

# Using Technology to Bring Realism, Improved Learning and Motivation to Capstone Design

W. M. Butler, J.P. Terpenney and R.M. Goff  
*Virginia Tech*

The engineering capstone design course is the culmination of all previous undergraduate training in engineering expressed in the act and art of design. In the Aerospace and Ocean Engineering Department of Virginia Tech, Aerospace Engineering Seniors interested in aircraft design can work on the conceptual design of an aircraft that is defined by the yearly Design Competition sponsored by the American Institute of Aeronautics and Astronautics (AIAA). This paper explores the aircraft design course and the impact on student learning of an experimental interactive lesson on the use of Computer Aided Design or CAD in aircraft design. In the present design course, CAD is not covered and the course follows the teacher-centered paradigm. This learner-centered approach attempted to engage the students in an interactive CAD experience with the goal of an initial design layout of an aircraft. This is the first step of a proposed study of the implementation of simulation and virtual reality into aerospace engineering capstone design. Initial student feedback for the CAD lesson was positive.

*Corresponding Author: Wm. Michael Butler, mbphd11@vt.edu*

## Introduction

Capstone design courses are the culmination of all previous undergraduate training in engineering expressed in the act and art of design. In the Department of Aerospace and Ocean Engineering (AOE) at Virginia Tech, capstone design projects may be categorized into three areas: aircraft, spacecraft, and seafaring vehicles. These projects are typically year long and are often part of a national design competition such as the American Institute of Aeronautics and Astronautics (AIAA) annual aircraft design competition and assorted National Aeronautics and Space Administration (NASA) design projects<sup>1</sup>. This paper focuses on an informal experiment in adding learner-centered instruction on the use of Computer Aided Design or CAD to the existing AOE aircraft design course. The implementation of CAD is part of a larger proposed study to increase realism for the students through the use of virtual environments and simulation. Though discussion focuses on the aircraft design experience, the lessons learned may be applied to other capstone design experiences.

## Current Design Class Structure & Proposed Changes

The Virginia Tech aircraft design course is a combination of formal classroom instruction (teacher-centered large lecture) and student led design activities. Formal instruction includes an introduction to the design process, discussions on aircraft features, vehicle sizing, vehicle layout, aircraft stability & control, and

engineering design teams. The course also addresses topics not covered elsewhere in the curriculum such as the business aspect of engineering and its impact on design<sup>2</sup>. Student-led activities are meant to introduce the student to the relative autonomy and personal responsibility the students will encounter upon graduation and entry into the workforce.

All AOE students participate in this form of classroom instruction. Some of these students participate in *Design, Build, and Fly* projects that typically involve the construction of small to medium sized radio controlled aircraft which allow them to gain the experience of designing, building, and testing a vehicle of their own design. Valuable experience is gained by those who participate in this project but this only partially replicates the experiences of designers on real world design teams in industry. The construction techniques of six to ten foot flyable aircraft models do not directly translate into the construction techniques of full scale fighters, transports and airliners. It is believed by the first author that “capstone” design should truly be a “crowning achievement” and provide students with as much realism as possible under controlled conditions. As such, students can be better prepared for their future work experiences.

To this end, it is believed that a way to enhance the capstone aerospace design experience is to introduce virtual reality and simulation to capstone design. The use of virtual reality and simulation has been explored in Chemical Engineering at the University of Michigan. It has been shown to have made progress in enhancing “undergraduate chemical engineering education by

addressing educational objectives and various learning styles, particularly in those areas which are not addressed well by alternative teaching tools”<sup>3</sup>. A first step in implementing virtual reality and simulation into student aircraft design is the use of CAD in the design process. The creation of student designs in CAD will permit the use of models in flight simulations such as the commercial off-the-shelf program *X-Plane* or *FlightGear* which allow the students to input their aircraft designs and fly them with flight models that are constantly updated based upon the geometry and environmental conditions prescribed in the program<sup>4</sup>. These aircraft CAD models may also be used in construction and manufacturing simulations to provide students with insight into how manufacturing and construction influence aircraft design. It is thought that the combination of these simulation experiences with the existing foundational course material will increase student learning by reinforcing lessons learned in previous courses and providing a simulated industrial aircraft design experience. The following discussion presents the results of the initial experiment to implement CAD into the present course.

### **Present Lesson on Aircraft Configuration Layout**

In the present Configuration Layout lesson of the aircraft capstone design course, the students are introduced to drawing standards and practices, aircraft layout procedures, and drawing analysis. This lesson focuses on procedures used when creating aircraft drawings by hand on the on the drawing board. CAD is mentioned but there are no in-depth CAD demonstrations or discussions in the present course. Virginia Tech engineering students are introduced to CAD in general during the freshman year when they must purchase AutoCAD as part of their freshman engineering software package. This is the last CAD experience they are required to have unless they elect to take one of the handful of sophomore and senior level CAD courses offered by the Engineering Education and Mechanical Engineering departments, respectively.

In present aerospace industry design practice, CAD programs such as CATIA, NX (formerly Unigraphics) and ProEngineer (ProE) are used extensively. These programs have some capabilities beyond AutoCAD. As an aerospace industry designer, the first author feels that exposure to such design codes by the undergraduates permits the students to see modern aircraft design tools and practice and exposes them to the application of the standards and analyses taught in the current class as they are applied to the CAD medium. An additional benefit to this industrial CAD exercise is that it provides students who desire to pursue engineering design as a career with appropriate CAD experience.

The AOE department continues to update and modify its program and courses as evidenced in the 1997 International Journal of Engineering Education article by Marchman & Mason regarding the experiment of integrating freshman engineers into senior capstone design courses in Aerospace and Mechanical Engineering<sup>2</sup>. Following this mindset, it was proposed to update the Aerospace Senior Design Lesson on Configuration Layout to include a discussion/demonstration of CAD in aircraft design. The following section will discuss the intended structure of this experiment.

### **Experiment Structure**

The large lecture portion of the capstone design course met two times a week for 75 minutes. The students included members from all of the aircraft design projects. In the 2009-2010 school year the projects included the AIAA Environmentally Friendly Commercial Aircraft project, the aforementioned *Design, Build, and Fly* project with students from Mechanical Engineering and the ongoing Human Powered Aircraft (HPA) project. The lectures were traditional teacher centered lessons where the students were introduced to topics that are applicable to all design projects as listed in the beginning of previous section on *Current Design Class Structure & Proposed Changes*<sup>5</sup>.

The original plan for the experiment was to take the existing course structure and modify the Configuration Layout lesson so that the students would be given a demonstration of CAD in addition to a discussion of general arrangement and inboard drawing standards and configuration design related analysis approaches. (Figure 1 provides examples of the slides that are presented to the large lecture classes.) A separate lesson would be held with the designers of the different design groups that would focus on an interactive lesson on aircraft design using CAD. Virginia Tech is a part of the Partners for the Advancement of Collaborative Engineering Education or PACE effort and as such students in engineering have access to the NX CAD program which can be loaded on their personal laptops and used on campus or at home using the Virtual Private Network (VPN) protocol<sup>6</sup>. As mentioned before, this program is used in industry by companies such as B/E Aerospace, Inc., a provider of aircraft interior products from seating to oxygen systems<sup>7</sup>. This program is generally similar to CATIA used by Lockheed Martin Aeronautics Company and it is thought that exposure to either program by an undergraduate would be beneficial to any professional pursuits involving the use of CAD. The design students would be asked to load the software on their laptops prior to class and in the class the instructor would play the role of a facilitator guiding the

students through the exercise of constructing a complete sample aircraft that is illustrated in Figure 2. (Such an approach to teaching was encountered by the first author when taking CAD training classes on the job in industry.) Scheduling conflicts prevented execution of the experiment as originally planned but elements of the plan were executed and are discussed in the next section.

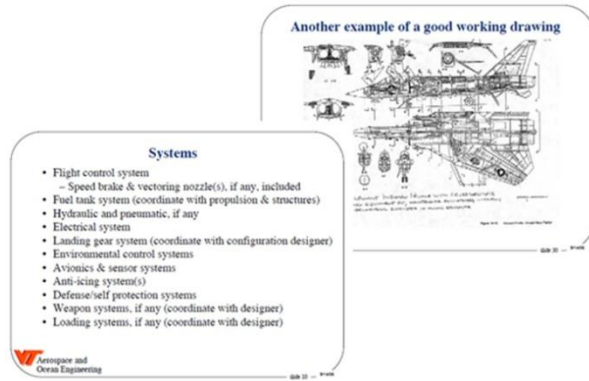


Figure 1 - Examples of Slides Presented in the Original Configuration Layout Lesson

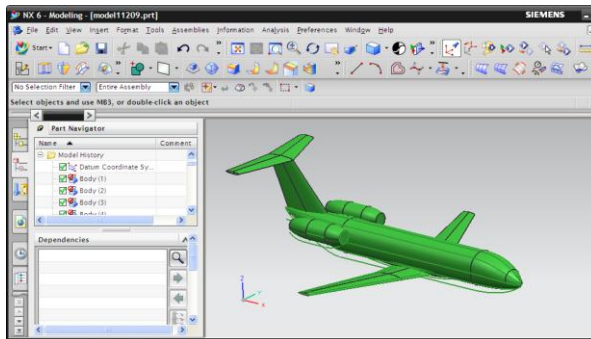


Figure 2 - Constructed in NX CAD during the CAD Exercise

## Results

### Large Lecture

The Configuration Layout lecture was held at the end of September 2009. Due to scheduling restrictions, the class was presented with the current course Configuration Layout lecture that was created six years ago and slightly modified from year to year. The lesson was created by retired Grumman Configuration Designer and Adjunct Professor Nathan Kirschbaum and present AOE Professor William Mason. An addendum was added to this current lecture and presented by the first author (see Figure 3). This addendum addressed areas of the original class presentation where CAD may be used in current

practice. For instance the original lecture discusses the use of airfoil sections and wing drawings to determine wing fuel volume. Model construction (making solid elements) and the use of analysis tools (part volume determination) within typical CAD systems were introduced as the current method used to determine such values. The extended session lasted for approximately 20 minutes and including questions. Surveys were not issued for the class but reaction of the students as seen by the first author appeared to be positive. It was proposed to continue with a more involved lesson on CAD in a separate session that involved only those students that either had a general interest or would be directly involved in the creation of a CAD model of their respective vehicle concepts.

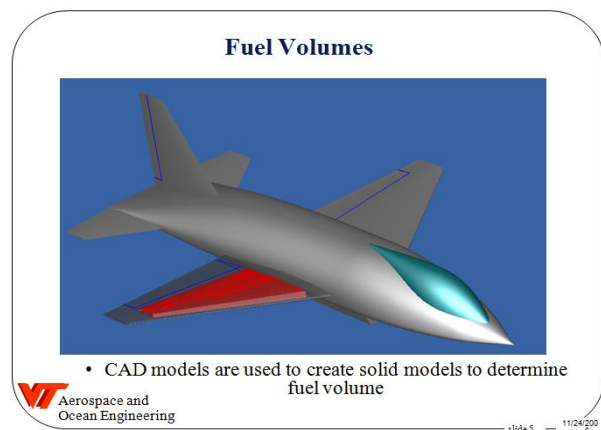


Figure 3 - Sample Slide on Wing Fuel Volume from Large Lecture Addendum Presentation

### Interactive CAD Lesson for Designers

The interactive design lesson took place over two 50 minute sessions in late October and mid-November 2009. The first session involved a demonstration of some basics (terminology, functions etc.) in CAD using the NX CAD system on a mini-book computer and a review of configuration design related items of interest in relation to each of the projects. (Students were not able to have NX preloaded on their machines prior to class and thus the CAD demonstration was held.) Ten students attended and the students were shown the basics of conic sections and conic surfaces, introduced to some of the 3D drawing and analysis capabilities of NX and shown the basic steps used in creating any aircraft geometry in CAD. As before, student reaction appeared positive and the students asked if another session could be held.

The follow-up session involved six students who were able to load a CAD system on their laptops prior to class. Five of the six used the NX CAD system while the sixth had SolidWorks loaded on his laptop. (The student with SolidWorks preloaded had some prior

experience with the program and chose to use this system for his group's drawings and models. This student planned to take the basic CAD concepts presented and use them with the SolidWorks program.) This lesson proceeded with a review of the CAD demonstration from the previous session but with the students themselves creating the CAD part seen in Figure 4. The selected exercise allowed the students to build a conic curve, a conic surface, and a filler surface in addition to working in 3D space and construction on "sketch planes". As instructor of the class, the first author, moved between presentation/demonstration of a concept and walking around the classroom to view progress and help with any issues the individual students might have had in executing the exercise. It was observed that the five NX students helped each other between different design groups as they learned to work in the NX system. One student had prior CAD experience on CATIA as a summer intern at Lockheed Martin Aeronautics Company and was actively relating and comparing the capabilities of the two CAD systems. The students were encouraged and started to experiment with other features of the NX system and were actively seeking out different capabilities available to them. The students were presented with enough basic concepts to start construction of their respective group's designs and were given the extra exercise to try to build the surface model of the demonstration aircraft shown in Figure 2. An informal survey was given at the end of the class to see if the students thought the lesson would be helpful to their design projects and all students responded in the affirmative. The session ended with the students being informed that the first author would be available for questions as the students started creating their unique geometries.

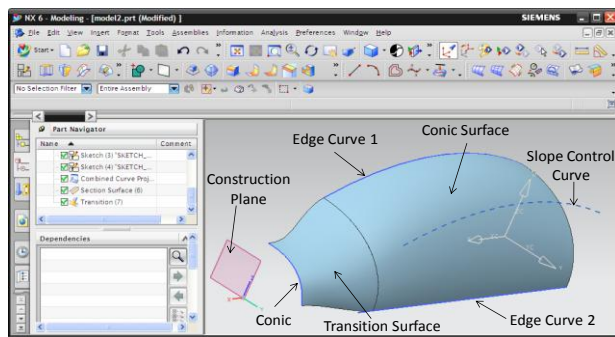


Figure 4 - Conic Curves & Surfaces Demo/Exercise

### Conclusions

An experimental hands-on lesson on aircraft CAD design was held with the 2009-2010 Aerospace Engineering Capstone design class. Students were exposed to the NX CAD system and the basic procedures for the construction of geometry. Reaction

of the students to the lesson was positive and the students indicated that they found it helpful. The lesson was presented in a student-centered fashion the students guiding the lesson progress and discovering capabilities of the CAD system on their own with instructor help available as needed. The experiment appears promising for implementation of the other elements of the capstone design simulation effort. Based upon the experience of this experiment, future immediate changes in the execution of Configuration Layout lesson should involve:

1. An in-class demonstration of CAD combined with formal presentation of basic vehicle layout and drawing concepts.
2. Separate lesson with group designers to allow for in-depth discussion and hands-on aircraft CAD experience. The students should have an agreed upon CAD system loaded on their laptops to allow for in-class participation and out of class follow-up work on their designs.

### References

1. Mason, William, "Aircraft Design at Virginia Tech: Experience in Developing an Integrated Program," *1st AIAA Aircraft Engineering, Technology, and Operations Conference*, AIAA, Los Angeles, CA, September 19-21, 1995, AIAA 95-3893.
2. Marchman, James and Mason, William, "International Journal of Engineering Education," *Freshman/Senior Design Education*, TEMPUS Publications, Great Britain, 1997, pp. 143-152.
3. Bell, John and Fogler, H. Scott, "The Investigation and Application of Virtual Reality as an Educational Tool," *Proceedings of the American Society for Engineering Education 1995 Annual Conference*, ASEE, Anaheim, CA, June 1995, Session number 2513.
4. "How X-Plane Works:" Retrieved January 21, 2010, from [http://www.x-plane.com/pg\\_Inside\\_X-Plane.html](http://www.x-plane.com/pg_Inside_X-Plane.html).
5. Catalano, G. D. and Catalano, K. C., "Transformation: From Teacher-Centered to Student-Centered Engineering Education," *Journal of Engineering Education*, Vol. 88, No. 1, 1999, pp. 59-64.
6. Chapman-Moore, Elaine, editor, "PACE Software," *Pace in Action*, PACE Strategic Planning, 2009, pg.20, <http://www.pacepartners.org>
7. Siemens Product Lifecycle Management Software Inc, *Stunning new airplane seat illustrates beauty of single data format*, Siemens, 2008, <http://www.siemens.com/plm>.