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How Does the Image of Engineering Affect Student Recruitment and Retention? A Perspective from the USA*

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During the past decade, as the total number of bachelors degree earners in all fields increased by 16% in the USA, there was a 15% decline in the number of engineering bachelors degrees granted. Even with the phenomenal growth of new technology, increases in engineering enrolments have been modest. One significant challenge in recruiting students to study engineering is the negative image of the profession as a whole and the image of the engineer as a person in US society. A typical stereotype engineer fits the image of *Dilbert*, a cartoon character of a corporate engineer who is smart, honest, inflexible and dull. This contrasts to the image of a true renaissance engineer, Leonardo da Vinci, who was creative, literate, well rounded and exciting. This paper attempts to trace the image of an engineer throughout history and to describe how the modern day engineer is viewed in the USA. Some of the projects funded by various engineering societies and foundations in hopes of enhancing the image of engineering in the USA are also included in the paper.

INTRODUCTION

The engineering profession has a long and distinguished history. The word *engineer* originates from the word *ingeniator*, which means *ingenious* in Latin [1]. During the Roman Empire, as the armies marched across the landscape of Europe, the Middle East and North Africa, a core of soldiers and army staff would find ingenious ways of helping the army cross the rivers and lakes over the bridges built by them or through the thick forestation cleared by them. Romans labelled these especially talented people as *engineers*.

When the internal combustion and steam devices of the 16th Century later were called *engines* around the time of the first industrial revolution, the words *engine* and *engineer* were linked (at least in the English language) and this led to the image of the engineering profession as the profession of running and maintaining of engines. This perception still lingers in many English-speaking countries today.

Early engineering feats go as far as to 5500 BC with the use of metal tools and weapons in the Middle East. Engineers have historically been the primary designer and maker of tools since at that time they were influential in the stages of production, use and distribution of tools and goods. The research and development functions of engineers as an organised activity came later in history after the industrial revolutions.

The early focus of engineering has been on agriculture and the military. With printing becoming widely available in the 15th Century, the applications of engineering principles have been shared by many groups and nations, especially in Europe after the Renaissance, leading to a series of industrial revolutions.

The role of an engineer has evolved with the advance of technology from an independent, self-sufficient and highly motivated inventor to an inter-dependent team member of a corporate world, small or large. The perception of the engineer has also been transformed in the eyes of society from *a know-it-all inventor* and *tinkerer* to a highly skilled and narrowly specialised technical expert.

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ENGINEERING AND ENGINEERS IN THE USA

There are a little over two million engineers in the USA today comprising approximately 1% of the total US population. The absolute numbers of employed engineers grew at an average rate of 10% per year during the last half of the century.

It is interesting to note that only 1.2 million of these engineers are in jobs that are engineering related. Over one million engineers do not actually practice engineering. They are most likely employed in business and management areas. More than 400,000 people from other fields such as science or technology, etc, work in the engineering practice as illustrated in Figure 1.

It is also significant that out of 2.6 million engineers, almost 2.1 million of them stayed within engineering, ie about 1.6 million did not pursue an advanced degree after the bachelor's degree in engineering. Close to 400,000 received masters degrees in engineering, and 80,000 continued and obtained PhD degrees in engineering.

The remaining half a million engineers pursued second degrees in another field and more than half of them went the Master of Business Administration route. Slightly more than 160,000 combined engineering and science, while the remaining combined engineering with law, liberal arts, humanities, etc.

The number of baccalaureate engineering degrees awarded in the USA during the last half of the century is shown in Figure 2. The sharp variations coincide with the US economic cycles as expected.

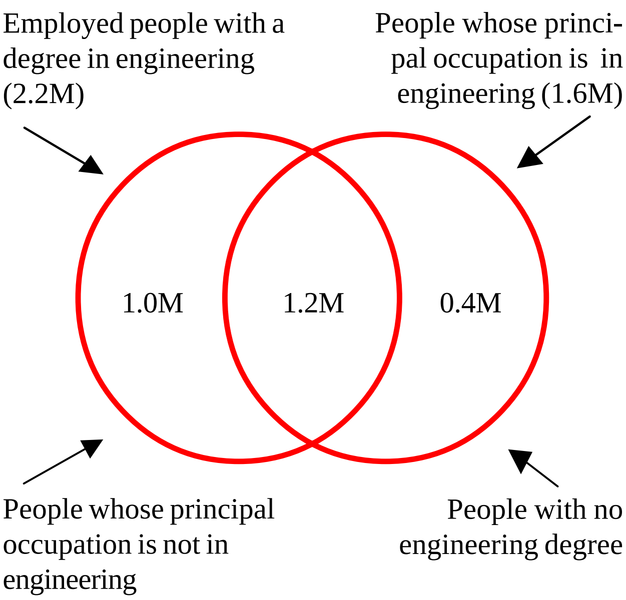

Figure 1: Breakdown of engineering degrees and engineering occupations in the USA.

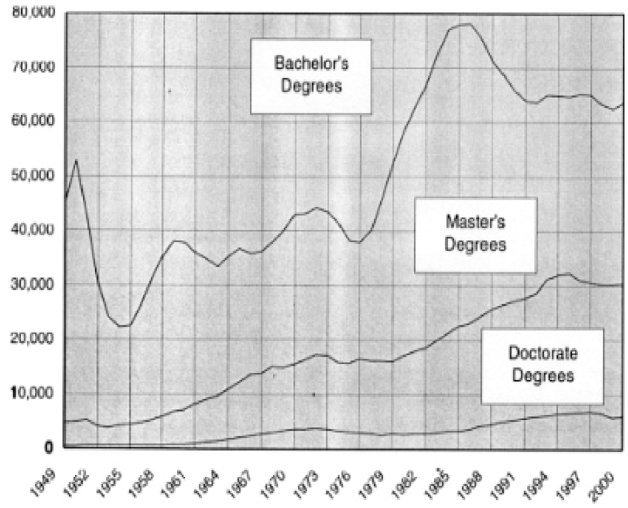

Figure 2: Number of BS degrees in engineering awarded in the USA over the last half century.

For example, there are significant increases right after the Second World War, at the beginning of the space race with the USSR in the early 1960s, and the economic boom as a result of a microprocessor revolution in the 1980s.

Similarly, the dips in the mid-1950s, mid-1980s and mid-1990s were the result of the much slower US economy during the same periods. Figure 3 shows the details of the decline since 1986.

As these figures point out, only about 60,000 students graduate as engineers in a little over 300 engineering schools. This is far below the current demand of the economy. In order to compensate for the shortage, the USA increased the ceiling of number of immigrant engineers and scientists from 60,000 a year to 120,000 a year during the past two years. However,

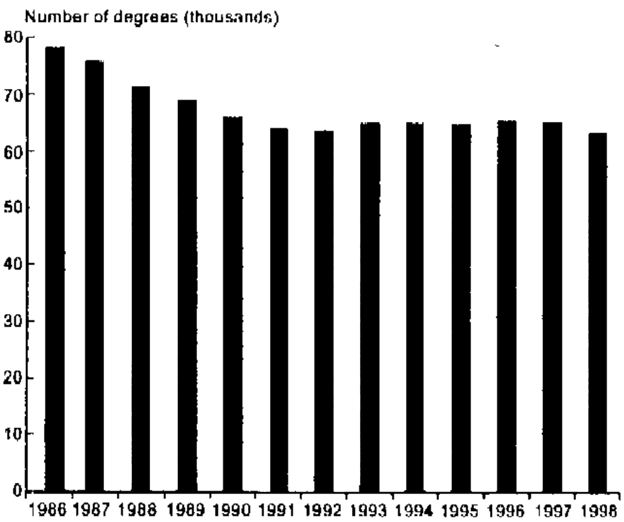

Figure 3: BS Degrees in Engineering in the USA since 1986.

business and industry leaders have urged the US Congress to increase the ceiling even further for the upcoming legislative session. For 2002 and 2003, about 195,000 H1B visa permits are expected to be granted for this purpose.

The trend in the largest engineering disciplines over a decade is shown in Figure 4. Mechanical engineering appears to have the largest number of graduates with electrical and electronics engineering coming a close second. The field of computer engineering, however, has shown significant increases during the past three years, becoming a strong third discipline. The domains of civil and chemical engineering have had a decreasing pattern of graduates.

The percentage representations of minority groups and women amongst practicing engineers and students enrolling in engineering programmes also lagged the pace of economic growth and expansion in USA. For the first time, in 2000 the percentage of women receiving bachelor's degrees in engineering exceeded 20%. As shown in Figure 5, the increase is not as sharp as in the late 1970s and early 1980s, but the number of women engineers is still on the rise. However, the percentage of underrepresented minorities is still below 12%.

The starting salaries offered to BS and MS engineering graduates are in the top 5% of all professions, as shown in Table 1. How engineering salaries compare to other professions is shown in Table 2. It is interesting to note that master's degree increases the starting salaries by up to 25%.

There are several indications that the US companies offer additional incentives to attract new gradu-

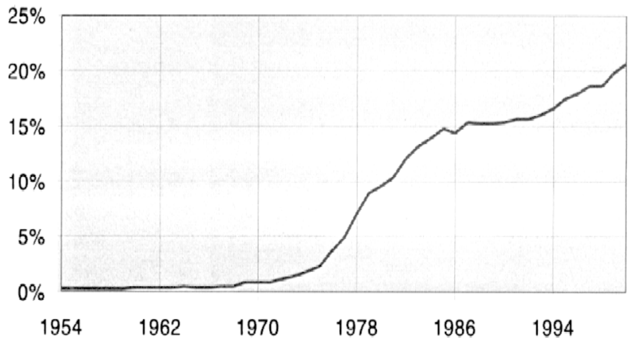

Figure 5: Percentage of minority groups and women undertaking engineering bachelors degrees.

Table 1: Average starting salaries for engineering graduates

	Average offer	Increase from last year
Bachelors		
Chemical engineering	$47,705	6.5%
Civil engineering	$36,030	8.1%
Computer engineering	$46,190	5.8%
Electrical engineering	$44,803	7.8%
Industrial engineering	$43,475	7.7%
Mechanical engineering	$43,337	6.4%
Engineering technology	$33,366	2.8%
Computer science	$45,562	9.8%
Masters		
Electrical engineering	$58,294	7.1%
Mechanical engineering	$51,657	5.2%
Computer science	$51,886	17.7%

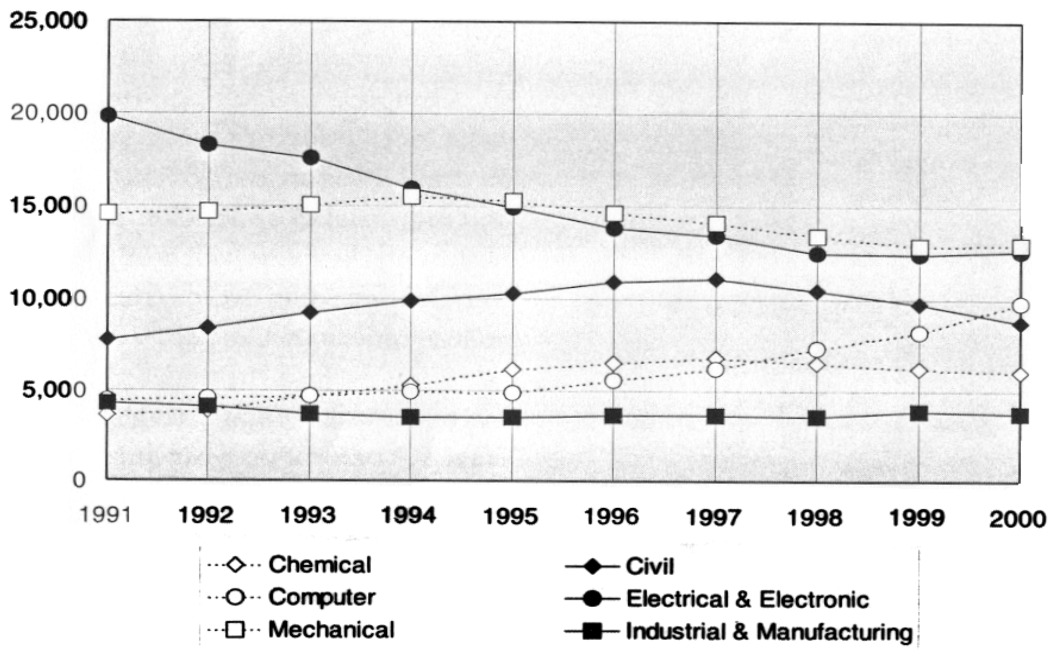

Figure 4: Ten-year trend for the largest engineering disciplines in the USA.

Table 2: National Association of Colleges and Employers Spring 2000 Survey

Major	Average Salary	% increase from last year
Psychology	$27,525	2.1
English	$29,830	5.5
Marketing	$33,760	7.3
Accounting	$37,208	8.8
Info sys	$44,064	12.0
EE	$47,403	5.8
Comp Sci	$48,468	6.4

ates such as a down payment for a home mortgage, an automobile, cash, stock options, equity in the company, etc. This would seem to be a good time to be an engineer, but is it?

WHAT IS WRONG WITH THIS PICTURE?

As evidenced in the previous sections, the US economy is still doing well despite a slowdown in early 2001. Technology is advancing at an accelerated pace, the salaries are high and the benefits are great. But there is an acute shortage of technically well-prepared graduates. This is even greater amongst women and minorities, even when employers are willing to go the extra mile to recruit them.

Now comes the obvious question. Why are the engineering schools in the country not flooded with applications and inquiries? With the exception of half a dozen star programmes and big name schools that cap the engineering enrolment whether the USA is in good economic times or bad, why is it that high school graduates within the 50 states do not flock to their state and city universities to study engineering? Why are there no more women and minorities applying to engineering programmes for admission?

There are several reasonable answers to these questions and some possible explanations. These include:

- The engineering curriculum is not an easy and trivial subject matter to study. Many high school graduates in the USA are not academically prepared to study engineering since they do not take a sufficient dose of mathematics, science and technology based courses before they graduate from high school. Over 300 engineering programmes in the USA compete to recruit students from a slowly growing pool of eligible and prepared population. The low mathematics and science aptitude of USA high school students is of major concern for engineering educators. Many pre-college programmes have been created in the hopes of compensating for the academic deficiencies that many students have prior to their entrance to engineering programmes.
- The combination of low unemployment and the low inflation rate of the current US economy has created more job opportunities for both the skilled and the semi-skilled workforce. Therefore, one does not have to become an engineer to make a reasonably good living.
- Many potential students, their families, primary and secondary education teachers, counsellors and administrators are not aware of the opportunities available in engineering. They do not, in general, encourage students to consider engineering as a choice of college study.

This third plausible explanation above is the subject of this paper as the next section provides additional details and supporting evidence.

THE CURRENT IMAGE

The American Society for Engineering Education (ASEE) funded a survey in 1998 conducted by Harris Poll [2]. The survey showed that 45% of the public was not very well informed about the profession of engineering and engineers as practitioners. The same survey showed that 55% of women were not very well informed. Of those surveyed, 16% said that they were not at all informed about engineering and amongst the women the number went up to 23%.

If one thinks that perhaps the college graduates would be well informed about engineers, there is a disappointment again. A whopping 53% of surveyed college graduates said that they were not very well or not at all well informed about engineering. In light of these awakening statistics, it is not surprising that parents and teachers would not advise or counsel their children and students to study engineering.

The image of an engineer appears to have changed historically from someone who resembles the great Renaissance man, Leonardo da Vinci, to a fictional cartoon character of *Dilbert*. Leonardo da Vinci was an accomplished painter, architect, scientist, and an engineer. *The Last Supper* is one of his magnificent paintings. He designed and built many cathedrals and public buildings both in his native country of Italy and also in France, where he moved to at a later stage in his life. As a scientist, he conducted careful studies of cloud formations in the sky, connecting them to weather patterns; he studied the surface of Mars for water canal designs, building similar canals in Milan, Italy; and published his findings about the hydraulic properties of blood flow in veins. As a practical engineer, he built canals, designed weapons, and even proposed the rudimentary design of a helicopter.

As humankind went through several industrial revolutions, starting with the use of the steam engine in the mid-18th Century, the invention of production lines by Ford in the early 1900s, and perhaps with the introduction of microprocessors in mid-1970s, the role and image of an engineer eventually became more narrowly defined as a highly skilled technology specialist. That is why it is not a great stretch to portray the fictional character *Dilbert*, a frustrated engineer locked in a cubicle, treated like an abnormal human species as the cartoon sequence in Figure 6 shows.

As engineers, we see ourselves as bright, articulate, honest, responsible, conscientious and capable. There will not be any argument against this from an engineer of course. The US public version of our image as engineers is not, however, this complimentary. We are seen as predominantly male, too bright for our own good, honest to a fault, non communicative, dull, and loners.

The issue of *image perception* for an engineer has been pointed out by many authors who themselves are engineers. Mueller points out that although engineers are the ones that make most of everyday life possible with their designs and manufacturing of products, they do not have the political sense or power to protect themselves from inferior status that they have in the society [3]. Their long and exhaustive workaholic habits are not recognised or rewarded according to Mueller. When something goes wrong in using a device or a process, engineer is, however, held responsible.

Schirra notes that more engineers and computer scientists are needed for the growing needs of computer-games industry [4]. However, those engineers are treated as the necessary specialists with extraordinary and narrow skills but with all the handicaps of any form of communication outside of their domain.

If engineers want to be celebrities, then they should choose another field claims Lee in a recent paper [5]. The image of an engineer according to him varies from a hard working professional to a warmonger helping in the design and production of weapons and from a nerd to a tool for environmental destruction.

The root of the word *engineer* is connected to the word *engine* in North American folklore rather than originating from a Latin word *ingeniator* meaning ingenious. In many of the blues songs, an important form of black American music, an engineer operates the train, which sometimes separates and at times brings the lovers together. Blind Willy McTell recorded *Travellin' Blues* in 1929 in which he sings *Mr Engineer, let a poor man ride the train* [6]. When the engineer replies that he does not own the train (how true for most of the engineers who work for others), the singer labels him as *a low down and a cruel old engineer.*

Otis Rush [7] refer to a train engineer in the song *So Many Roads* as a mean spirited person when he sings *it was a mean fireman and an old cruel engineer taking my baby away and left me standing here*.

In one of the classic films of all time, *Metropolis*, by Fritz Lang in 1926, engineers are portrayed as the creators of the technological beast of the future city, which is harsh and unforgiving when it comes to human workers. In the popular 1980s TV series *The A-Team*, a nerdy engineer-like character fixes all the technical problems. The Chief Engineer on *Star Trek: The Next Generation*, Geordi La Forge, portrays a black and blind engineer who owes his eyesight in different bandwidths to an advanced technology. He is one of the rare positive role models for engineers that came from the television and film industry [8].

REMAKING THE IMAGE

In an effort to enhance this unflattering image of an engineer, some engineering societies along with

Figure 6: Dilbert, the frustrated engineer.

Note: *Dilbert* is a syndicated cartoon by Scott Adams, distributed by United Media and © United Feature Syndicate.

private foundations and organisations have attempted to use the media, primarily through Hollywood and television [9]. One of the very few movies in which the main character is an engineer is titled *October Sky*, released in 1998 in the USA. It is based on the true story of a young boy from a small coal-mining town in West Virginia who is interested in building model rockets during his middle and high school years with a group of friends. The story continued with the boy obtaining his engineering degree, working for NASA and then retiring as one of NASA's engineering managers.

It is still possible to catch reruns of an old TV show titled *MacGuyver*. In this series the main character, MacGuyver, is a young, very smart and good looking engineer who always manages to get out of difficult and dangerous situations with what else but ingenious engineering schemes, at times armed with only a simple piece of string and a Swiss Army Knife.

The American Institute of Engineers seriously looked into creating a TV show serial called *L.A. Engineer*, after the success of *L.A. Law* of course. The Sloan Foundation even proposed a TV series *NYPhd Blue*, again a take-off from the popular *NYPD Blue*. Twentieth Century Fox Television plans to create another TV series, *Killer App* with collaboration of Gary Trudeau and Robert Altman.

One pilot TV show, *Hyperion Bay* made its way to the WB Television Network two years ago. The main character was a software engineer in the Silicon Valley. As expected, the ratings for the show were low and it was pulled out after just a few weeks. The show later brought in one of the attractive actresses from the popular television show *Baywatch* as the daughter of this software engineer but the ratings did not improve enough to keep the show on the air.

David Macaulay, author of *The New Way Things Work*, has launched a new five-part TV series called *Building Big* in the fall of 2000, which was aired on most Public Broadcasting Service stations in the USA [9]. The series focuses on civil engineering marvels such as the Sadd-el-Kafara Dam in Egypt, the Golden Gate Bridge in the USA, and others.

Robert Llewellyn started *Scrapheap Challenge* for England's Channel 4 in 1998. In 2001, the TLC cable company in the USA changed this into *Junkyard Wars*, which was created, produced and hosted by Cathy Rogers. Teams of three friends build, design, and test complex machines using scraps and junk provided for them. Each team has to use the mechanical skills, ingenuity and team spirit to outdo other teams in a competition.

CONCLUSIONS

Recruiting US students to study engineering has not been an easy task for over 300 engineering schools. In spite of the shortage of engineers, great technological leaps and attractive job offers for graduates, the number of bachelor of science in engineering degree holder decreased by 15% during the past decade while the degree holders in all other fields combined increased during the same period. The percentage of women and minority students coming into engineering is also disappointingly low as compared to patterns in the general population.

Many possible reasons for this phenomenon have been forwarded in the engineering education literature. This paper focuses on one of these reasons, the issue of the image of engineering. It also provides some examples of the efforts to improve the image of the profession. The observations and conclusions in this paper are restricted to the USA only.

Note: The data for Figures 1-3 and Tables 1-2 are from The American Association of Engineering Societies and the US Bureau of Labor Statistics.

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BIOGRAPHY

H. Oner Yurtseven was born on 3 October1945. He obtained a BSc in electrical engineering) from the Middle East Technical University in Ankara, Turkey, and a Doctor of Philosophy in electrical engineering from Johns Hopkins University, in 1967 and 1974 respectively. From 1970 to 1972, he was an Instructor in the Johns Hopkins University. Between 1973 and 1974, he was a technical staff at the Computer Sciences Corporation and from 1974 to 1977 was an Assistant Professor of Electrical Engineering at the Middle East Technical University. From 1979 to 1983 he was Assistant Dean (Academic Affairs) at Indiana University - Purdue University Indianapolis (IUPUI) in Indianapolis, the USA, and later Associate Dean for Academic Affairs between 1983 and 1986. Between 1986 and 1989, he was Chairman for the Division of Engineering at IUPUI. From 1989 to1992, he was Associate Dean for Engineering at IUPUI. From 1992 to 1994, he was Associate Dean for Academics Programs at IUPUI. Between 1994 and 1996 he was Provost for the IUPUI Malaysia Programme (Kuala Lumpar, Malaysia). He is presently Professor of Electrical Engineering and Dean in the School of Engineering and Technology at IUPUI.

Professor Yurtseven is a Senior Member of the IEEE. He also holds memberships in the American Society for Engineering Education, the IEEE Robotics and Automation Society and the Indianapolis Rotary Club. He received the General Kemal Taran Scholarhip during 1962-1967 and the Cento Scholarship during 1967-1969. both at the Middle East Technical University. He was awarded the Fulbright Scholarship during 1969-1971 to study at the Johns Hopkins University. He received the Wisner-Stoelk Outstanding Teaching award from the Purdue School of Engineering and Technology at IUPUI. He is the author of two electrical engineering textbooks (in Turkish) and numerous technical articles in signal processing, robotics, engineering and technology education, and international engineering education.