X-Plane® software [6] demonstrating the particular maneuvers and the forces generated (Figure 1).

Figure 1. University of North Dakota *AeroCast* flight training podcast image [5]

UAH FLIGHT SIMULATION ENVIRONMENT

Enrollment in the University of Alabama in Huntsville (UAH) aerospace engineering program has grown more than 33% over the last 3 years [7]. The Mechanical and Aerospace engineering (MAE) department has also initiated a rapidly growing graduate program in rotorcraft and unmanned aerial vehicle (UAV) systems engineering. Instruction in vehicle aerodynamics, performance, and design are core undergraduate and graduate program components. Students need exposure to modern flight simulation tools since simulation has rapidly become an integral tool in the design, development, validation, procurement, and operational phases of the life cycle of many vehicles and their subsystems. However, limited academic resources require leveraging research funds to support this effort.

Full flight simulators can cost millions of dollars, which precludes their use in academic research or student projects. However, today's commercially available flight simulator software such as the Microsoft© Flight Simulator, X-Plane® [6] and FlightGear [3] offer the opportunity to develop affordable desktop computer based simulators. UAH personnel identified the following flight simulation tool requirements [7]:

- User friendly;
- Minimal initial and recurring costs;
- Reasonable accuracy/fidelity;
- Moderate learning curve;
- Ability to support a broad range of vehicle applications (aircrafts, helicopters, UAVs);
- "Open source" for customizing and future upgrades;
- Visual interfaces that can be modified; and
- Quantitative output

The X-Plane® software was identified to meet all these requirements. This software is not only a flight simulator, but it also includes a number of specialized modules. ***Airfoil-Maker*** is used for custom designed airfoils. The ***Plane-Maker*** module is used to develop custom planes and helicopters. The ***World-Maker*** module is used to make custom scenery to fly in. The ***Weather-Briefer*** is used to download a weather briefing from the internet before a flight.

ASSET Lab

In 2005 the UAH Rotorcraft Systems Engineering and Simulation Center (RSESC) was awarded a contract for compiling and evaluating technologies related to the terminated Comanche helicopter program. As part of this project, the Army provided a full Comanche cockpit simulator including several crew support stations. One requirement of the Army funded effort was to establish a helicopter systems engineering lab that included UAV and helicopter flight simulation. This led to the establishment of the UAH Aerospace Simulation & Systems Engineering Teaming (ASSET) laboratory. The ASSET lab (Figure 2) consists of six X-Plane® software equipped desktop computers. Each computer is also equipped with a multifunctional control joystick and foot pedals. The ASSET laboratory is used to teach basic aerodynamics and flight dynamics and for student flight training.

Figure 2. Desktop Simulators in UAH ASSET Lab

USSRC Aviation Challenge

In 2006, the US Space and Rocket Center's Aviation Challenge chose the UAH/Laminar Research team to upgrade their simulation software with a modified version of X-Plane®. This required development of a new instructor operating station (IOS) (Figure 3). The IOS development required the use of the X-Plane® open source plug-in feature [7] in combination with Visual Basic, C++ and DLL. Figure 4 shows a screenshot example of the IOS which uses a network link to efficiently monitor each aircraft, set aircraft states (i.e. location, aircraft type, fuel state, and weapons payload), set time, and enable/disable simulators. Figure 5 shows an Aviation Challenge simulator running the new software. The X-Plane® enhanced capability is being used by Aviation Challenge to inspire the current generation of K-12 students to pursue future careers in science and engineering.

Figure 3. X-Plane® Based IOS Station at USSRC Aviation Challenge

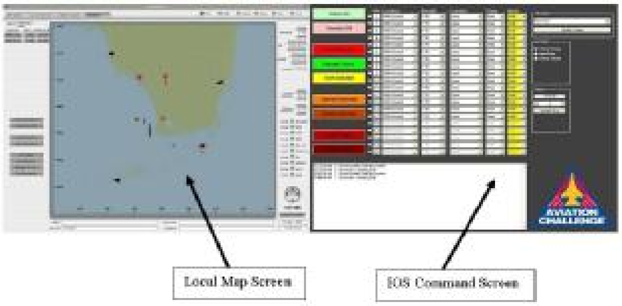

Figure 4. Instructor Operating Station Layout

Figure 5. USSRC Aviation Challenge Mach2 Flight Simulator with X-Plane®

COVE Lab

During 2006 and 2007 UAH developed the Collaborative Operation of Vehicles Engineering (COVE) lab. This lab is housed in an air conditioned Comanche cockpit simulator trailer provided by the Army in 2005 (Figure 6). The original trailer included a set of silicon Graphics workstations. Due to the high yearly maintenance cost the workstations were replaced with eleven inexpensive personal computers.

The primary purpose of the COVE lab is to simulate collaborative operations between helicopters and UAVs. The trailer lab includes a tandem Comanche cockpit station (Figure 7), two helicopter stations (Figure 8), two UAV stations (Figure 9) and the IOS station (Figure 10). The two helicopter stations are equipped with Flightlink™ helicopter flight controllers including cyclic stick, collective stick, anti-torque pedals, and a pilot seat.

Figure 6. UAH COVE Lab Trailer

Figure 7. Comanche Cockpit Station Inside COVE Lab Trailer

Figure 8. Helicopter Stations Inside COVE Lab Trailer

Three desktop computers drive the tandem Comanche cockpit station (Figure 7). One of the computers drives the cockpit view, while the other two run the instrument panel screens. Each helicopter station (Figure 8) is run by a personal computer. A third computer allows the two stations to be linked to simulate two-seat helicopter configuration. Either seat can be designated the primary pilot seat or the co-pilot seat.

Figure 9. UAV Stations Inside COVE Lab Trailer

Figure 10. IOS Station Inside COVE Lab Trailer

The UAV stations (Figure 9) are each driven by two computers. One runs the instrument panel and video feedback view; while the other runs a map view of the UAV location. The IOS station (Figure 10) links all simulators together on one network and commands aircraft location on the world map, aircraft type, and fuel and weapons loadout. The IOS operator is the primary commander of collaborative operations simulations. A research station is also connected to the various stations to record flight data and video via a network hub.

The COVE lab provides an effective tool for teaching the aerodynamics and flight mechanics fixed and rotary-wing aircraft, and for flight training. It also provides the ability to simulate collaborative operations scenarios between multiple combinations of airplanes, helicopters and UAVs.

Portable Simulator

Due to the high cost of transportation, the COVE trailer is essentially a fixed facility. A "portable simulator" was developed that is a one-seat version of Comanche cockpit (Figure 11). The portable simulator uses the actual Comanche cyclic controller, which has three axis of motion: roll, pitch and yaw (Figure 12). A Flightlink^{TM} collective is also included. One desktop computer drives the cockpit view, while another runs four dashboard instrument screens.

Figure 11. Portable Helicopter Simulator with Research Station

Figure 12. Portable Helicopter Simulator Showing Controls and Instruments

A research station is also connected to the portable simulator to record flight data and video via a network hub. The portable simulator can be used for training and teaching as well as a research tool. It is also heavily used as a recruiting tool. High school students consistently identify flying the helicopter simulator as one of the highlights of student visit days.

An Affordable Environment

The ASSET and COVE labs are significant enhancements to the academic and research capabilities at UAH. They provide students access to real-world, high-fidelity flight simulation tools. The Army contributions of the Comanche trailer and portable cockpit represent a significant investment. However, making these components functional would have not been possible without the enabling use of desktop computers and commercially available simulation software. A conservative estimate is that an additional $55,000 of UAH funds was invested.

The ASSET lab and the portable simulator do not require significant maintenance. The COVE lab trailer requires minimal maintenance for air-conditioning, light bulbs, etc. which is estimated to be $500-$1000 per year.

FLIGHT SIMULATION APPLICATIONS

A number of academic and research applications have been demonstrated with the UAH flight simulation capability [8]. Several of these applications are described in the following sections.

Extracting Aerodynamic Data

The X-Plane® *Plane Maker* module can be used to change basic aircraft components and observe the impact on flight performance. Figure 13 shows an original Boeing 747 configuration. One of the innovative features of X-Plane® is the ability to visualize the aerodynamic forces and moments in "real-time" flight. Figure 14 shows the configuration with a T-tail. The "pilot" can fly the modified configuration and evaluate handling qualities. In addition, flight data, such as the drag polar (Figure 15) can also be extracted and evaluated.

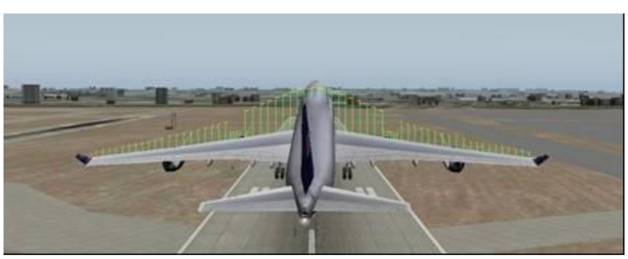

Figure 13. Original Boeing 747 Configuration

Figure 14. Boeing 747 With Modified T-tail

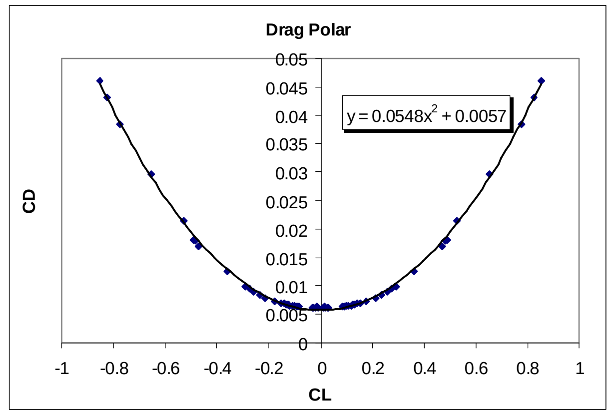

Figure 15. Aerodynamic Flight Data Extracted From X-Plane® Simulation

Helicopter Flight Loads Estimation

The purpose of this project was to investigate a helicopter's flight loads and control interfaces via flight simulation. One specific area of concern is how test pilot variability affects the helicopter flight loads during a maneuver. Due to the difficulty and cost of test flights, simulators can be used to obtain flight data. Simulation can also be used to "reproduce" a given maneuver and use the predictions to interpret measured flight load data.

For this study the pilots were a former Chinook (CH-47) maintenance pilot and a current Chinook pilot and UAH graduate student. The fairly extreme pitch back attack (Figures 16 and 17) was one of the maneuvers analyzed. In addition, the portable simulator and the COVE standard helicopter simulator were flown.

As shown in Figures 18 and 19, the two simulators have different control mechanisms. The COVE simulator uses a standard collective handle, cyclic stick and foot pedals for anti-torque. The portable simulator uses the Comanche helicopter's multi-axis side-stick controller. This controller provides standard cyclic control, but the pilot twists it for lateral, anti-torque control. Another issue is that the two simulators provide different pilot views. The portable simulator has a physical dashboard with digital instrument readouts (Figure 20). The COVE simulator reproduces the dashboard instruments on the display screen (Figure 21).

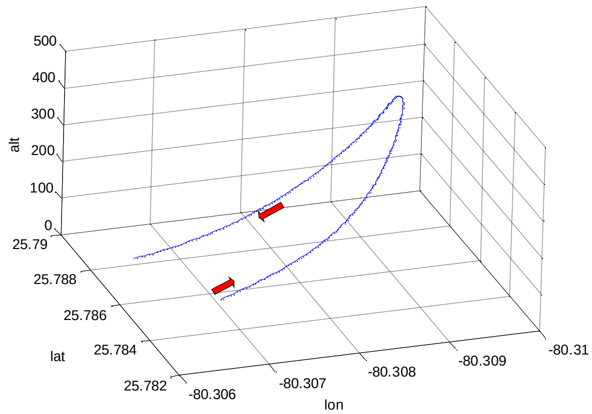

Figure 16. Pitch Back Attack Maneuver, Pilot 1

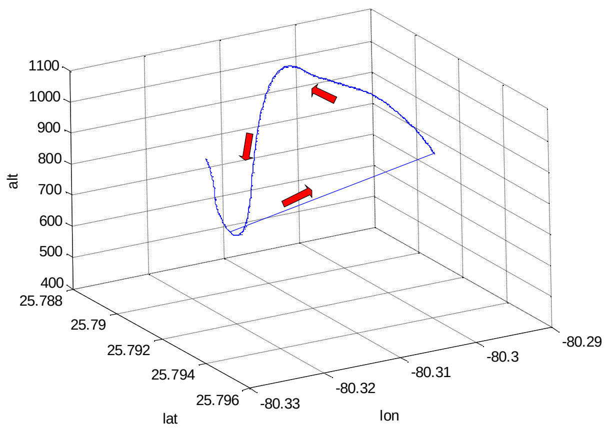

Figure 17. Pitch Back Attack Maneuver, Pilot 2

Figure 18. Portable Flight Simulator Controllers

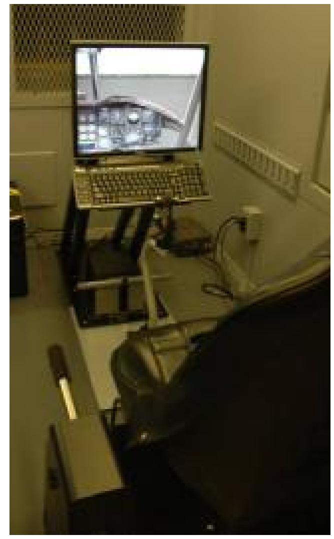

Figure 19. COVE Helicopter Simulator Controls

Figure 20. Protable Simulator Pilot View

Figure 21. COVE Helicopter Simulator Pilot View

As shown in Figures 16 and 17, the two pilots perform the "same" maneuver in very different fashions. The only constraints are the entry and exit states (speed and orientation). Figures 22 and 23 consistently show this difference in the simulated helicopter roll, pitch and yaw rates. From the analysis, pilot 2 flew the vehicle faster and more aggressively than pilot 1 with a higher roll rate to quickly turn the helicopter back and continue to maintain course. Other data (provided in Reference 8) also show that the pitch back attack maneuvers flown on the portable simulator are more oscillatory than on the COVE simulator. This is due to the multi-axis hand controller on the portable simulator. This was harder for the pilots to use than the familiar standard foot pedal control.

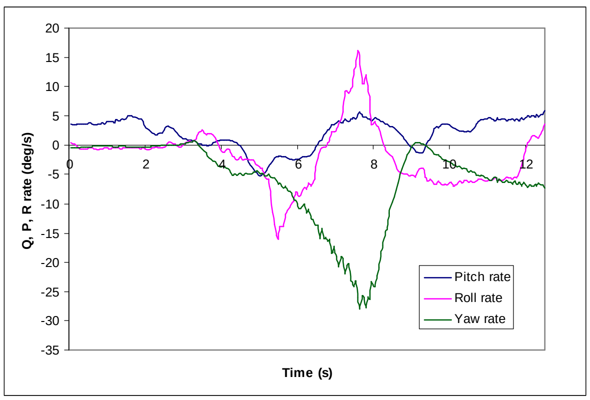

Figure 22. Pitch Back Attack Roll, Pitch and Yaw Rates For Pilot 1

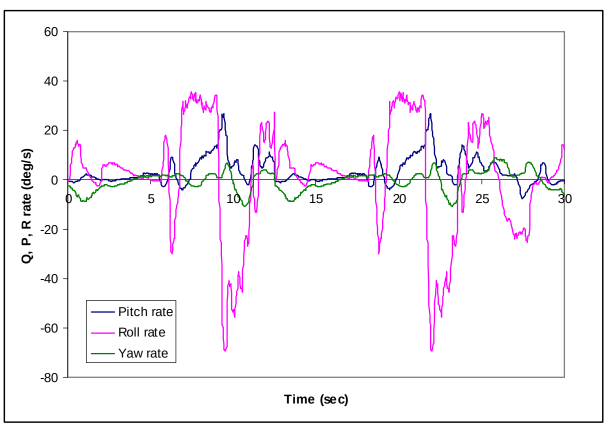

Figure 23. Pitch Back Attack Roll, Pitch and Yaw Rates For Pilot 2

CONCLUSIONS

Flight simulation has been identified as an important component of the UAH academic and research program. An affordable flight simulation environment has been developed using personal computers and the commercial, off-the-shelf X-Plane® software. This capability is being used in research studies of helicopters and unmanned aerial vehicles, and in the aerodynamics and flight dynamics curriculum.

REFERENCES

[1] Deters, R.W, Dimock, G.A., and Selig, M.S., 2006, "Icing Encounter Flight Simulator," AIAA Journal of Aircraft, 43(5), pp. 1528-1537.

[2] Horn, J. F., Bridges, D. O., Lopes, L. V., and Brentner, K. S., 2005, “Development of a Low-Cost, Multi-Disciplinary Rotorcraft Simulation Facility,” Journal of Aerospace Computing, Information, and Communication, 1542-9423, 2(7), pp. 267-284.

[3] Perry, A. R. and Olson, C., 2001, “FlightGear from History to Future,” LinuxTag 2001, Stuttgart, Germany.

[4] Howlett, J., 1989, “UH-60A Black Hawk Engineering Simulation Program: Vol. I – Mathematical Model,” NASA CR-177542, USAAVSCOM TR-89-A-001.

[5] University of North Dakota Aerospace *AeroCast*, http://www.undaerocast.com. Accessed 2008 Sept. 19.

[6] Laminar Research X-Plane® Software Description, http://www.x-plane.com/about.html. Accessed 2008 Sept. 19.

[7] Landrum, D. B., Cerny, J., Warden, L., Meyer, A., 2007, “Affordable Flight Simulation in an Educational Environment,” American Helicopter Society Forum 63, Virginia Beach, VA.

[8] Piputsitee, T., 2008, “Flight Simulation Capability for an Academic Environment,” Master thesis, University of Alabama in Huntsville, Huntsville, AL.