Science Fiction in Engineering Instruction: The Final Frontier?

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***Abstract* – Unfortunately, Science Fiction has not been integrated with engineering education to any appreciable extent. This is regrettable since a potent combination of theory and imagery has been shown to help students to "get it", especially in the early core courses. A fun connection between concept and application may also help avoid a "disconnect" between the ideals of engineering and the early curriculum of math, physics and chemistry. In fact, a recent poll found that most do not associate the technological gains of the last century with engineers. Hence, the absence of Science Fiction in the engineering classroom represents a significant loss of valuable resources and opportunities for enhancing engineering education, as well as attracting new students to the profession. As such, a new class has been developed that uses science and engineering (films and literature) to teach the fundamentals of engineering. Central to the course delivery is "poking fun" at the disobedience of the laws of physics and engineering and teaching the correct behaviors through example. In this fashion, students develop lasting mental pictures of the way things function and the complexities of design. The course also discusses the interactions and implications of technology and society, as well as the ethical considerations of engineering.**

Index Terms – Dynamics, Engineering, Science Fiction, Statics.

INTRODUCTION

Even though it has not been used by engineering instructors, the application of science fiction in education is not a new concept. In fact, science and physics education has long recognized "Sci Fi's" intrinsic value for teaching basic principles [1]-[3] at the undergraduate level. Since physics is certainly the foundation for engineering, the obvious question becomes: why not use science fiction to enhance and illustrate engineering as well? The answer is that "sci fi" can and should be used to convey a wide range of concepts from basic mechanics all the way up to advanced design and analysis. In fact, the importance of such usage cannot be overstated for a number of reasons. Firstly, "Sci Fi's" creation of lasting mental images to the underlying theory will help students through the seemingly abstract core physics, math, and mechanics classes. Clearly, a potent combination of theory and visual imagery could easily provide a critical nudge to help students to "get it [4]." Another advantage is that a visual and fun connection between concept and application may also help avoid a "disconnect" between original (and arguably, often erroneous) idea of engineering and the freshman and sophomore curriculum that plunges into math, physics and chemistry without a clear linkage to anything related to engineering and more importantly, design.

However, it should be noted that limiting the use of science fiction to just teaching basic mechanics may be an underutilization of the medium since other equally important opportunities also exist. For instance, a recent Harris Poll [5] revealed that "*People do not think of engineers as researchers, inventors, and discoverers—they attribute these functions to scientists.*" Unfortunately, this misperception is widespread as epitomized by the typical class answer of *scientist* to the age-old question: what is the professor on the campy 1960's television show, Gilligan's Island? While the professor is certainly knowledgeable in scientific theory, he is clearly able to translate this knowledge into practical solutions – the very definition of engineering! Since there appears to be many misperceptions about engineering that may reduce the number of prospective students, why not use science fiction to illustrate the many contributions of engineering and hopefully create a more positive image of the profession? Moreover, why not use the class to help recruit students to the profession by showing the many exiting aspects of the profession not usually seen in TV and movies. Finally, why not use the same techniques to teach others about the engineering concepts they unknowingly encounter every day? Regardless of the audience, the class and subject matter can and should be made fun and interesting.

Another underutilized aspect of science fiction in engineering education revolves around technology and societal issues [6]-[7] and the underlying ethical considerations that go with them. Given our limited resources and the interrelated global problems of food, water, energy, and pollution, these issues should be included in engineering education. In this regard, science fiction is a "natural" since it can easily (but not always accurately) depict a wide range of "what ifs" as already demonstrated [8]. Hopefully, the next generation of engineers will at least be able to contemplate and understand the ethical and societal implications of their actions. Given the many possibilities for topics to be taught and science fiction stories to use, virtually any combination is possible. In this paper,

two science fiction stories (a movie and a TV series) will be used to illustrate the many possibilities. It is hoped that these illustrations will serve as a guide and spur many new innovations that can help improve engineering education. Furthermore and more importantly, the humorous and discussion-like style of this paper is intended to reflect how the various topics can be conveyed to the students during the class.

MECHANICS

The 1997 movie "Independence Day" (ID4, Paramount Pictures) was chosen to be an integral part of an introductory class for freshmen/sophomores of all majors; the idea for the course was actually spawned while watching this movie with my children. ID4 was chosen in part because of its "looseness" with the laws of nature and stunning visual effects that create a great opportunity to leave a lasting and hopefully educational impression. As mentioned earlier, there are numerous topics and sub-topics that can be explored using science fiction; "Independence Day" definitely hits on many of the major themes and can be readily used to illustrate a number of points integral to engineering practice. For instance, as the alien's evil plot unfolds, a number of extremely large ships descend to the surface and silently hover over earth's major cities as shown in Figure 1. Based on estimates [9],[10] of the mass of one ship to be ~$9x10^3$kg and the diameter to be approximately 24km , the concepts of both static equilibrium and pressure can be explored. Obviously, for the ship to remain stationary over any given location, the ship must exert a downward force on the ground (and the ground back up on to the ship) equal to the total weight of the craft. Thus the concept of static equilibrium can be demonstrated. While this may represent a rudimentary "statics" concept that is easily understood by most sophomores, the distribution of this force and the consequences might go unexplored. Given the force required for equilibrium and the diameter of the ship, the resulting pressure (if assumed uniform) would be a staggering 21 times our normal atmospheric pressure and would easily crush the hapless inhabitants below. An instructor can then proceed to discuss pressure and the concept of distribution of force over an area. Once these concepts are understood by the students, the discussion can be further expanded to include stress as a measure of the intensity of a force over a given area or cross-section for a solid.

More advanced concepts such as conductive and radiative heat transfer can also be explored by reviewing key scenes of the movie. One such exhilarating sequence involves the residents of Los Angeles attempting to quickly escape the city using the freeways (a major falsity in and of itself). Some are trapped in a tunnel and find refuge from the alien destructive plasma-like weapon in a utility room with a metal door. Under the assumptions that the plasma is at least 2200°C and the steel door is 50 mm thick, classroom calculations can easily show that the door will reach at least 1900°C within 2-3 minutes. Given the door's temperature and a conservative estimate that approximately one-half of the total radiative flux will reach anyone inside, the unfortunate inhabitants would quickly be "barbecued". Discussion can also be held about the differences between a solid steel-door where thermal conduction governs and a more likely hollow door scenario where radiation between the panels could ultimately allow a faster heat-up.

Figure 1
CONCEPTS OF EQUILIBRIUM AND PRESSURE UNDERLIE THE ALIEN'S SUCCESSFUL EFFORT TO RUIN NEW YORK'S DAY.

There are many other aspects of engineering (and the underlying physics) that can be discussed in class. Topics such as the aerodynamics of the behemoth battleships and the staggering energy required to levitate and propel them are engineering realities glossed-over in the movie. Other discussions can delve into the structural aspects of ship construction all the way to the tremendous impact energy sustained by the earth and its falsely victorious inhabitants when the aliens are finally defeated.

Along these lines, the universally reviled, sophomore dynamics class can also benefit from the use of science fiction. Concepts such as force, acceleration, and inertia can be discussed and visually explored using many science fiction stories; entertaining cartoons such as the roadrunner are also great ways to illustrate basic concepts of dynamics. In this regard, Star Trek (Paramount Home Video) and the Starship Enterprise shown in Figure 2 can be used to illustrate dynamics and concept of a mass acceleration diagram (MAD) since the ship should be doing somersaults as it travels through space. Computers, mass, and energy concepts, as well as new propulsion system and the engineering challenges also be discussed.

TECHNOLOGY AND SOCIETY

While hopefully creating lasting links between engineering theory and practice, equally important concepts of technology and society can also be explored. In this respect, both ID4 and Star Trek present a number of useful seeds for insightful discussions. For instance, analogies between the aliens' locust-like behavior of moving from planet to planet and using all resources and our own throw-away culture can be drawn. What are the ethics of stimulating an ever-increasing consumer demand when the result is increased

pollution, possible long-term or irreversible environmental changes, and diminished resources? How can engineering help create a balance between economic prosperity and the limited resources of the earth? Can science and engineering ultimately solve all problems as many assume or hope? As illustrated by our inability to cure the AIDS virus or harness fusion for power after decades of research, we are a long way off from Scotty's and Dr. McCoy's ability to use technology to solve any problem in less than one hour.

Figure 2
THE OFF-CENTER OF GRAVITY THRUST WILL TRULY CAUSE THE STARSHIP ENTERPRISE TO TRAVEL AT DIZZYING SPEEDS.

The Hugo award-winning Star Trek episode "The Menagerie" can also be used to illustrate our increasing dependence on technology and the problems that can arise when we lose the ability to manufacture or repair as suffered by the inhabitants of Talos IV after a horrific war. Compelling stories such as "The Menagerie" also highlights the pitfalls of a society overly dependent on technology that is not understood by a vast majority of users. While many might "scoff" at the idea of losing important skills and technology even if we grow big heads like the Talosions (Figure 3), how many could start a fire without a match even if their life depended on it? Perhaps these insights can eventually lead to required engineering and science courses for all college students to help balance a liberal arts education.

BACKGROUND AND CLASS FORMAT

The course was originally taught at Washington State University Vancouver (WSUV). However, because WSUV was restricted at the time to upper division undergraduate and graduate level courses only (2+2 system), it was not feasible to teach the science fiction course to freshman engineering students as originally intended. Instead, the science fiction course was taught at Clark College (Vancouver, WA) where many WSUV students take their freshman and sophomore classes; the Engr 280 class was open to all majors and had no prerequisites or minimum term standing requirements. Since 2002, the course has been offered in essentially the same format at The Pennsylvania State University as a freshman seminar with approximately 100+ students enrolled.

Figure 3
EVEN BIG HEADS COULD NOT HELP THE TALOSIANS WITH THEIR MACHINES AND PHYSICAL NEEDS.

Because of the inclusion of all majors, the class format consisted of demonstrations (including movies), some lecture including limited use of equations and diagrams, and discussion. Using a 1-2 hour class period, a brief introduction to a movie combined with a listing of key points to observe was used to prime the students. The class is then allowed to watch the movie without any interruptions. Following the presentation, the class is then asked to describe and explain at least five events in the movie where they first felt that the laws of physics/engineering were observed and/or violated. The students were also asked to highlight and discuss any technology and society and/or ethical issues that were raised by the story. The one- to two-page essays were collected the following class and were primarily intended to help spur thought and discussions. PowerPoint presentations and classroom demos using models and other props are also used to illustrate points. For instance, a large book with the outline of the Starship Enterprise is placed on a desk and the students asked to push it at the engine pods and at the center of gravity. As the ship begins to spin when pushed at the engines, but not at the CG, the MAD diagram begins to comes to life.

While the essays accounted for 50% of the student's grade, the accuracy of their review of the physics was not used as a basis for their score. This is an important point since the purpose of the course is to help teach basic engineering concepts and not to evaluate existing knowledge. Class participation accounted for another 10% of the grade with the remaining 40% of the grade awarded for a term paper collected during the final class. For this paper, students were expected to choose (or assigned) a science fiction book such as H.G. Well's War of the Worlds not covered in class and analyze the story for its accuracy and any pertinent technology versus society issues raised. The students were expected to incorporate the concepts and issues raised in the classes so the technical accuracy of their paper and the discussions contained within were evaluated.

STUDENT FEEDBACK

As mentioned earlier, the class has been taught for 7 years at two universities. Based on an "exit" discussion held on the last day of the course, the following feedback has been received. In general, the students felt that the class was worthwhile in terms of illuminating the important role of engineering and basic concepts. While the class did not necessarily convince any students to change their major, all of the students did report a greater appreciation of the role of engineers. In fact, (and perhaps most importantly), most of the students now believe that the "Professor" was an engineer and not a scientist.

In terms of understanding and visualizing basic engineering concepts, the engineering students stated that they believed they were better equipped to take their courses. More importantly, the students indicated that they could to some extent, see a link between their original vision of engineering and their current coursework. Since the students will go to a variety of engineering schools to complete their degrees, it is not feasible to track the success and grades of the students. Not surprisingly, a majority of the students (especially non-engineering majors) preferred that the use of equations be kept to a minimum with an emphasis placed on more physical demonstrations such as the somersaulting motion of the enterprise mentioned earlier.

CONCLUSIONS

A new course using science fiction found in the literature and movies was created for all majors. While there are many facets to this course, the primary reasons behind its inception were to help illustrate basic engineering principles and create a positive image of engineering. The course also served a useful purpose in that it can highlight many important, albeit neglected, issues of man, technology, and society. Feedback from the students indicates that the science fiction course is capable of reaching and teaching a wide spectrum of students. Given the critical need to maintain an innovative and technically capable engineering force, the use of science fiction in engineering education should be studied further.

RECOMMENDATIONS

In addition to tracking student success and opinions, it is also recommended that a basic questionnaire be developed and given to the students at the beginning and end of the class. The purpose of the questionnaire will be to assess changes in the students understanding of basic engineering principles. When crafting the questions and developing the course, great care must be taken to avoid teaching to the evaluation or directly covering any given question. When asking these questions at the beginning and end of the course, it should be emphasized that the answers will not influence the students' grade. Furthermore, it is recommended that each answer be followed by a brief explanation to help frame the mind and intent of the student.

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