

An Experiment in Learner –Centered Instruction in Aerospace Engineering Capstone Design

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Abstract – 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 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 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 layout of an aircraft. Initial student feedback for the lesson was positive. Future work should include refinement and expansion of lesson material.

Keywords: design, aerospace, CAD, engineering.

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 [1]. This paper focuses on the aircraft design project and the introduction of an interactive lesson on computer aided design (CAD). Though discussion focuses on the aircraft design experience, the lessons learned may be applied to other capstone design experiences that utilize CAD.

CURRENT LESSON STRUCTURE

The aircraft design courses are a combination of formal classroom instruction (large lecture) and student led design activities. Formal instruction includes an introduction to the design process, discussions on aircraft features, sizing, layout, 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 [2]. 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. In the present Configuration Layout lesson of the 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.

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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 [2]. 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 Design/Build/Fly project with 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 the previous section of this paper [3].

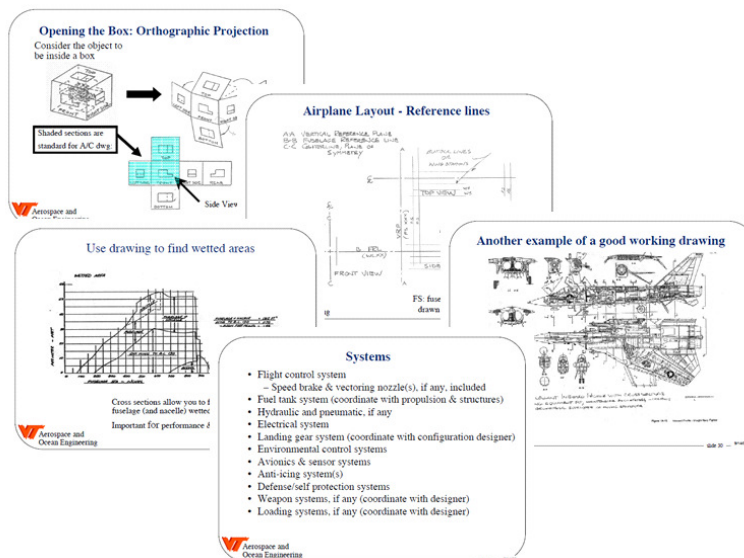


Figure 1 – Examples of Slides Presented in the Original Configuration Layout Lesson

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 [4]. 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 [5]. 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. Scheduling conflicts prevented execution of the experiment as originally planned but elements of the plan were executed and are discussed in the next section.

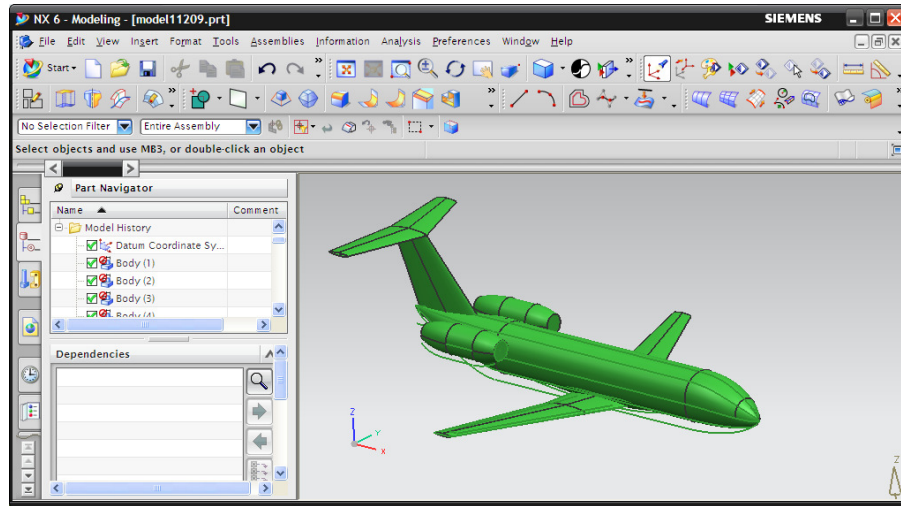


Figure 2 – Aircraft Constructed in NX CAD during the CAD Exercise

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 6 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).

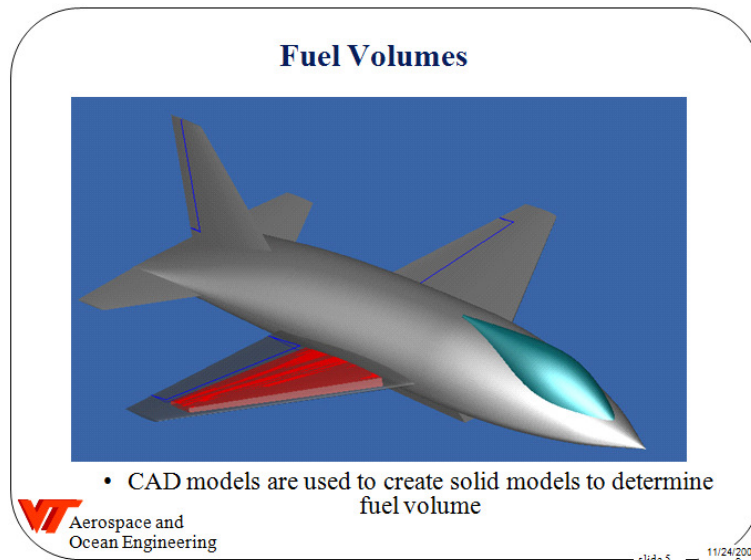


Figure 3 – Sample Slide on Wing Fuel Volume from Large Lecture Addendum Presentation

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 included questions. Surveys were not issued for the class but verbal comments by students after class indicated a positive reaction by the students, as observed by the first author. 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.

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.

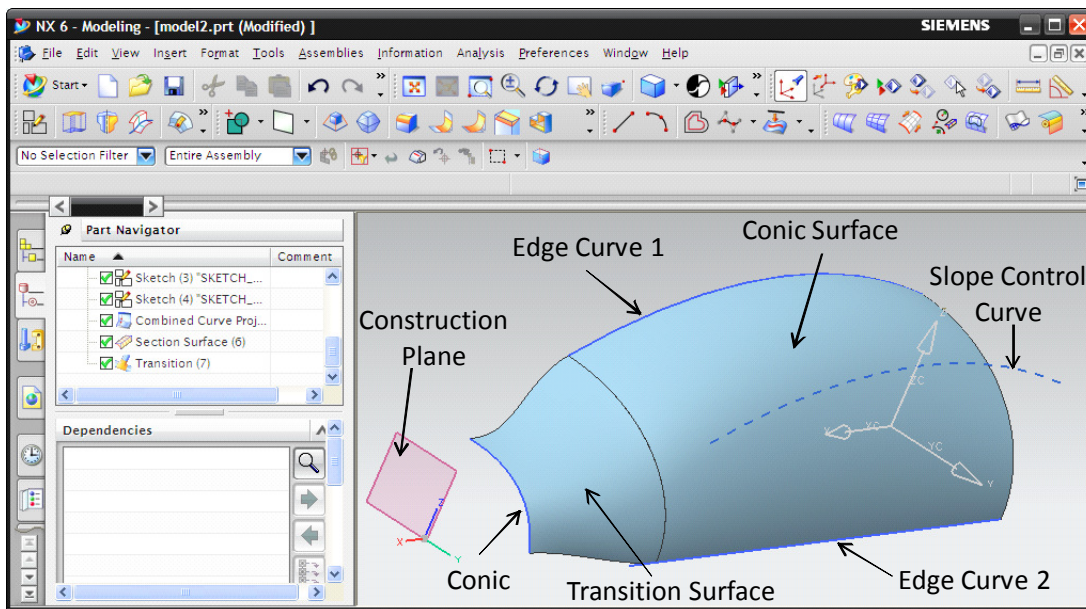


Figure 4 – Conic Curves & Surfaces Demo/Exercise Part

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.

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 lesson may become a new part of the existing lecture on Configuration Layout. Based upon the experience of this experiment, future execution of this lesson should involve:

- a) An in-class demonstration of CAD combined with formal presentation of basic vehicle layout and drawing concepts.
- b) 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.

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