

Science Fiction in Engineering Instruction: To Boldly Go Where No Educator Has Gone Before

A.E. Segall

**Washington State University Vancouver
Associate Professor of Mechanical and Manufacturing Engineering**

Abstract

Long used for enhancing science and physics education, science fiction has not been effectively integrated with engineering education. Unfortunately, this represents a loss of a valuable resource and opportunity for enhancing engineering education, as well as attracting new students to the profession. With these basic goals in mind, a new class has been developed that uses science as conveyed in science fiction films and literature to illustrate and teach basic engineering concepts. Central to the course delivery is “poking fun” at the disobedience of the laws of physics and engineering in “sci fi” and teaching the correct behaviors. In this fashion, students can develop lasting mental pictures of the way things function and the complexities of design. This course also discusses the interactions and implications of technology and society, as well as the ethical considerations of engineering given human nature and the limited natural resources of the earth.

I. Introduction

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 principles¹⁻³ 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 concepts. For a number of reasons, the importance of this potential enhancement cannot be overstated. First, “sci fi’s” creation of lasting mental images to the underlying theory will help students through the seemingly abstract core physics and mechanics classes. Arguably, a potent combination of theory and visual imagery may provide a critical nudge to help students to “get it⁴.” Another advantage is that a visual and fun connection between concept and application may also help avoid a “disconnect” between a student’s original (and sometimes erroneous) idea of engineering and the freshman and sophomore curriculum that plunges into math, physics and chemistry without a clear linkage to engineering and design.

However, 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 Poll⁵ revealed that most individuals equate the many technological advances enjoyed today with scientists and not engineers; “*People do not think of engineers as researchers, inventors, and discoverers—they attribute these functions to scientists.*” Unfortunately, this erroneous point of view is widespread as epitomized by the typical class answer of *scientist* to the age-old question: what is the professor on 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? 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. Furthermore, why not use the same techniques to enlighten the often technologically less literate “masses” about the engineering concepts they 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 issues⁶⁻⁷ and the underlying ethical considerations that go with them. Given our limited resources and the related global problems of food, 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.” 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, only two science fiction stories (a movie and a TV series) will be used to illustrate the many possibilities. It is hoped that the illustrations that follow will serve as a guide and spur many new innovations that can help improve engineering education. Furthermore, 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.

II. 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. 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. In terms of basic mechanics, ID4 can be used to illustrate a number of points integral to engineering practice. For instance, as the alien’s evil

* It is doubtful that a fictitious television show such as “Detroit Engineering” would produce a surge of engineers in the same way as “LA Law” swelled the legal profession.

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 estimates⁸⁻⁹ of the mass of one ship to be $\sim 9 \times 10^3 \text{ kg}$ and the diameter to be 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 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 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.

There are many other facets of engineering and 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[‡]. 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.

III. 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

[‡] Cartoons such as the roadrunner are also great ways to illustrate basic concepts of dynamics.

between the aliens' locust-like behavior of moving from planet to planet and using all resources and our own use-and-discard behavior 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, 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.

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. 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, 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.

IV. Class Format

Since Washington State University Vancouver (WSUV) is restricted 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 intended⁶. 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.

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 two-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 was then allowed to watch the movie without any interruptions. Following the presentation, the class was 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.

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 a science fiction story (movie or book) not covered in class and analyze the story for

⁶ The course was originally conceived and planned by the author while at Penn State University to be delivered as a freshman-engineering seminar.

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.

V. Student Feedback

The class has been taught for two semesters and has served 20 students with a variety of interests. 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, most of the students now believed 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. For example, after discussing MAD diagrams and force-mass-acceleration concepts, the true somersaulting motion of the enterprise was quickly (and clearly) illustrated by simply pushing a book on a table with the force applied off of the centroidal axis.

VI. 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. The 2+2 system used by Washington State University Vancouver with Clark College precludes a thorough evaluation and tracking of student success at this point in time. Nevertheless, 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.

VII. Recommendations

While the 2+2 system limited the ability to track the success of the course in terms of teaching engineering theory and student retention, traditional 4-years programs have a far greater latitude to do so. 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. Some suggested evaluation questions are as follows for an open class that includes both engineering and other majors:

1. If a person is standing on the surface of the earth, what force must be exerted by the earth to avoid having them crash to the center?
 - A. Any force up to the persons weight
 - B. Any force greater than the persons weight
 - C. The person's weight

2. Two equal sized trays of water are placed in a freezer at -10°C ? If one tray is at 50°C and the other is 75°F , which one is more likely to freeze first?
 - A. 50°C
 - B. 75°C
 - C. Both the same

3. A 500 kg body at a height of 100 m and a 100 kg body at height of 500m are both dropped to the ground. Neglecting air resistance, which body will do more damage at impact?
 - A. 500kg
 - B. 100kg
 - C. Both the same

- D. If both are dropped from the same height, which one will hit first if air resistance is neglected?
 - A. 500kg
 - B. 100kg
 - C. Both the same

- E. Is the Professor on "Gilligan's Island" a scientist or engineer?
 - A. Scientists
 - B. Engineers

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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Albert E. Segall is currently the Director of Engineering Programs and Associate Professor of Mechanical and Manufacturing Engineering at Washington State University Vancouver. He Received his Ph.D. in Engineering Science and Mechanics from the Pennsylvania State University in 1992. While at Penn State, he has also served as the Associate Director of the Center for Advanced Materials and a Senior Research Associate at the Applied Research Laboratory.



Figure 1. Concepts of equilibrium and pressure underlie the alien's successful effort to ruin New York's day.



Figure 2. The off-center of gravity thrust of the warp engines will truly cause the Starship Enterprise to travel at dizzying speeds.