Chapter 2
Military Engineering

The military establishment is ubiquitous and omnipresent in American life. Almost everything is of concern to the military, including housing, medicine, agriculture, manufacturing, and transportation. It is impossible to escape the reach of the military because everything has some military relevance.

Resources devoted to military work are staggering. The USA is responsible for over 40% of the more than $1.2 trillion dollar global military expenditure, with the UK second, accounting for 20% [1]. In the UK, funding of military research topped $4 billion in 2003–2004, with 40% of all government researchers employed by the Ministry of Defense [2]. The single largest employer of engineers in the UK is an armaments company [3].

The reason for the huge expenditure in the USA is that the defense establishment believes that it is necessary to have military forces and technology second to none. In the *1997 Quadrennial Defense Review* the Department of Defense reaffirmed that "it is imperative that the United States maintain its military superiority …" During that same year, the National Defense Panel reported that if the United States does "not lead the technological revolution we will be vulnerable to it," and in the Senate Armed Services Committee Report, the committee wrote that its priority is "to maintain a strong, stable investment in science and technology in order to develop superior technology that will permit the United States to maintain its current military advantages … and hedge against technological surprise" [4].

Military work is by far the most important source of employment and income for American engineers. Two thirds of all scientists and engineers in the USA work directly or indirectly on defense contracts, and about 60% of all federally funded research is defense related [5]. Papadoupoulos conducted a study of American engineers in defense-related work and concluded that 8.7% of engineers, compared to 2.9% of all workers (including engineers), work at a company or organization that can be described as defense related.

A disproportionate number of engineers are engaged in military activities. According to the US Bureau of Labor Statistics and the Department of Defense, about 3% of the total work force in the USA is employed in military-related work,

P.A. Vesilind, *Engineering Peace and Justice*,

© Springer 2010

while over 10% of the engineers work in defense-related industry [6]. Engineers have the highest fraction of their research and development funding from the Department of Defense, accounting for fully 33% of their total funding [6].

Because of the many technical jobs available in armaments or weapons systems, most engineers have little choice but to work on military projects. In a free market democracy, it should theoretically be possible to move between different types of jobs, but this is not easy for engineers. Most engineers are not privately employed but instead work for employers who must sell their collective engineering skills as an entire company. A consulting engineering firm, for example, obtains business from clients because it convinces the client that the collection of engineers employed by that firm can perform the required job. A single engineer, working by himself or herself, is severely limited in the types of work he or she can do.

Because large engineering projects can be compartmentalized, it is often impossible for one engineer to tell just what the overall objective of the project is. The engineer who thought he was working on a toaster and was instead participating in the Star Wars project is an example. At other times, the result of engineering projects can be put to unintended use. Columbia University electrical engineering professor Steve Unger relates a story where he, while working for Bell Labs, was asked to work on an electronic telephone switching system. He believed that such a telephone system was clearly beneficial to the public, but after working for 2 years on the project, he found that the switching software they developed was of interest to the military and the first use of the compiler was by the military. Without knowing it, he had been doing military engineering (s. Unger, pers. commun., 2006).

One reason so many graduates of engineering schools go to work in military engineering is that, quite honestly, it is exciting work. Peter Singer, author of *Wired for War,* a bestselling book on the use of robots in warfare, told an interviewer, when asked why he wrote a book about robots, "I think the opening line of my book explains it all: 'Because robots are freakin' cool'" [7]. Many projects undertaken by military engineers *are* cool. The robotic, or unmanned, systems are especially neat. You design the mechanism and software, and then you program it to do what you tell it to do. How cool is that? It is almost beside the point that the robot is designed to kill someone, or, if the robot malfunctions, it is capable of killing you without any moral qualms.

One way of illustrating what military engineering is all about is to tell the stories of engineers who have devoted their careers to military matters. There are, of course, hundreds of thousands of stories about engineers who have had military engineering careers. I have selected a few exemplars that illustrate both the best and worst of military engineering, with the objective of defining what is meant by the term "military engineering." The purpose in telling their stories is to illustrate how military engineering is both timeless and ubiquitous. Some stories are about engineers who work directly for the military, while other stories focus on engineers who might have been surprised how their engineering invention or effort ended up being applied for a military purpose.

The use of short biographies in order to define the field is akin to defining a genre of art by visiting a museum and studying the paintings of many artists. A visit to the

Musée d'Orsay in Paris, for example, will reveal a large and varied collection of Impressionist art. Paintings by Monet can be viewed next to works by Cézanne, van Gogh, Gauguin, and Renoir. It is only by immersing oneself in the collected paintings in this incredible museum that one begins to understand Impressionist art.

The life stories of the engineers below are similarly meant to define what we mean by military engineering. The stories are grouped into three categories:

1. engineers who were in the armed forces,
2. engineers who worked in armaments production, research, or other activity directly funded by the military, and
3. engineers who believed that they were working on civilian projects but found that their work was used for military purposes.

The stories illustrate how military engineers are integral to the society in which they live and work and how they are indispensable to the leaders of their nations when these leaders want to wage war. In reading these stories, it might be useful to reflect on how these engineers interpreted their responsibility to the public. Did they understand what they were doing and then rationalize their actions, or did they ignore the implications and results of their work? If, at the conclusion of their professional lives, they had occasion to reflect on their life's work, would they have had any regrets or second thoughts?

2.1 Exemplars of Military Engineering

2.1.1 Engineers Who Were in the Military and Worked Directly for the Armed Forces

As noted in Chapter 1, armies need engineers. In the USA, the military academies emphasize engineering, and often the best and the brightest, on graduation, take commissions in the US Army Corps of Engineers or in similar organizations in the other armed services. This is military engineering in its historically most pure form.

Engineers working directly for the military are not free to choose the work they do. If they do not like their work, their only alternative is to resign their commissions, but even this is not an option at wartime. Moral conflicts can therefore be intense when the military engineer is asked to do something that he or she finds to be morally abhorrent. Military engineers often have to balance their commitment to their military service with their commitment to serve the public good.

In James A. Michener's book *Tales from the South Pacific* [8], a lieutenant on a small island toward the end of the Second World War is told to construct a landing strip. The construction requires cutting down a strand of stately Norfolk pines that are protected by an elderly islander. The lieutenant knows that the war is almost

over and there really is no need for the airstrip, or for cutting down the strand of trees, but he has been told to do so. He has a moral conflict, as a commissioned military engineer, to follow orders on the one hand or to do what he perceives as being in the best interests of the public (and the trees!) on the other. Some of the engineers described below may have experienced similar conflicts, and some certainly did not. The common thread in all of these stories is that these engineers were engaged in military engineering.

Thaddeus Kosciuszko (1746–1817)



Fig. 2.1 Thaddeus Kosciuszko

Kosciuszko, born in 1746 in a small Lithuanian town, went to the military academy in Warsaw and graduated with an engineering degree. He fell in love with the daughter of the Marquis of Lithuania, but when his advances were not reciprocated, he left Poland and offered his assistance to the rebel army in the American colonies. He arrived with a letter of recommendation from Benjamin Franklin, addressed to General George Washington. Upon meeting Kosciuszko, Washington asked him what he could do. "Try me," was the answer.

Kosciuszko received his commission and went to work as a military engineer. Horatio Gates, a general in the Revolutionary army, described Kosciuszko as an able engineer and one of the best and neatest draftsmen he had ever seen. Kosciuszko planned and constructed the encampment at Berets Heights, near Saratoga, which held out against the British attack, thus destroying the British strategy of cutting off New England from the rest of the colonies. Kosciuszko became the principal engineer in the construction of the fort at West Point, and the superior fortress assured the control of the Hudson River. He eventually became Washington's adjutant and was promoted to brigadier-general at the end of the Revolutionary War.

With his mission accomplished, he returned to Poland where he lived several years in retirement, but then the Russians threatened to invade Poland and Kosciuszko was recruited to the defense of independent Poland. When the Russians overwhelmed the Polish army, Kosciuszko resigned his commission and went to live in France. The Russian occupation of Poland was, however, unacceptable and he became involved in a plot to drive out the Russians. He suddenly appeared in Krakow and issued a declaration of independence. He organized an army made up of mostly poor peasants with few weapons but they nevertheless routed the Russian army twice their size. Eventually, however, the Russians defeated the Poles, who retreated to Warsaw where they continued to defend the city against both the Russians and the Prussians. When the Austrians also attacked Poland, the

Polish army was defeated and the nation of Poland ceased to exist. Kosciuszko was wounded, captured, and imprisoned in St. Petersburg. After the death of Catherine the Great, the new tsar released him from prison and offered him his sword. Kosciuszko refused to accept it, saying, "I have no need of a sword; I have no country to defend."

Kosciuszko visited the USA in 1797 and was received as a hero. Even though Congress gave him a grant of land and a pension, he decided to go back to Europe, where he spent the rest of his life in retirement, continuing to agitate for the independence of Poland.

Kosciuszko was not only a military engineer but a gallant soldier as well who seemed to always be fighting on the side of liberty and independence. He was buried in Wawel Cathedral (*Katedra Wawelska*) near Krakow, and the people constructed a huge mound nearby using earth brought from every great battlefield in Poland. A monument was erected to his memory at West Point by the US Military Academy cadet corps of 1828 [9].

Curtis LeMay (1906–1990)



Fig. 2.2 Curtis LeMay

Sometimes engineers are asked to use their knowledge and skills directly in line command, and often they are highly successful. One of the most successful engineers in combat was General Curtis LeMay.

Curtis LeMay studied civil engineering at Ohio State University and in 1930 became a second lieutenant in the US Army Air Corps. As WWII approached, he moved quickly up the chain of command, using his engineering education and skills to become a lieutenant colonel at the start of America's involvement in Europe. He was transferred to the bombardment division and in 1944 to the Pacific theater as a major general in charge of the bomber command.

As the USA began to island hop toward Japan, air bases were established from which bombers could attack the Japanese mainland. LeMay received a new bomber, the B-29, designed for high-altitude bombing, and he was pressed by his superiors to achieve "results." But the problem was that the bombers had to fly at altitudes of over 30,000 feet to be clear of antiaircraft fire, and thus their bombs were largely ineffective. LeMay discovered that Japanese antiaircraft guns were designed for defending against airplanes at high altitudes and could not be swiveled quickly. If an airplane came in at a low altitude, such as 3000 feet, the antiaircraft guns could not be turned quickly enough to fire effectively at the airplane. In addition, such low-level attacks allowed pilots to concentrate bombs accurately on small areas.

Most Japanese cities were susceptible to fire, and LeMay decided to drop incendiary bombs that would create huge firestorms in cities. He learned this technique from the British, who unwittingly had created such a firestorm in Hamburg, Germany, and then had intentionally firebombed Dresden where the entire city and its inhabitants were incinerated.

The new technique was applied to Japan with great success, and city after city was destroyed. On 9 May 1945 LeMay's bombers firebombed Tokyo, killing at least 100,000 people in one night. LeMay justified these attacks by arguing that the Japanese had decentralized their war manufacturing, and entire cities therefore became legitimate military targets. By the time the atomic bombs were dropped on Hiroshima and Nagasaki, there were no cities left to bomb on the Japanese islands since all significant population centers had been firebombed, with the loss of perhaps over 1,000,000 lives.

At the end of the war, LeMay observed that it was a good thing his side had won. Otherwise he believed that he would certainly have been tried as a war criminal.

Lucius Clay (1897–1978)



Fig. 2.3 Lucius Clay

Lucius D. Clay entered West Point in 1915, intending to become an army engineer. After graduation he taught civil and military engineering at West Point for 4 years. Before the Second World War he worked on several domestic construction projects and then served on the staff of General Douglas McArthur. In 1937 he became responsible for enlarging and improving military airports in the USA.

During the Second World War Clay became the head of supply for all of the armed services. His most remarkable accomplishment occurred during the Normandy invasion. He was sent by General Dwight Eisenhower to reopen the Port of Cherbourg so that critical supplies could be shipped to the troops. The Germans had destroyed the port facilities and the port was in chaos. Nevertheless, he was able to stabilize the situation and within one day the port was again operating with speed and efficiency. His contribution to the success of the D-Day landings was significant and he was awarded the Bronze Star for his efforts. His most notable achievement, however, occurred after the war. He became the governor general of Germany and set about helping Germany get back on its feet. He worried about the division of Germany into four zones, and mostly about the fate of those Berliners who were trapped in the Russian zone. When Soviet harassment of war-torn Berlin began in early 1948, Clay

acted on his own initiative and ordered an airlift to supply Berlin. Only after the operation was already in full swing did he convince his superiors that Berlin should be supplied by air. His optimism and hard work helped the USA to carry out the dangerous mission of flying into the Berlin airport with vital supplies for the beleaguered city.

General Clay retired in 1949, within days after the Soviet blockade of Berlin had been lifted. To Berliners he was a hero for having broken the Russian blockage, and a wide boulevard in the middle of the city is now named Clayallee in his honor. General Clay was buried in the cadet cemetery at West Point [10].

George Goethals (1858–1928)



Fig. 2.4 George Goethals

George Washington Goethals studied engineering at the City College of New York but graduated from West Point, second in his class. On graduation he returned to West Point as an instructor in engineering. During the Spanish-American War he served as chief of engineers and was later placed in charge of the Muscle Shoals canal construction on the Tennessee River. In 1907 received the assignment of a lifetime: President Teddy Roosevelt told him to build the Panama Canal.

As chief engineer in charge of canal construction he faced many obstacles, only some of which had to do with construction. Heat and tropical diseases took their toll on workers and many doubted if the canal could ever be finished. But by 1915 the job was done and Goethals stayed on to serve as the Governor of the Panama Canal. In the USA he was universally praised for this engineering feat and was even awarded an honorary doctorate from the University of Pennsylvania.

When America entered the First World War he was appointed quartermaster general and put in charge of all materiel used by the U.S. army. After the war he resigned his commission and went into private practice, which included serving as a consulting engineer to the Port Authority of New York.

The Panama Canal became immensely important to the USA during the Second World War when troops and materiel had to be transferred between the two oceans. Fighting a war on two oceans would have been impossible if troops and supplies could not have been easily transported by sea through the canal. What was originally a commercial venture became a most crucial advantage to the US military.

Yahya Ayyash (1966–1996)



Fig. 2.5 Yahya Ayyash

Yahya Ayyash was not in any official army, did not wear a uniform, and did not get paid for his work, but he was a military engineer.

Yahya Ayyash did not build anything useful, but he nevertheless became known as "The Engineer" and was adored by thousands to whom he was a hero. What Ayyash did was build bombs. He worked with the Palestinian group Hamas, which during 1994 and 1995 organized suicide attacks on Israel. Ayyash is alleged to have participated in 11 suicide attacks, killing from 50 to 75 people, with hundreds more wounded.

Ayyash was from all accounts an exemplary person with a talent for engineering. He was born in 1966 in the Gaza Strip, a barren, impoverished strip of sand created after Israeli independence to hold displaced Palestinians. After high school, Ayyash studied chemical engineering at Bir Zeit University. He apparently was a devout scholar of the Koran in addition to his work in engineering. After graduation he married and had two sons.

His experiences in Gaza during his childhood and his dedication to the Islamic cause led to his becoming active in Hamas, which in the mid-1990s was a terrorist organization dedicated to the destruction of Israel. In April 1994 he built his first bomb, which was used in an attack on a bus station in northern Israel, killing nine people. As his effectiveness as a builder of bombs increased, he became a priority target for Israeli intelligence, which finally caught up with him in 1996. He was given a new cell phone by an uncle of a friend, and as soon as he tried to use it, it exploded, killing him instantly. His funeral was attended by 100,000 people and he was declared a martyr by Hamas [11].

2.1.2 Engineers Who Worked Directly for the Military

Many engineers work indirectly for the military, doing research on armaments or consulting with the military. Their income comes from the military establishment, but they have the option to not work on projects they consider immoral. Their

military engineering work differs from those who are officers in the services because they are not required to follow orders. Their cost for doing the right thing is far less than for those in active military service, and for this reason they have a greater responsibility to society.

Vauban (1633–1707)



Fig. 2.6 Vauban

During the 17th century, the geographical position of France required it to fortify its borders, and a series of forts was constructed in its periphery. The work of building these forts was entrusted to Sebastian le Prestre de Vauban, who had distinguished himself both as a soldier and engineer. Vauban used the idea of the star-shaped fort originally developed by the Italians (Chapter 1) and refined these so that they were thought to be almost impregnable.

Although Vauban built the forts, this was a case of a fox building a chicken coop, because Vauban soon figured out ways of attacking the very same impregnable forts he had designed. His plan for attacking the forts involved digging ditches in parallel arcs, constantly moving closer to the fort. The diggers piled the dirt between them and the fort and thus were protected by the very earth they were digging out. Artillery was then brought forward into the trenches, again protected by the earth embankment. Eventually the attackers were able to get so close that cannons could obliterate a section of the wall and the infantry could storm the relatively low and now demolished walls. This technique was used by General George Washington in the Battle of Yorktown and ensured the survival of the new United States of America. Vauban's trench technique remained a system of siege warfare through the First World War.

While Vauban is remembered as a great engineer, his single most important contribution was a short pamphlet he wrote that foreshadowed the French Revolution. He argued that the deplorable condition of the peasants was unacceptable and that a tax must be levied on all persons, including the nobility, if the defense of France was to be assured. King Louis XVIII immediately suppressed the document and had Vauban banished from court. After Vauban died, his reputation was restored by Napoleon, who had Vauban's heart reburied in the church at Invalides.

Wernher von Braun (1912–1977)



Fig. 2.7 Wernher von Braun

A characteristic of military engineering, both in days past and today, is that the engineer often is not concerned on whose side he or she works. A classic case is Wernher von Braun.

While von Braun was a student at the Institute of Technology in Berlin he became interested in rockets and worked in his spare time with Germany's most imaginative scientists. He graduated in 1932 with a degree in aeronautical engineering and looked forward to a career in aviation, including getting his pilot's license. He soon became convinced that if rocketry were to be used to explore space, more advanced technology would be needed, and he enrolled at the University of Berlin to work toward a PhD in physics. His dissertation was on the use of liquid fuels in rockets, then a new concept. After graduating in 1934 he was hired by the German Army Ordnance Corps where he conducted experiments using liquid fuel rockets. When war came, von Braun continued his work as a civilian employee for the German army. He designed the dreaded V-2 rocket that terrorized London during the last months of the war. After Germany's capitulation, von Braun and 120 of his colleagues surrendered to US forces in order to avoid capture by the Russians.

The German scientists and engineers were brought to the United States and began their work for the US army, designing and building the Redstone, Jupiter, Juno, and Saturn rockets. In 1957, one of von Braun's rockets put Explorer 1, the first American satellite, into orbit, after an embarrassing misfire and explosion by the Navy's Vanguard rocket. Von Braun's rockets were used for the Mercury manned missions into space, and his Saturn rockets lifted the Apollo teams into orbit. When President Kennedy declared our intention to put a man on the moon, von Braun was asked to build the rocket that would get them there. His Saturn V was highly successful and is still used, decades later, for the space shuttles.

The most important use of von Braun's rockets was to serve as vehicles for carrying nuclear warheads, and thousands were built and stored in silos all over the USA. The rockets were thought to be a deterrent against attack by the Soviet Union and remained active throughout the Cold War, from about 1950 to about 1990. The USA continues to have an unspecified number of these rockets in underground silos, armed with nuclear warheads, to be used in case of attack.

The ease with which Wernher von Braun became the leading rocket expert for the USA after serving in the same capacity for Germany during the Second World

War illustrates how some engineers concentrate on their jobs without being concerned with what their efforts can produce. During the 1960s Tom Lehrer, a satirist and also a mathematics instructor at Harvard, recorded some wonderful songs that spoke to the craziness of the age. One of his songs was about Wernher von Braun; it goes like this:

Gather 'round as I sing you of Wernher von Braun,
A man whose allegiance
is ruled by expedience.
Call him a Nazi and he won't even frown.
"Ha, Nazi, Schmazi," says Wernher von Braun.
Don't say that he's hypocritical,
Say rather that he's apolitical.
"Vonce zee rockets are up, who cares vere zey come down?
Zat's not my department," says Wernher von Braun.

Some have harsh words for this man of renown,
But some think our attitude
Should be one of gratitude,
Like the widows and cripples of old London town,
Who owe their large pensions to Wernher von Braun.

You too can be such a hero
If you can count backward to zero.

"In English or German, I know how to count down,
Und I'm learning Chinese!" says Wernher von Braun. [12] [T. Lehrer, pers. comm.]

John Napier (1550–1617)



Fig. 2.8 John Napier

Learned men in the 1500s, such as John Napier, might have been engineers if that designation had existed. Their work was certainly in military engineering. While better known as a mathematician and the inventor of logarithms, John Napier also proposed military inventions, including burning mirrors that set enemy ships on fire, artillery that destroyed everything within a radius of 4 miles, bulletproof clothing, a crude version of a tank, and a submarinelike device. We have no evidence that he actually developed any of these, and he took great pains to conceal the details of his inventions. On his deathbed in 1617 he worried about the development of more advanced armaments. He was a reluctant military engineer.

Kurt Prüfer (1891–1952)



Fig. 2.9 Kurt Prüfer

Sometimes the tasks given to engineers during wartime are so horrific that it is difficult to understand why the engineers simply do not refuse to do the work. One such case, and perhaps one of the most horrible cases, is Kurt Prüfer.

Kurt Prüfer was a German civil engineer who, after returning from the First World War, went to work for Topf and Sons, a venerable company founded in 1878 that made customized incinerators and malting equipment. In the 1920s, under Prüfer's direction, the firm pioneered in the design and construction of clean crematoria, furnaces that complied with strict regulations on preserving the dignity of the body. No flame was to come into contact with the coffin and the process had to be smoke and odor free. In 1928 Prüfer was promoted to head the crematorium-construction division. The Great Depression strained the viability of the business, but by 1934 conditions improved and Prüfer retained his job. He further strengthened his position with the firm when he joined the Nazi party.

The firm was located close to what later became the Buchenwald concentration camp and had attained such a good reputation for quality work in the construction of crematoria that in 1939 the Nazi SS approached Prüfer with an order for a crematorium. An epidemic at Buchenwald had allegedly killed hundreds of prisoners, and an efficient furnace was needed to cremate the remains. Prüfer designed a crematorium resembling an incinerator used for animal carcasses, knowing that the dead were not to be burned individually or in coffins.

The furnaces were quite successful, and orders came rolling in from the other concentration camps. It ought to have been quite clear to Prüfer that the furnaces at these camps were not being used for burning people killed by epidemics. Prüfer even visited Auschwitz several times and saw that his ovens were being used for "special operations." Rather than recoiling in disgust, Prüfer accepted the engineering challenge to develop increasingly efficient means of extermination.

After the war he was captured by Americans but then inexplicably released. The Russians then arrested him and tried him for war crimes, sentencing him to 25 years in prison. The transcripts recorded during his interrogation show he felt no remorse for what he had done. In fact, after the Nazis abandoned Auschwitz in January 1945, Prüfer suggested to the Nazis that they could reassemble parts of the furnaces in Mauthausen concentration camp in Austria so that they could continue with their program of extermination.

During the interview with the Russian interrogators, this exchange occurred:

> Q. What motivated you to continue with the building of the other crematoriums as senior engineer with Topf and Sons?
> R. I had my contract with the Topf firm and I was aware of the fact that my work was of great importance for the national socialist state. I knew that if I refused to continue with this work, I would be liquidated by the Gestapo [12].

His response is important in understanding his commitment to society. The first reaction was that he was just doing his job and thus was absolved of all blame. Perhaps he then recognized that this was not a valid excuse, and rationalized his actions by saying that he had no choice but to go along with the Nazis. He was, however, a member of the Nazi party and enthusiastically participated in the exterminations, so this is hardly a legitimate excuse.

After the war the firm of Topf and Sons was nationalized by the East Germans and remained in business until 1996.

Gerald Bull (1928–1990)



Fig. 2.10 Gerald Bull

One of Gerald Bull's biographers said of him: "Oddly enough, Bull was not a militarist. He never saw military service or even owned a handgun. He was said to be generous and thoughtful. He just found something that he really loved doing" [13]. What he loved doing was building really big guns, guns that could achieve muzzle velocities great enough to place satellites into orbit, or send missiles to targets thousands of miles away.

Bull, born in 1928, was a Canadian who did not have a happy childhood, but who excelled in school, obtaining his engineering degree and then, at age 23, a PhD in engineering from the University of Toronto. He went to work for the Canadian Armament and Research Development Establishment (CADRE), which, before the Second World War, was involved in bringing German scientists and engineers to Canada in order to deprive the Nazis of their talents. Some of their research involved supersonic aircraft, and they needed to construct a large wind tunnel to test the missiles. This was very expensive, and Bull hit on the idea of testing supersonic flight by shooting the missile out of a large gun. The idea worked brilliantly, and this work encouraged Bull to continue work on large guns. But Bull was apparently not a very social person and alienated the research establishment, which finally eliminated his funding.

Undeterred, he set up a private company to continue the research and looked around for anyone willing to pay money for his knowledge. South Africa, which was fighting Angolan rebels at the time, hired him to build a gun that could shoot long distances. Bull built and sold them hundreds of 155 howitzers that could shoot shells 50% farther than any other artillery in use at the time. The sale, however, got Bull in trouble for illegal arms dealing, and he served 6 months in an American jail. When he got out of jail he was broke and had few options, so he began to sell his expertise to anyone willing to buy. Iraq at the time was at war with Iran and hired Bull to build the howitzers it used with devastating effect in the Desert War. Part of the deal with Iraq was that Bull could also continue his research on large guns capable of sending satellites into space (or nuclear warheads into Israel). Iraq was interested in the possibility of launching missiles using the big guns, but before this project could be completed, Bull was assassinated by Israeli agents, and the supergun project was abandoned [14].

Gerald Bull became so involved in his work that he became estranged from Canada, went to prison in the USA, and eventually was assassinated by Israel. His vision was of an entirely new way to get into space – the use of giant guns to send the payloads into orbit. To achieve this objective he worked at various times for some of the least savory regimes on earth: apartheid South Africa, Communist China, and, ultimately, Iraq. His work might have had a devastatingly destabilizing effect in the Middle East and could have resulted in the deaths of millions of people [15]. Did Bull ever think of this when he was happily building his big guns?

Galileo Galilei (1564–1642)

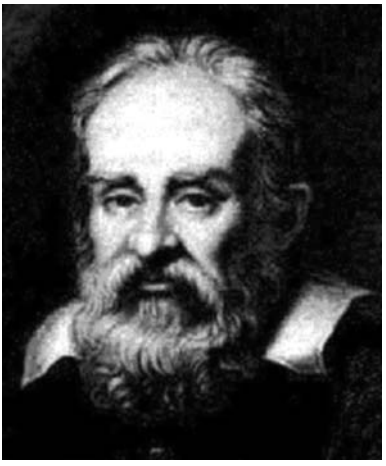


Fig. 2.11 Galileo Galilei

Galileo was often strapped for cash and went into the private tutoring business, teaching all comers everything he knew about military architecture, fortifications, and surveying. In 1597 a lot of foreigners lived in Padua, and his tutoring business was good.

He was an inveterate inventor and developed many gadgets that were useful for the military, such as a "geometric compass," which made possible the rapid calculations of geometric shapes, for example estimating the midpoint of a line. The device, which could be thought of as a primitive slide rule, is simple in construction but requires instruction in its use. Galileo set up a company that sold these instruments and hired craftsmen to construct them. He held seminars explaining their use, especially in warfare. During this time many of the city-states in Italy were at war with each

other, and the pope was fighting with most every one of them, so Galileo's business prospered. Much has been written about Galileo's scientific discoveries and contributions to basic knowledge but the source of his income came from military engineering. He did not seem to have much moral concern about doing military engineering as long as it paid well. The only instance when he seemed to care about killing others was when he "invented" the submarine. He decided not to publish his invention because he feared that this would cause too much harm.

Galileo is well known for his arguments with the Church during which he raised all kinds of moral concerns, but except for not divulging the plans for the submarine, he did not have any trouble selling his expertise to those who would use the information for warfare. He was just a military engineer doing his clients' bidding [16, 17].

Michael Cantrell (1955–)



Fig. 2.12 Michael Cantrell

A more recent example of an engineer who, while working on military projects, did well for himself is Michael Cantrell. Cantrell worked for the Army Space and Missile Defense Command in Huntsville, AL, which was the central organization on the so-called "Star Wars" project initiated by President Ronald Reagan and continued under subsequent administrations. Even though there is every reason to believe that the entire concept of Star Wars is faulty, we have thus far spent over $110 billion, with no end in sight [18].

At the inception of Star Wars a great deal of money flowed into Huntsville, but as the idiocy of the project began to permeate military planning, the rate of money flow slowed down. Middle-level managers such as Michael Cantrell, in order to be able to continue their programs and to pay for their research and development facilities, had to compete with other defense agencies for public money. Cantrell emerged as a master at getting defense contracts and was able to find funding for projects that the Department of Defense did not even want to fund.

Though it was strictly against the rules for federal employees to lobby for work, Cantrell started to find ways of getting money for Huntsville. He set up an office at the US Airways lounge at the Washington National Airport and hid from his bosses, all the while arguing with lawmakers and congressional staff for money for his projects. He was able to get contractors to send contributions to the election funds of congressmen and then called their offices to collect on the favors. He paid lobbyists to make sure the projects were funded, and he counted on the lawmakers to protect him and his activities. The oversight from the Pentagon was so lax that Cantrell was

able to bamboozle the Department of Defense into paying for phantom projects. They would, for example, send a section of a rocket back and forth between two contractors and charge the government each time for the construction costs.

Getting money to Huntsville was so easy that Cantrell and another engineering colleague decided to tap into the funds. They contrived to bill the government for work not done and to pocket the funds, and they were highly successful. Any concerns expressed by those who recognized the scam were rapidly quelled by powerful congressmen who received money from Cantrell or from contractors. With his new-found riches, Cantrell built a mansion in an exclusive neighborhood in Huntsville and lived the high life. Eventually, however, the investigators caught up with him. He was convicted of conspiracy and bribery and is now in jail [19].

Simon Stevin (1548/49–1620)



Fig. 2.13 Simon Stevin

Little is known of Simon Stevin's childhood or of his education. He was brought up in what is today the Netherlands in the Calvinist tradition. He attended the university at Leiden, matriculating at age 35.

In the middle 1500s the states in the low countries were rebelling against the Spanish, who were trying to control the region. While at the university, Stevin met and befriended Maurits, the second son of William of Orange. When William was assassinated, Maurits became the head of the army and the republic of the Netherlands, and Stevin became his advisor, helping Maurits beat back the Spanish in several key battles. Maurits understood the importance of military strategy, tactics, and engineering and asked Stevin to set up an engineering school within the University of Leiden. During these years, Stevin invented a way of flooding the lowlands in the path of an invading army by opening selected sluices in dikes, and he advised on the building of windmills, locks, and ports. He helped Prince Maurits build fortifications for the war against Spain and wrote detailed descriptions of military innovations that were adopted by the army.

In addition to being the most prominent military engineer of the emerging Dutch nation, he also authored 11 books, making significant contributions to trigonometry, mechanics, architecture, music theory, geography, fortification, and navigation. In 1585 he published a booklet that introduced decimal fractions, a development that greatly benefited trade and manufacturing. He also wrote important works on mechanics, mainly dealing with hydrostatics, recognizing for the

first time that the pressure exerted by a liquid upon a surface depends on the height of the liquid and the area of the surface. He also beat Galileo to the punch (by 3 years) by conducting experiments involving dropping lead balls of different weights and finding that, when dropped from the Delft church steeple, they hit the ground at the same time. He also contributed to the science of music, for the first time explaining the correct theory of the division of the octave into 12 equal intervals [20].

The most significant contribution Stevin made was his work in support of his country and his people. The independent state of the Netherlands would not have been possible without the work of Simon Stevin, who is now venerated as a national hero.

Abdul Khan (1936–)

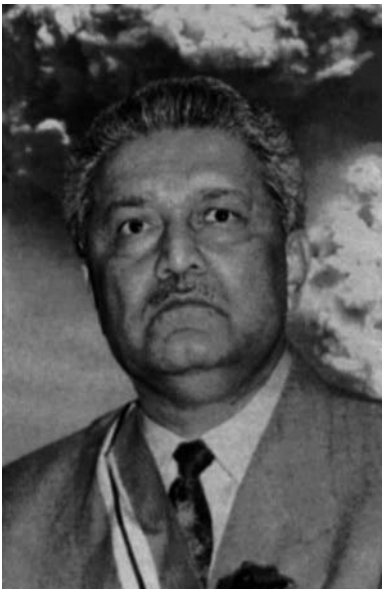


Fig. 2.14 Abdul Khan

Abdul Quadeer Khan was born in Bhopal, India in 1936 to a Muslim family. At that time the population of Bhopal was made up of both Muslims and Hindus who lived an uneasy but peaceful coexistence. When India was partitioned, forming Pakistan, a huge migration occurred with Muslims moving north to Pakistan and Hindus moving south to India. Abdul Khan, one of seven children, moved with his family. It was a cruel trip. The Khan family was harassed, beaten, and robbed, and Abdul Khan ended up walking barefoot to Pakistan. The experience forever impressed on him a distrust and hatred of Hindus and India.

Khan studied at the university in Pakistan and then at the Catholic University in Belgium. After graduating with a PhD in metallurgical engineering, he was employed in the Netherlands by a German company that manufactured high-speed centrifuges used in the production of weapons-grade uranium. India had developed and demonstrated its nuclear bombs and was threatening the newly ceded Pakistan. Taking advantage of an insurrection in eastern Pakistan, the Indian army had already soundly defeated the Pakistani forces, resulting in the formation of a new country, Bangladesh.

Recognizing the perilous situation, the Pakistani dictators decided that they also needed nuclear weapons. Part of the plan was to have Khan send classified information from his job in the Netherlands on the processes used to enrich uranium. Khan was highly successful in his spying, but eventually his activities were dis-

covered and he had to flee to Pakistan, where he was given the job of organizing a facility for producing nuclear bombs and the missiles to carry them. Using his engineering skills and an unlimited budget he soon succeeded in producing a nuclear weapon and became a national hero, living a life of privilege and amassing honors and adulations.

It is unclear whether he or the government of Pakistan decided that there was money to be made in sharing his knowledge for producing nuclear weapons. At any rate, Khan began to sell this knowledge on the manufacture of nuclear weapons to rogue nations such as Lybia, Syria, and North Korea. Apparently even al-Qaeda tried to get a nuclear weapon from Khan. In 2001 the Pakistani government arrested three nuclear scientists who had close ties to Khan for trying to get nuclear weapons to the Taliban in Afghanistan. Khan's activities were soon revealed, much to the embarrassment of the government of Pakistan, which decided to make Khan the scapegoat, arresting him and keeping him in detention and incommunicado [21]. He was given limited freedom in 2009.

Khan's actions demonstrate how easy it is for a talented engineer to act immorally and with little regard for the public – in this case providing nuclear weapons to countries that may have every intention of using them to terrorize the world.

Fritz Haber (1868–1934)



Fig. 2.15 Fritz Haber

Fritz Haber was born into a well-to-do German-Jewish family. He studied science and engineering at several German universities and upon graduation took an appointment at the Department of Chemical and Fuel Technology at the Polytechnic in Karlsruhe, Germany. In 1911 he became director of the Institute for Physical Chemistry and Electrochemistry at the new Kaiser Wilhelm Gesellschaft in Berlin, where academic scientists, government, and industry cooperated to promote original research.

During the First World War the British blockade prevented Germany from importing ammonia nitrogen, which was crucial in the manufacture of gunpowder. This could have spelled the end of the war, but Fritz Haber figured out how to fix nitrogen from the air, and, using high pressure and a catalyst, he was able to produce ammonia. The process was soon scaled up by the scientists working at the huge chemical firm BASF. One of their scientists, Carl Bosch, was able to apply it to the manufacture of ammonia nitrogen and the process became

known as the Haber–Bosch process. Germany was able to produce unlimited gunpowder, and this development was responsible for the loss of countless lives in the prolonging of the war.

Haber continued to use chemistry to help his country win the war in whatever way he could, and one of his contributions was the development of a new weapon, poison gas. On 22 April 1915, near Ypes, Belgium, the Germans opened 6,000 cylinders of chlorine under the supervision of Fritz Haber himself and watched as the cloud of yellowish gas soon reached the French positions and suffocated the soldiers who had not fled in time. Because of his work with poison gas, Haber is often referred to as the "father of modern chemical warfare." Although perhaps 10,000 troops died from poison gas that day, the weapon did not prove to be decisive since the Allies soon learned to cope with it and retaliated with poison gas attacks of their own. The success of the poison gas weapon was not without personal cost, however. Haber's wife, Clara, who was also a chemist, became distraught when she found out about Haber's involvement in the use of poison gas and committed suicide.

In 1918 Haber was awarded the Nobel Prize for his work on the synthesis of ammonia. Given his involvement in the war, the prize was roundly criticized. When the Nazis came to power, Haber's situation in Germany became untenable because of his Jewish ancestry, and in 1933 he decided to leave Germany for Switzerland. He became an outcast from a country he loved and which he had worked so hard to support. His life has become a popular subject of many plays and books because of the intense moral conflicts he must have wrestled with. Or did he?

Henry Kaiser (1882–1967)



Fig. 2.16 Henry Kaiser

Henry J. Kaiser did not have an engineering education, but he had an exemplary engineering career. He got things done. Going to work when he was 13 years old, he eventually founded over 100 companies including Kaiser Aluminum, Kaiser Steel, and Kaiser Cement and Gypsum, and he created the first health maintenance organization (HMO) for his shipyard workers. After the Second World War he was one of the first to mass-produce cars for the public. The Kaiser and the Henry J (one of the first compacts) were initially wildly popular, but eventually the larger companies caught up with Kaiser and he was forced him to stop producing cars.

Kaiser's first career was in construction, beginning with a gravel company and ending with the formation of a consortium of companies that built the Hoover Dam, the Bonneville Dam, and the Grand Coulee Dam, as well as many other large projects.

During the Second World War, German submarines in the Atlantic were extracting a dreadful toll on American shipping, with more ships being lost than could be constructed. Kaiser's solution was to speed up the construction of ships. He introduced assembly-line production to his seven shipyards, and by the end of the war his yards had produced 1,490 ships. These so-called "liberty ships" were instrumental in carrying military cargo and troops overseas.

After the war, it became clear that the USA could not have become the military power it did in Europe without the ships Henry Kaiser had built. The overwhelming superiority of the American military in Europe was responsible for the lingering effect of American social influence even today, including the use of American English as the new international language of commerce and technology.

Jerry Baber (1937–)



Fig. 2.17 Jerry Baber with his robot helicopter. The shotguns are slung on the side

The rifle has been the infantry's weapon of choice for several hundred years, but its days may be numbered. A shotgun, spraying small pellets at very high velocities, is much more lethal at limited distances such as would occur in urban warfare. But the shotgun also has disadvantages. Its range is limited, and shotguns must be manually loaded, with shells placed one at a time into the barrel. Jerry Baber, an electrical engineering graduate of Virginia Tech, working out of his garage in Piney Flats, TN, figured out how to eliminate this problem and has manufactured a rapid-fire, fully automatic shotgun. Its most innovative feature is the absence of recoil, increasing its accuracy and preventing bruised shoulders. With this gun the bolt never bottoms out or slams into a fixed object at the end of its rearward travel, but stops gradually against the long recoil spring.

When Rototex, a manufacturer of small robots, wanted to install firepower on their battlefield robots, they called Jerry Baber. The result of the collaboration is a lethal and scary robotic tank, about the size of a medium dog that can move into a firefight and blast the enemy at 300 rounds a minute, more firepower than that of a platoon of soldiers. The weapon on the tank is made of stainless steel so it cannot rust and never needs lubricating, and the fact that it does not recoil makes it perfect for use in the robotic tank. Another one of Baber's innovations is a small helicopter with shotguns slung on the side. This unit can carry the robots into battle [22, 23].

One of Baber's most ardent supporters and customers is Blackwater, the North Carolina security firm that had the security contract in Iraq and is now fighting

several lawsuits stemming from their insensitive treatment and alleged murder of Iraqi civilians.

Baber believes that the deploying of the robots will revolutionize warfare. Others, including the armed services, are not so sure. Robots in the battlefield have the advantage that no human being is being put at risk, but on the other hand, robots can be compromised and turned on the very people who initially deployed them. Having no brains and no morals, robots kill indiscriminantly, and thus their use in a combat situation can be problematic. Nevertheless, Jerry Baber believes that his gun will find wide use in modern warfare, whether carried by a robot or a living soldier [24].

Willy Messerschmitt (1898–1978)

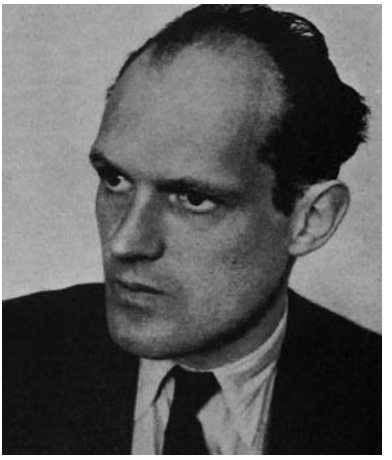


Fig. 2.18 Willy Messerschmitt

The Battle of Britain defined the course of the Second World War. Once the British fighter squadrons in their Spitfires and Hurricanes showed that they could hold their own against the German Luftwaffe, it was clear who would win the war. The Royal Air Force denied air superiority to the Germans and forced Hitler to abandon the invasion of the British Isles. Victory in the Battle of Britain was not a foregone conclusion, however, due mostly to one airplane, the ME (for Messerschmitt) 109.

Willy Messerschmitt loved aviation from the time he was a little boy and went to a military flying school during the First World War. He then started to build gliders and small airplanes that were revolutionary in design but tended to crash easily. Then, working for the Bavarian Aircraft Works, he designed and produced a small transport plane that was cheap to build but also had stability problems. Nevertheless, when the Nazis came to power in 1933, Bavarian Aircraft Works was awarded several large contracts to build airplanes that could be used for military purposes, secretly contravening the Treaty of Versailles. When the Luftwaffe announced a contest for the design of a fighter plane, Messerschmitt and his colleagues designed what was to become the ME 109. It was a revolutionary aircraft, built with a metal frame, an enclosed cockpit, and a thin single wing and using a powerful water-cooled engine. The Luftwaffe agreed that the 109 was the best airplane that had ever been built and ordered large numbers of them. It became the very weapon the Germans needed to gain air superiority in Europe during 1939–1940. Although other airplanes such as the Focke–Wulf (FW) 190 was supposed to eventually replace the ME 109, these were never produced in sufficient numbers and the ME 109 remained the first-line fighter for the Luftwaffe. It was an effective match for the British Spitfire with a higher ceiling and better armaments.



Fig. 2.19 The ME 109

Messerschmitt did not rest on his laurels and went on to design other aircraft such as the ME 110, a twin-engine, two-seat fighter that was an effective weapon against Allied bombers. His ME 210, however, was a disaster. The airplane was supposed to be a new twin-engine bomber, but Messerschmitt insisted on reducing the weight of the airplane in order to increase its speed, but in so doing, its ruggedness was reduced. The biggest problem was that the undercarriage tended to collapse on landing, causing catastrophic crashes. Relying on Messerschmitt to produce useful airplanes, the Luftwaffe had ordered over 1000 of the ME 210s "off the drawing board" without prior shakedowns and flight tests, and with the failure of the plane, they did not have a replacement for the Heinkels and other small bombers being shot down by the British.

Toward the end of the war Messerschmitt started to experiment with jet engines and produced a jet fighter, the ME 163, that was vastly superior to the piston-powered airplanes, but by then the production of aircraft in Germany had slowed to the point where the jet had little overall effect on the outcome of the war. Messerschmitt also had on his drawing board a large bomber that would have had the capability of crossing the Atlantic Ocean and bombing the USA, but this aircraft was never built.

After the war, the Bavarian Aircraft Works was merged into a large conglomerate and went into the business of building cars as well as working in the design of transport planes for the European consortium. Messerschmitt did not design another airplane, although he helped the aircraft industries in other countries with the development of their own air forces.

Was Willy Messerschmitt an engineering design genius, or was he simply a good organizer who got others to do the design work? Certainly he left behind a legacy of unsuccessful airplanes, and perhaps no engineer has ever been responsible for more crashes during shakedowns and flight tests. What is true is that he loved

aviation, and the war and the Nazis allowed him the opportunity to apply his engineering skills to the manufacture of airplanes [25].

2.1.3 Engineers Who Worked in the Civilian Sector but Whose Work Became Useful to the Military

Vannevar Bush (1890–1974)



Fig. 2.20 Vannevar Bush

Vannevar (van-NEE-var) Bush has been called the "engineer of the American century," and rightfully so. The present military/government/industry/university research establishment in America is largely his doing.

Born in Chelsea, MA, to Unitarian parents, he did well in school and developed a self-confidence he was to carry throughout his life. He went to Tufts University to study engineering and earned a master's degree in the same time it usually takes to finish the bachelor's degree. After graduation he went to work for General Electric but, after being laid off, took a teaching position at Clark University. The next stop was MIT, where he earned a PhD in 1 year. He then returned to Tufts as an assistant professor. By this time the USA was about to enter the First World War, and Bush decided to aid the war effort. He invented a device that used magnetic fields to detect submarines, and although this instrument was successful in field trials, the war ended before it could be effectively deployed on ships.

In 1919 Bush accepted a position in the electrical engineering department at MIT and started work on what we now call analog computers. By 1931 he had invented an analyzer that could solve differential equations. The idea of data storage and rapid retrieval fascinated him, and he developed a microfilm device that could review 1,000 fingerprints a minute, but the FBI was not interested in his research. In 1937 he became the president of the Carnegie Institution which conducted contract research, and the prestige of this position gave him access to governmental research laboratories.

The USA was woefully unprepared when it entered the Second World War. Military research was done in governmental labs and their output was dismal. Many scientists and engineers felt that an organization was needed that could do independent work, but with government research funding. In a meeting with President Roosevelt, Bush proposed a new organization for conducting research.

The president agreed, and the National Defense Research Committee was formed, with Bush as its head. The initial purpose of the organization was to coordinate military research, which led to the creation of the Office of Scientific Research and Development, which ultimately conducted most of the military research during the war. Some of the innovations from these laboratories during the Second World War were improvements in radar, the development of the proximity fuse for antiaircraft guns, and improvements in submarine tactics. Most of the work done was, of course, secret, including work on the Manhattan Project.

After the war Bush pushed for what became the National Science Foundation. Bush's idea was that all military research funding would be run through this organization, but this did not occur and today the NSF remains a minor player in military research. But Bush's most important victory was in having much of this funding go to universities, which, prior to the Second World War, had not been players in military research [26].

Bush's own research in memory retrieval led to something he called "memex," a storage and retrieval device using microfilm that could extend the powers of human memory and association. His device projected images on a screen, allowing the researcher to make associations and extensions of ideas, establishing links between documents just as the human mind forms memories through associations. The notion was the forerunner of what today we call hypertext, and thus Bush is often credited as one of the founders of the Internet.

Bush's effort without doubt helped to win the Second World War, but more than that, he changed the way military (and related) research was conducted. He was responsible for creating the system that defines the way military research is funded today [27].

Gaspard Monge (1746–1818)

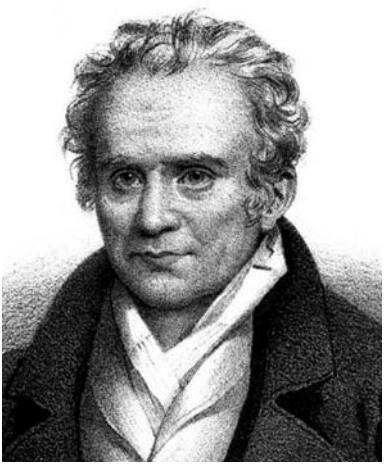


Fig. 2.21 Gaspard Monge

As discussed in Chapter 1, during the 17th and 18th centuries the best military engineers were French. In addition to the development of shrapnel shells, pontoon bridges, gun carriages, and the semaphore signaling system, the French invented descriptive geometry, which was essential in the description of three-dimensional objects on two-dimensional paper, leading to what we today call technical drawing. The invention of orthographic projection is credited to Gaspard Monge, but the French military recognized the importance of this invention in the construction of military hardware and fortifications and prevented the invention from being published. Monge had to wait 25 years before his ideas became public.

Gaspard Monge was born in 1746 into a poor household. He was educated in schools that emphasized science and mathematics, skills that were useful to the military. Even though Monge was a brilliant student, he was not of noble birth and therefore could not be admitted to officer training. Instead, he was sent to a technical school to learn surveying and drawing. While he was a student, he was asked to plan a fortress based on surveying data, and while solving this problem, Monge invented the concept of orthographic projection. His finished drawings were at first rejected because they were done too fast, but Monge was able to show how his new technique was superior to the old slow way. He was so persuasive that he was soon appointed professor at the very school where he had been studying, but only on the condition that the principles of orthographic projection be kept a military secret and shared only with officers above a certain rank. In 1780 he was appointed to a chaired professorship in mathematics in Paris where he published an influential paper on curvature, a problem that had first been considered by Euler, the Prussian mathematician.

Monge was an early supporter of the French revolution, but during The Terror he was denounced and escaped the guillotine only by a hasty flight from Paris. He eventually joined Napoleon's armies in Egypt, where he watched from land as the French fleet was destroyed by the British. He escaped back to France and was made professor at L'Ecole Polytechnique, where he gave lectures on descriptive geometry. While he thought of himself as a mathematician, his development of the orthographic projection technique contributed significantly to military engineering where three-dimensional objects such as fortifications and weapons needed to be expressed in two dimensions on paper so that they could be reproduced in quantity.

Garrett Morgan (1877–1963)



Fig. 2.22 Garrett Morgan

Garrett A. Morgan was born in Kentucky to former slaves and spent his childhood on the family farm. When he was 14 years old he went to Cincinnati in search of employment. The only work he could find was menial handyman work, but he made enough to hire his own tutor, thus continuing his education.

In 1907 Morgan opened his own sewing machine and shoe repair shop and later expanded his business to include a tailor shop that made coats and suits, all with equipment that he had designed and constructed. In 1920, Morgan moved into the newspaper business, establishing *The Cleveland Call* and becoming a prosperous and widely respected businessman.

Morgan continued to invent things, including a safety hood and smoke protector. His "safety hood" was patented as a "breathing device" and consisted of a hood worn over the head of a person onto which was attached tubes that reached near the ground, bringing in clean air. The bottom of the tube was lined with a sponge-type material that helped to filter the air. He sold his invention around the country, although in many instances he was forced to allow a white partner to take credit for the invention. He became famous when he and his brother used the safety hood to rescue 32 men trapped during an explosion in an underground tunnel 250 feet beneath Lake Erie. The tunnel had filled with poison gas, and several men had died trying to reach the workers. Morgan, his brother, and a team of volunteers donned the new "gas masks" and went to the rescue.

Although other kinds of gas masks had been invented, the heroic efforts in saving the men trapped in the tunnel explosion was great publicity and the Morgan safety hood became widely used by fire and rescue workers. A refined model of the mask won a gold medal at the International Exposition of Sanitation and Safety and another gold medal from the International Association of Fire Chiefs.

When Morgan invented the "safety hood" he could never have imagined that the most important use of his mask, now much improved, would be as a life-saving device during the First World War. The British version of the respirator was distributed a month before the Battle of the Somme and its use greatly reduced casualties from German poison gas attacks.



Fig. 2.23 Morgan's "safety hood"

2.2 The Morality of Military Engineering

The above engineers were all in some way and at least during some part of their careers engaged in military engineering. For the most part, these military engineers were not morally bad people and would have insisted that working for the military is an honorable profession. This is not unexpected. Sociological studies have found that all employees, including engineers, have a tendency to focus on the task at hand and to bracket this from their personal moral values. Work seems to be a special case, so to speak, and one's personal values do not apply. This compartmentalization allows employees to function at a level of minimally acceptable ethical behavior [1].

One might be tempted to argue that weapons research and military engineering are *always* morally wrong because both killing and enabling killing are blameworthy under all conditions. But it is not all that simple, and it is possible to mount strong arguments for doing military engineering. Most moral systems agree that killing in self-defense is not morally wrong and can be justified under certain special circumstances. Killing as a means of preventing or stopping the abuse or the certain death of innocents is also ambiguous. It is not possible, therefore, to categorically declare military engineering morally bankrupt.

When military engineers are asked to defend their work on moral grounds, they often use one of four ethical arguments:

1. Some argue that military research and armament production is a gift from God, and therefore "it is inherently good" and thus morally acceptable. Many people in the military have strong religious convictions and believe that their cause is just and that God is on their side. Given such a belief, it is not difficult to assert that military research is also a gift from God and, therefore, inherently good. But if military research is a gift from God, and therefore finds favor in God's eyes, then everything else must also be a gift from God. It is not possible to know what is and what is not a gift from God. Is it possible that racism, religious intolerance, and terrorism are also gifts from God? If so, does that make them either admirable or morally acceptable? [28].
2. The second argument states that working in military research and development is a civic duty. Since the country as a whole has agreed that this activity is to continue, and since the people are willing to pay for it, it is the civil duty of engineers to carry out the work without worry about moral implications. This argument is hollow because it assumes that the society that hires engineers always knows what the morally right thing to do is. If we accept this argument, we would also then have to say that the cruel treatment of African Americans during the Jim Crow years was morally acceptable because the majority of the people supported it [29].
3. A third approach to arguing for armaments research and manufacturing is that the work is actually intended to promote peace. These engineers point to the winning of the Cold War with the Soviet Union as proof that a strong defense eventually results in a peaceful settlement of disputes. World history, however,

disputes this claim and instead shows that military buildups almost always result in conflicts. The Cold War was won more by the collapse of the Soviet economic system than by the superiority of our military establishment. And having this establishment available for use by political leaders has resulted in numerous local conflicts.

4. A fourth approach, credited to Samuel Florman, who wrote so eloquently in the 1970s on the value and worth of engineering and engineers, is that engineers should engage themselves in whatever needs to be done and to leave the moral questions up to those who use the engineer's skill. This is known as the "gun for hire" approach. There is no problem with doing murderous work. One is simply doing what one was trained to do, and the value in the work is the quality of the outcome. Good engineering is good engineering, regardless of how the work is eventually applied. Engineering thus is an amoral activity and engineers should not be required to make moral decisions [30]. Florman used the "responsibility of the professions" argument to press his case:

> If each person is entitled to medical care and legal representation, is it not equally important that each legitimate business entity, governmental agency, and citizen's group should have access to expert engineering advice? If so, then it follows that engineers (within the limits of conscience) will sometimes labor on behalf of causes in which they do not believe [30].

This is, however, a spurious argument. A physician is beholden to give care when life is threatened but is not at all required to perform surgery or prescribe medications if there is no need for it. The lawyer may defend a client that he or she believes is guilty, but can always ask to be relieved of the duty. Similarly, there is no moral responsibility for an engineer to perform engineering on a project that he or she believes to be morally reprehensible.

As demonstrated by some of the short biographies above, clearly some engineering is not moral, even if it is good engineering. Engineers do have an opportunity and a professional mandate to make moral decisions. Stephen Unger suggests that engineers should

> … endeavor to direct their professional skills toward conscientiously chosen ends they deem, on balance, to be of positive value to humanity, declining to use those skills for purposes they consider, on balance, to conflict with their moral values [31].

But this mandate is not without problems. Debra Johnson, for example, has pointed out that some engineers might have some pretty rotten moral values. Should this absolve them of any blame for unethical behavior? Secondly, most engineers who share societal moral values might not realize that their decisions are morally laden. Asking an engineer to do what he or she thinks is the right thing to do therefore opens up some serious difficulties and leaves the public no better off [32].

Unger replies that engineers share a core set of values such as truthfulness and openness, and that the vast majority of engineers respect human rights and human

welfare. He argues that we achieve the greater good when we ask engineers to decline work that might be in conflict with their moral values [33].

John Forge points out that engineers have both a "positive duty" and a "negative duty" to do the right thing. The former is the duty to do well, while the latter is the duty to prevent harm. For example, during the Second World War when Britain stood alone against the Nazi war machine, did engineers have a "positive duty" to work on military research in order to prevent Germany from invading England? Their work on radar and in deciphering the German Enigma code prevented harm to their countrymen and saved England from being invaded by Nazi Germany. Was it also a "positive duty" for American nuclear scientists to manufacture an atomic bomb? Forge continues:

> If we propose that the injunction "Never do war research" be included among the responsibilities of the engineer, and if this is understood as absolute, then we have to deal with the objection that, in times of extraordinary emergency, the engineer should be free to do weapons research. So must we treat the injunction as one that could be over-ridden in extraordinary circumstances? And can it in any case be defended as the norm? In peacetime, when there are no enemies bent on conquest and genocide, can the injunction be imposed? I would answer "yes" to all these questions [33].

One approach used to judge the level of immorality of military work is to argue that one should only work on defensive projects. The department, after all, is not the Department of War (which it used to be until the 1930s) but the Department of Defense, and thus much of the work they sponsor has to be defensive. The argument is that engineers who have qualms about doing military work should limit what they do to defensive armament systems, that this will be morally permissible. But the trouble is that it is difficult if not impossible to classify a weapon as defensive or offensive. Perhaps there are some that can be so cataloged, but most cannot. From the simplest weapon, the rifle, for example, to the most intricate, the laser-guided smart bomb, these are all both offensive and defensive. In some cases one might argue that body armor, or armor for the trucks in Iraq, is purely defensive, but the point is that by having such armor or protection, the soldier or the truck becomes capable of undertaking clearly offensive actions.

All weapons are therefore both offensive and defensive, depending on one's perspective. For example, the Star Wars system was viewed by the Reagan administration (and subsequent administrations) as purely defensive, but Russia believes that it is an offensive weapon that destabilizes the armaments balance. Russia's view is that if the shield is indeed successful, the USA would be free to use its nuclear arsenal without fear of retribution. Also, the mere presence and availability of weapons and an army make some leaders more likely to use them for nondefensive purposes. We have witnessed the use of our forces, which are in place to defend against aggression, as an offensive weapon in Iraq.

Moving along a continuum – from military work without concern for consequences to work limited by one's moral concerns – we come to the option that an engineer should not do any military work under any circumstances and instead endeavor to use his or her skills for the promotion of peace. This position, which

in effect argues for pacifist engineering, is the limiting position. As Albert Camus, in his powerful booklet "Neither Victims Nor Executioners," writes:

> All I ask in the midst of a murderous world, we agree to reflect on murder and to make a choice. After that, we can distinguish those who accept the consequences of being murderers themselves or the accomplices to murderers, and those who refuse to do so with all their force and being [34].

Such is not an easy decision and may not even be the best one, all things considered. There may be times and instances when doing military work will be the most morally acceptable alternative. Perhaps the wisdom of Aristotle, seeking moderation in all things, is again the best alternative.

2.3 Military Work in the Legal and Medical Professions

Engineering is not the only profession that wrestles with the application of professional skills to the military and the making of war. Consider the military lawyers who have justified the need for the concentration camp called Guantanamo in Cuba. Should an attorney condone the torture of prisoners, knowing that this is both illegal and immoral?

Some attorneys assigned to prosecute the prisoners have already rebelled against the mistreatment received by these prisoners. Writing in the *Washington Post,* former military prosecutor Darrel Vandeveld says that prosecutors were bullied by Bush political appointees to bring charges before the cases were ready. He also described how one 16-year-old detainee was "hooded, slapped repeatedly across the face and then thrown down at least one flight of stairs." Detainees were also subjected to sleep deprivation and other forms of abuse. Finally Vanderveld decided to quit his post, saying he had ethical qualms about the system. "I am ashamed that it took me so long to recognize the stain of Guantanamo, not simply on America's standing in the world, but as part, now, of a history we cannot undo," Vandeveld writes [35]. The American Bar Association has not taken a stand on the treatment of prisoners at Guantanamo and apparently does not intend to do so.

Another case of professionals being confronted by ethical dilemmas is the use of medicine in warfare. Historically, conflicting armies have used physical means to kill each other. Chemical warfare in modern times was first used by the Germans in the First World War and by Saddam Hussein against the Kurds in Iraq. The use of chemicals is theoretically not permitted according to the Geneva Convention, but stocks of chemical warfare agents still exist in arsenals of all major powers, including the USA.

A third method of subduing the enemy is to use biological agents such as anthrax or other lethal viruses and microorganisms. Even more insidious is the use of medicines that were developed to help those who suffer from various illnesses. For example, what would happen if the drug Valium were somehow introduced into

the bodies of an opposing army? The effect would be relaxation, lethargy, and inability or unwillingness to fight. Valium, if it could act quickly enough, could also be used as a means of riot control by law enforcement officials.

This use of "drugs as weapons" has worried many healthcare professionals and prompted the Royal Academy of Medicine in the UK to convene a special study committee. Their conclusion was that the use of a drug as a method of warfare would constitute a violation of the 1925 Geneva Protocol and the 1993 Chemical Weapons Convention (CWC). "The committee believed that the use of drugs as weapons is simply not feasible without causing great harm to non-combatants. They believed that it would be impossible to deliver the exact dose of a drug to the right people, thus causing unacceptable collateral damage." The bottom line, according to the British Medical Association, is that any physician who participates in a "drugs as weapons" program is acting unethically and can be censured [36].

If physicians can declare the use of their skills in warfare morally unacceptable, what would it take for the engineering profession to do likewise?

2.4 Military Engineering at American Universities

It seems reasonable that if peace engineering is to prosper and someday take its place alongside other engineering endeavors, then we need to engage American universities. At the present time, the situation at engineering schools is rigged in favor of military engineering. Zussman writes:

> Because engineers are embedded in industry or the military, they typically serve the ends of profit-making, or defense, and it has not traditionally been considered a professional duty to question those ends [37].

The funding of graduate students by the military has long-term effects. Students become experts in a specific area, and if this is of importance to the military, the students, upon graduation, have to seek funding from the military to continue their work. They would have to completely retool their skills to avoid this, and thus the military can control their academic careers [38].

The military needs engineering talent, and they thus do aggressive recruiting. Manion and Kam write:

> One only needs to look at the history of the engineering profession to see how closely engineering schools and large corporations work together to tailor an engineering curriculum suited to the immediate needs of the military-industrial complex [39].

American universities, now so critically and financially in need of the overhead dollars that come from doing research, can only push for more funding, and the defense establishment is the governmental sector with the most money. As an example of the kind of slithering beggars university presidents can become when

they need more money, we have the testimony of the president of the Association of American Universities, an elite group that admits only 50 of the largest and most prestigious universities. The following testimony in front of the House of Representatives Committee on Appropriations shows how students are used as pawns to squeeze more money out of the government:

> I think it … would be helpful to the Department of Defense to enlist the loyalty of a group of students with funds that it awards, to enable students to pursue their graduate studies with the sense that they are beginning an engagement in work that is of interest, that will ultimately be of interest to the Department of Defense and related agencies.
> So I think from that point of view, to the extent that the Defense Department supports graduate students in the sciences and engineering, it is beginning to build cadres of scientists and engineers who will be participants in the programs in the future …
> … If they are engaged early in work that is intellectually stimulating to them and that has some promise for the future and is supported by the Department of Defense, it seems to me you are well on the way to having them hooked into that enterprise for a long time [40].

"Hooked"? The presidents of our universities want to "hook" our students into doing military research?

Some years back the Office of Naval Research was casting around to find a suitable university where it could set up shop and condone high-level biological research. It eventually settled on MIT and offered the university huge research funding. The faculty of the Department of Biology were coerced into accepting this offer, but not without having their say first. Professor Jonathan King, the head of the department, wrote an article that described the process:

> Funding for biological research by the military serves several purposes. It contributes to the increasing incorporation of the university into the military-industrial complex. It provides a veneer of respectability to cover the support of the military for its more destructive projects. It increasingly focuses academic research on problems of concern to the military. And it provides direct and indirect support for the resurgence of biological warfare research [41].

Some universities, such as the American Military University, have been established to serve the needs of military personnel, offering online degrees for returning servicemen and women. Their Web site advertisement reads:

> AMU students are active, working adults in the military, public safety and national security sectors, and beyond. Founded to provide relevant and affordable education to the military, AMU today serves a variety of students seeking liberal arts and professional studies degrees, and we place special program emphasis on programs in homeland security, national security, intelligence, and emergency and disaster management. Everyone associated with the University shares a passion for providing curriculum, class delivery, and service uniquely designed to meet the needs of those who serve others in their communities.

The high percentage of engineers engaged in defense-related industry is not altogether a random selection. The armed forces go to a great deal of trouble and expense to recruit engineers, often with advertising that plays up the exciting nature of military engineering and suggests that alternatives are boring and worthless. Figure 2.24 is an example of this advertising. The ad suggests that the only

cool thing for graduating engineers to do is to work for the military. It is no wonder that students perceive that the most excitement and the best jobs are all in the military/industrial complex.

In fact, when Dwight Eisenhower warned us of the military/industrial complex, he should perhaps have called it a *military/industrial/university* complex.

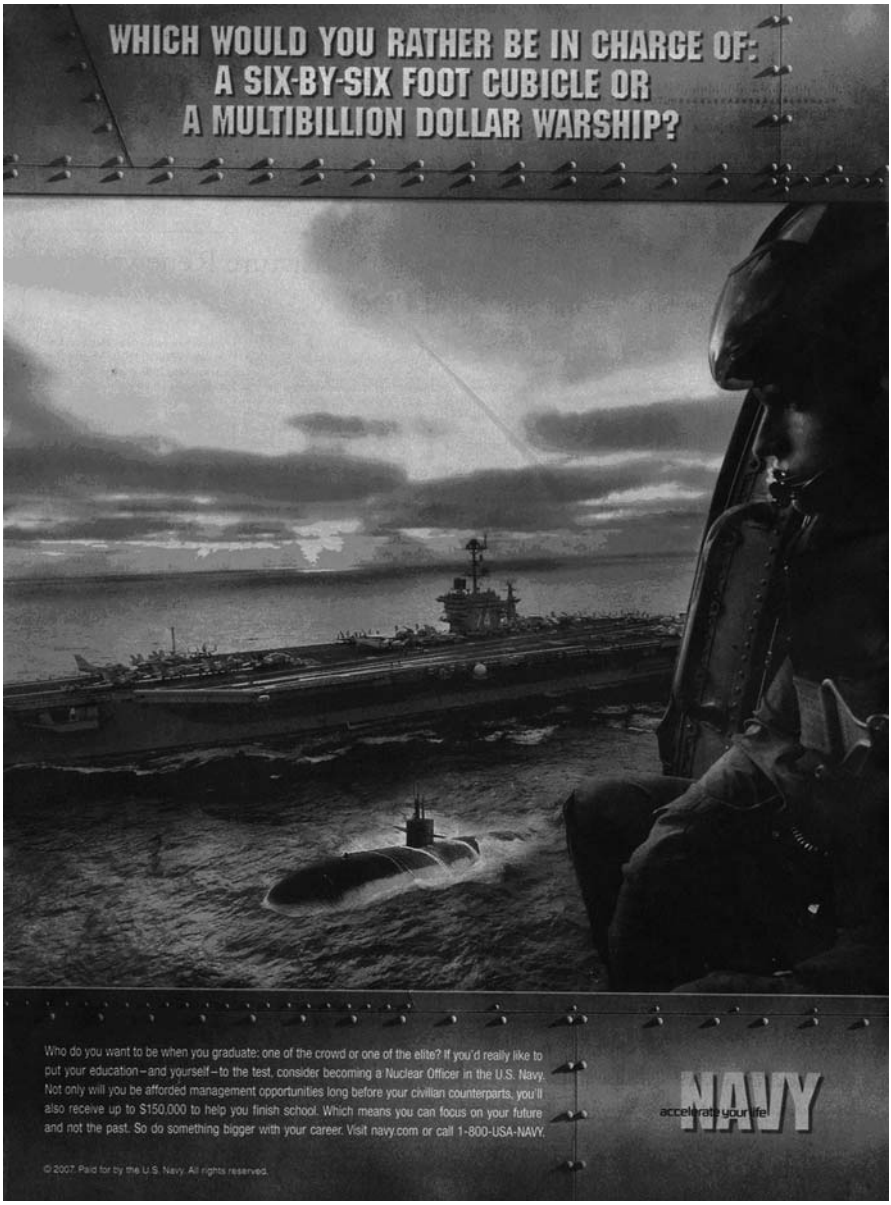


Fig. 2.24 A recruitment ad by the US Navy directed at engineering students

References

[1] Bowen WR (2006) Prioritising people – outline of an aspirational engineering ethic. In: Proceedings of the workshop on engineering and philosophy, Delft, The Netherlands
[2] Langley C (2005) Soldiers in the laboratory: military involvement in science and technology and some alternatives, Scientists for Global Responsibility, Kent, UK
[3] Stockholm International Peace Research Institute (2003) Yearbook. Stockholm
[4] Martel WC (2001) The technological arsenal: emerging defense capabilities. Smithsonian Institution, Washington, DC
[5] Feldman J (1989) Economic conversion: an alternative to military dependency in the university. In: Mitcham C, Siekevitz P (eds) Ethical issues associated with scientific and technological research for the military. New York Academy of Sciences, New York
[6] Papadoupoulos C, Hable A (2008) Including questions of military and defense technology in engineering ethics education. In: Proceedings of the ASEE conference and exposition
[7] Singer P (2009) Wired for war. Penguin, New York
[8] Michener JA (1984) Tales from the South Pacific. Fawcett, New York
[9] Kajencki FC (1998) Military engineer of the American Revolution. Southwest Polonia, Lafayette, LA
[10] Smith JE (1984) Dictionary of American military biography, vols 77–80/81–84 'Lucius Clay.' Gale Research, Farmington Hills, MI, pp. 685, 686
[11] Katz SM (2002) The hunt for the engineer: the inside story of how Israel's counterterrorist forces tracked and killed the Hamas master bomber. Lyons, Guilford, CT
[12] Prüfer K (1946) Testimony of crematorium engineers. Jewish Virtual Library: *www.jewishvirtuallibrary.org/jsource/Holocaust/crematorium_test.html*
[13] Redford J (1992) http://world.std.com/~jlr/doom/bull.htm
[14] Lowther W (1991) Arms and the man - Dr. Gerald Bull, Iraq, and the supergun. Presidio, New York
[15] William L (1991) Iraq and the supergun: Gerald Bull: the true story of Saddam Hussein's Dr. Doom. Macmillan, London
[16] Drake S (1978) Galileo at work: his scientific biography. University of Chicago Press, Chicago
[17] Roland A (1989) Hephaestus and history. In: Mitcham C, Siekevitz P (eds) Ethical issues associated with scientific and technological research for the military. New York Academy of Sciences, New York
[18] http://en.wikipedia.org/wiki/Strategic_Defense_Initiative
[19] Lipton E (2008) Pork-barrel insider drained missile-defense millions. New York Times 158(54,461):1. 12 October 2008
[20] Devreese JT, Vanden Berghe G (2008)'Magic is no magic': the wonderful world of Simon Stevin. WIT Press, Boston
[21] Langewiesche W (2005) The wrath of Khan. The Atlantic, November 2005
[22] O'Brien JM (2007) Killer robots could replace soldiers. Fortune, 4 December 2007
[23] Ratliff E (2009) Shoot!. New Yorker, 23 February 2009
[24] http://ethics.calpoly.edu/pr_022309.html
[25] Dinger's Aviation Page, http://freespace.virgin.net/john.dell/index.htm
[26] Mitcham C (1989) The spectrum of ethical issues associated with the military support of science and technology. In: Mitcham C, Siekevitz P (eds) Ethical issues associated with scientific and technological research for the military. Annals of the New York Academy of Sciences, vol 577. New York Academy of Sciences, New York
[27] Zachary GP (1999) Endless frontier: Vannevar Bush, engineer of the American century. MIT Press, Cambridge, MA
[28] Dinegar RH (1989) The moral arguments for military research. In: Mitcham C, Siekevitz P (eds) Ethical issues associated with scientific and technological research for the military. New York Academy of Sciences, New York

[29] Kemp K (1989) Conducting scientific research for the military as a civil duty. In: Mitcham C, Siekevitz P (eds) Ethical issues associated with scientific and technological research for the military. New York Academy of Sciences
[30] Florman S (1970) Moral blueprints: on regulating the ethics of engineers. Harper's, October 1970
[31] Unger S (1982) Controlling technology: ethics and the responsible engineer. Holt, Reinhart and Winston, New York
[32] Johnson D (1989) The social/professional responsibility of engineers. In: Mitcham C, Siekevitz P (eds) Ethical issues associated with scientific and technological research for the military. New York Academy of Sciences, New York
[33] Forge J (2006) The morality of weapons research. In: Vesilind PA (ed) Peace engineering. Lakeshore Press, Woodsville, NH
[34] Camus A (2002) Neither victims nor executioners. In: The power of nonviolence. Beacon Press, Boston
[35] Weiss C () How a military prosecutor changed from gung ho terrorism fighter to Gitmo critic. ABA J: *http://abajournal.com/news*
[36] Board of Science (2008) The use of drugs as weapons: the concerns and responsibilities of healthcare professionals. British Medical Association, London
[37] Zussman R (1985) Mechanics of the middle class: work and politics among American engineers. University of California Press, Berkeley
[38] Roth B (1989) The moral arguments against military research. In: Mitcham C, Siekevitz P (eds) Ethical issues associated with scientific and technological research for the military. New York Academy of Sciences, New York
[39] Manion M, Kam M (2000) Engineering ethics at Drexel University. In: Proceedings of the American Society for Engineering Education annual conference
[40] Rosenzweig R (1989) Congressional testimony on 15 May 1985, Department of Defense Appropriations for 1986, Committee on Appropriations, 99th Congress. US Government Printing Office, Washington, DC; quoted in B. Roth, Moral arguments against military research. In: Mitcham C, Siekevitz P (eds) Ethical issues associated with scientific and technological research for the military. New York Academy of Sciences, New York
[41] King J (1989) Biology goes to war. Sci People 20(1), 1988; quoted in: Mitcham C, Siekevitz P (eds) Ethical issues associated with scientific and technological research for the military. New York Academy of Sciences, New York



http://www.springer.com/978-1-84882-673-1

Engineering Peace and Justice
The Responsibility of Engineers to Society
Vesilind, P.A.
2010, VIII, 167 p., Hardcover
ISBN: 978-1-84882-673-1