Engineering and Technology in Society - Canada

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Jennifer Kirkey

Contents

Introduction

This book is a compilation of open source resources to be used in an Engineering in Society course.

Jennifer Kirkey started this work in the summer of 2018. She teaches physics and astronomy at Douglas College in New Westminster and works closely with the engineering program there.

The cover photo was taken by Jennifer Kirkey in 2015 at the Douglas Coupland art exhibit which was at the Vancouver Art Gallery. Photography was encouraged. CC BY 4.0.

ENGR1110 at Douglas College Course Syllabus

https://www.douglascollege.ca/about-douglas/news-and-media/news/2019/June/ubc-engineering-transfer-path

COURSE INFORMATION
Course Code & Number:ENGR 1100
Transcript Title:Engineering & Tech in Society
Descriptive Title:Engineering And Technology In Society
Institution Unit:Engineering
Credit: 3.0
Description: This course is designed to provide an introduction to the practice of engineering, surveying its history and its current state. The social and political aspects of engineering decisions will be illustrated by a number of case studies.

COURSE DETAILS
Learning Format:Lecture
Contact Hours:4.0 hours/week
Semester Length:15 weeks
Prerequisites

CorequisitesENGL 1130 or CMNS 1135 must be completed prior to OR at the same time as this course.
EquivalenciesNot Specified
Maximum Class Size:36
PLAR:No

COURSE CURRICULUM

Learning OutcomesAfter taking this course, the student will be able to:

- Analyze major engineering projects in terms of key resources such as cost, labour, and implementation time.
- Analyze major engineering projects in terms of societal benefits, and detriments.
- Identify, current and historical, key engineering projects, devices, and inventions.
- Identify, current and historical, key figures involved with engineering projects, devices, and inventions.
- Demonstrate how to apply general scientific principles such as the laws of thermodynamics, and conservation of energy to situational and mathematical problems.
- Apply scientific principles to debunk ‘junk’ science and engineering myths such as perpetual motion.

Course ContentStudents will explore the history and current state of engineering practice by analyzing engineering project case studies such as the Pyramids of Egypt, the Roman Aqueducts, the Great Wall of China, the Panama canal, and the Three Gorges dam.

The afore listed case study analysis will strongly emphasize the ethical, social and political aspects of engineering projects.

As well, students will be expected to analyze present day projects such as the Trans Mountain pipeline, and the BC Hydro Site C dam.

Methods Of Instruction

- Lectures
- In class group discussion
- In class case study analysis
- Group Projects
- Poster presentations
- Possible online Assignments and Discussion

Text Books\MaterialsStudents should consult the Douglas College Bookstore for the latest required textbooks and materials. The exact textbook and course materials will be decided by the course instructor. They will be similar to:

- “The Betterment of the Human Condition” by John D. Jones, current edition
- “The Ancient Engineers” by L. Sprague De Camp, 1995 edition
- “Engineer’s Toolkit: A First Course in Engineering” by Carl Mitcham, and Shannon Duval, current edition
- “Engineers withing a Local and Global Society” by Caroline Baillie
- “To Engineer is Human: The Role of Failure in Successful Design” by Henry Petroski, current edition

Means Of AssessmentEvaluation will be carried out in accordance with Douglas College policy. The instructor will present a written course outline with specific evaluation criteria at the beginning of the semester. Evaluation will be based on the following:

Research Paper: 30% – 40%
Project with subsequent poster presentation: 20% – 30%
In Class Participation and/or group exercise: 10% – 15%
In Class Quizzes: 15% – 30%
Assessment means could include online quizzes and assignments.

Henry Petroski and "To Engineer is Human: The Role of Failure in Successful Design"

I dedicate this book to Henry Petroski.

His book “To Engineer is Human: The Role of Failure is Successful Design” is a book that literally changed my life. Published in 1982, it has many editions.

https://www.amazon.ca/Engineer-Human-Failure-Successful-Design/dp/0679734163

This book is available at sensible bookstore everywhere. Amazon.ca describes it as follows:

“How did a simple design error cause one of the great disasters of the 1980s – the collapse of the walkways at the Kansas City Hyatt Regency Hotel? What made the graceful and innovative Tacoma Narrows Bridge twist apart in a mild wind in 1940? How did an oversized waterlily inspire the magnificent Crystal Palace, the crowning achievement of Victorian architecture and engineering? These are some of the failures and successes that Henry Petroski, author of the acclaimed “The Pencil,” examines in this engaging, wonderfully literate book. More than a series of fascinating case studies, “To Engineer is Human” is a work that looks at our deepest notions of progress and perfection, tracing the fine connection between the quantifiable realm of science and the chaotic realities of everyday life.”

He published a new book in 2008.

Success through failure: the paradox of design

https://press.princeton.edu/titles/8132.html

Here is a link to a ten minute video that was presented at Duke University in 2014. In it Henry Petroski talks about the role of engineers in our society and discusses why some designs eventually fail. In his book, “To Forgive Design,” Prof. Petroski looks at headline-making failures like the 1940 Tacoma Narrows Bridge collapse, the Space Shuttle Challenger explosion, and the Deep Water Horizon oil spill. This interview, conducted at the Washington Duke Inn in Durham, North Carolina, is part of Book TV’s College Series.

https://www.youtube.com/watch?v=Xz5lR9sromQ

Here is a link to one hour video where he talked about the book in April 2006 at Vanderbilt University. “The Paradox of Design: Success through Failure,” by Henry Petroski, Aleksander S. Vesic Professor of Civil Engineering and Professor of History, Duke University.

The Youtube link is ” https://www.youtube.com/watch?v=HzMZr2OA0IU ”

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.bccampus.ca/engineeringinsociety/?p=22

Chapter 1 - Engineering

What is Engineering? Definition, introduction and a brief history

What is engineering? Here is how it is defined in wikipedia.

https://en.wikipedia.org/wiki/Engineering

Engineering is the creative application of science, mathematical methods, and empirical evidence to the innovation, design, construction, and maintenance of structures, machines, materials, devices, systems, processes, and organizations. The discipline of engineering encompasses a broad range of more specialized fields of engineering, each with a more specific emphasis on particular areas of applied mathematics, applied science, and types of application. See glossary of engineering.

The term *engineering* is derived from the Latin *ingenium*, meaning "cleverness" and *ingeniare*, meaning "to contrive, devise".[1]

Definition

The American Engineers' Council for Professional Development (ECPD, the predecessor of ABET)[2] has defined "engineering" as:

> The creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behavior under specific operating conditions; all as respects an intended function, economics of operation and safety to life and property.[3][4]

History

Main article: History of engineering

Relief map of the Citadel of Lille, designed in 1668 by Vauban, the foremost military engineer of his age.

Engineering has existed since ancient times, when humans devised inventions such as the wedge, lever, wheel and pulley.

The term *engineering* is derived from the word *engineer*, which itself dates back to 1390 when an *engine'er* (literally, one who operates an *engine*) referred to "a constructor of military engines."[5] In this context, now obsolete, an "engine" referred to a military machine, *i.e.*, a mechanical contraption used in war (for example, a catapult). Notable examples of the obsolete usage which have survived to the present day are military engineering corps, *e.g.*, the U.S. Army Corps of Engineers.

The word "engine" itself is of even older origin, ultimately deriving from the Latin *ingenium* (c. 1250), meaning "innate quality, especially mental power, hence a clever invention."[6]

Later, as the design of civilian structures, such as bridges and buildings, matured as a technical discipline, the term civil engineering[4] entered the lexicon as a way to distinguish between those specializing in the construction of such non-military projects and those involved in the discipline of military engineering.

Ancient era

The Ancient Romans built aqueducts to bring a steady supply of clean and fresh water to cities and towns in the empire.

The pyramids in Egypt, the Acropolis and the Parthenon in Greece, the Roman aqueducts, Via Appia and the Colosseum, Teotihuacán, the Great Wall of China, the Brihadeeswarar Temple of Thanjavur, among many others, stand as a testament to the ingenuity and skill of ancient civil and military engineers. Other monuments, no longer standing, such as the Hanging Gardens of Babylon, and the Pharos of Alexandria were important engineering achievements of their time and were considered among the Seven Wonders of the Ancient World.

The earliest civil engineer known by name is Imhotep.[4] As one of the officials of the Pharaoh, Djosèr, he probably designed and supervised the construction of the Pyramid of Djoser (the Step Pyramid) at Saqqara in Egypt around 2630–2611 BC.[7] Ancient Greece developed machines in both civilian and military domains. The Antikythera mechanism, the first known mechanical computer,[8][9] and the mechanical inventions of Archimedes are examples of early mechanical engineering. Some of Archimedes' inventions as well as the Antikythera mechanism required sophisticated knowledge of differential gearing or epicyclic gearing, two key principles in machine theory that helped design the gear trains of the Industrial Revolution, and are still widely used today in diverse fields such as robotics and automotive engineering.[10]

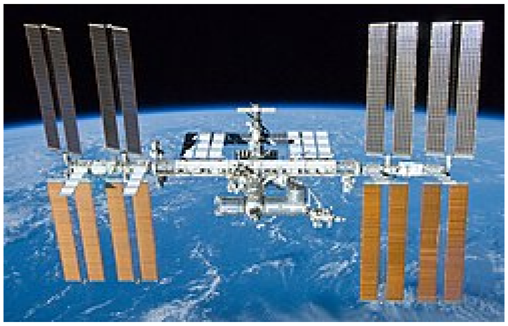
Ancient Chinese, Greek, Roman and Hungarian armies employed military machines and inventions such as artillery which was developed by the Greeks around the 4th century B.C.,[11] the trireme, the ballista and the catapult. In the Middle Ages, the trebuchet was developed.

Renaissance era

The first steam engine was built in 1698 by Thomas Savery.[12] The development of this device gave rise to the Industrial Revolution in the coming decades, allowing for the beginnings of mass production.

With the rise of engineering as a profession in the 18th century, the term became more narrowly applied to fields in which mathematics and science were applied to these ends. Similarly, in addition to military and civil engineering, the fields then known as the mechanic arts became incorporated into engineering.

Modern era



The International Space Stationrepresents a modern engineering challenge for many disciplines.

The inventions of Thomas Newcomen and James Watt gave rise to modern mechanical engineering. The development of specialized machines and machine tools during the industrial revolution led to the rapid growth of mechanical engineering both in its birthplace Britain and abroad.[4]

Structural engineers working on NASA's Mars-bound spacecraft, the Phoenix Mars Lander

John Smeaton was the first self-proclaimed civil engineer and is often regarded as the "father" of civil engineering. He was an English civil engineer responsible for the design of bridges, canals, harbours, and lighthouses. He was also a capable mechanical engineer and an eminent physicist. Smeaton designed the third Eddystone Lighthouse (1755–59) where he pioneered the use of 'hydraulic lime' (a form of mortar which will set under water) and developed a technique involving dovetailed blocks of granite in the building of the lighthouse. His lighthouse remained in use until 1877 and was dismantled and partially rebuilt at Plymouth Hoe where it is known as Smeaton's Tower. He is important in the history, rediscovery of, and development of modern cement, because he identified the compositional requirements needed to obtain "hydraulicity" in lime; work which led ultimately to the invention of Portland cement.

The United States census of 1850 listed the occupation of "engineer" for the first time with a count of 2,000.[13] There were fewer than 50 engineering graduates in the U.S. before 1865. In 1870 there were a dozen U.S. mechanical engineering graduates, with that number increasing to 43 per year in 1875. In 1890, there were 6,000 engineers in civil, mining, mechanical and electrical.[14]

There was no chair of applied mechanism and applied mechanics at Cambridge until 1875, and no chair of engineering at Oxford until 1907. Germany established technical universities earlier.[15]

The foundations of electrical engineering in the 1800s included the experiments of Alessandro Volta, Michael Faraday, Georg Ohm and others and the invention of the electric telegraph in 1816 and the electric motor in 1872. The theoretical work of James Maxwell (see: Maxwell's equations) and Heinrich Hertz in the late 19th century gave rise to the field of electronics. The later inventions of the vacuum tube and the transistor further accelerated the development of electronics to such an extent that electrical and electronics engineers currently outnumber their colleagues of any other engineering specialty.[4] Chemical engineering developed in the late nineteenth century.[4] Industrial scale manufacturing demanded new materials and new processes and by 1880 the need for large scale production of chemicals was such that a new industry was created, dedicated to the development and large scale manufacturing of chemicals in new industrial plants.[4] The role of the chemical engineer was the design of these chemical plants and processes.[4]

The Falkirk Wheel in Scotland

Aeronautical engineering deals with aircraft design process design while aerospace engineering is a more modern term that expands the reach of the discipline by including spacecraft design. Its origins can be traced back to the aviation pioneers around the start of the 20th century although the work of Sir George Cayley has recently been dated as being from the last decade of the 18th century. Early knowledge of aeronautical engineering was largely empirical with some concepts and skills imported from other branches of engineering.[16]

The first PhD in engineering (technically, *applied science and engineering*) awarded in the United States went to Josiah Willard Gibbs at Yale University in 1863; it was also the second PhD awarded in science in the U.S.[17]

Only a decade after the successful flights by the Wright brothers, there was extensive development of aeronautical engineering through development of military aircraft that were used in World War I. Meanwhile, research to provide fundamental background science continued by combining theoretical physics with experiments.

In 1990, with the rise of computer technology, the first search engine was built by computer engineer Alan Emtage.

Greatest Engineering Achievements of the 20th Century by the National Academy of Engineering

According to the USA's National Academy of Engineering, these are the top 20 engineering achievements of the last century.

http://greatachievements.org/

How many of the 20th century's greatest engineering achievements will you use today? A car? Computer? Telephone? Explore our list of the top 20 achievements and learn how engineering shaped a century and changed the world.

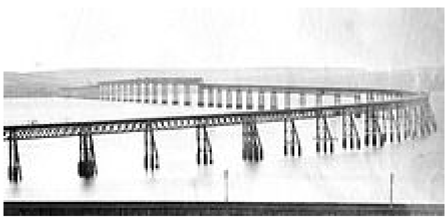
1. Electrification
2. Automobile
3. Airplace
4. Water supply and distribution
5. Electronics
6. Radio and televison
7. Agriculture mechanization
8. Computers
9. Telephone
10. Refrigeration and air conditioning
11. Highways
12. Spacecraft
13. Internat
14. Imaging
15. Household appliances
16. Health technologies
17. Petroleum and Petrochemical Technologies
18. Laser and fibre optics
19. Nuclear technologies
20. High performance materials

Engineering Ethics - Introduction and a brief history

https://en.wikipedia.org/wiki/Engineering_ethics

Engineering ethics is the field of applied ethics and system of moral principles that apply to the practice of engineering. The field examines and sets the obligations by engineers to society, to their clients, and to the profession. As a scholarly discipline, it is closely related to subjects such as the philosophy of science, the philosophy of engineering, and the ethics of technology.

The 18 th century and growing concern



The first Tay Bridge collapsed in 1879. At least sixty were killed.

As engineering rose as a distinct profession during the 19th century, engineers saw themselves as either independent professional practitioners or technical employees of large enterprises. There was considerable tension between the two sides as large industrial employers fought to maintain control of their employees.[1]

In the United States growing professionalism gave rise to the development of four founding engineering societies: The American Society of Civil Engineers (ASCE) (1851), the American Institute of Electrical Engineers (AIEE) (1884),[2] the American Society of Mechanical Engineers (ASME) (1880), and the American Institute of Mining Engineers (AIME) (1871).[3]ASCE and AIEE were more closely identified with the engineer as learned professional, where ASME, to an extent, and AIME almost entirely, identified with the view that the engineer is a technical employee.[4]

Even so, at that time ethics was viewed as a personal rather than a broad professional concern.[5][6]:6

Turning of the 20th century and turning point

The Boston molasses disaster provided a strong impetus for the establishment of professional licensing and codes of ethics in the United States.

When the 19th century drew to a close and the 20th century began, there had been series of significant structural failures, including some spectacular bridge failures, notably the Ashtabula River Railroad Disaster (1876), Tay Bridge Disaster(1879), and the Quebec Bridge collapse (1907). These had a profound effect on engineers and forced the profession to confront shortcomings in technical and construction practice, as well as ethical standards.[7]

Engineers and Geoscientists British Columbia (EGBC)

Who are they and what do they do? https://www.egbc.ca/

Engineers and Geoscientists British Columbia is the business name of the Association of Professional Engineers and Geoscientists of the Province of British Columbia. Engineers and Geoscientists BC regulates and governs these professions under the authority of the *Engineers and Geoscientists Act*.

The association is charged with protecting the public interest by setting and maintaining high academic, experience, and professional practice standards for over 37,000 members. Individuals licensed by Engineers and Geoscientists BC are the only persons permitted by law to undertake and assume responsibility for engineering and geoscience projects in BC.

There are a not-for-profit organization governed by a council of elected members, licensees and government appointees. Council is accountable to the public through the Ministry of the Attorney General, under the Office of the Superintendent of Professional Governance, for both the governance and management of the association.

If you are interested in programs for members: https://www.egbc.ca/Member-Programs
If you want practice resources: https://www.egbc.ca/Practice-Resources
If you are interested in complaints and discipline: https://www.egbc.ca/Complaints-Discipline
If you want to know more about them: https://www.egbc.ca/About
If you want to become a member: https://www.egbc.ca/Become-a-Member

Engineering Students – keep documenting your work experience in case you want to register as a Professional Engineer

Work you have done during your summer work terms or coop work terms might count towards your experience.

https://www.egbc.ca/Become-a-Member/Competency-Experience-Reporting-System

Engineering Ethics from EGBC

https://www.egbc.ca/About/Governance/The-Act,-Bylaws-and-Code-of-Ethics

THE ACT, BYLAWS AND CODE OF ETHICS

The *Engineers and Geoscientists Act*, the professions' governing legislation, as well as the Bylaws and Code of Ethics, guide the association and its members and licensees in performing their duties.

THE PURPOSE OF THE *ACT*, BYLAWS AND CODE OF ETHICS IS TO:

- Define the association's mandate;
- Outline its governing powers with respect to members and non-members alike; and
- Provide general statements regarding principles of ethical conduct to prepare professional engineers and geoscientists for the fulfillment of their duty to the public, the profession and fellow Engineers and Geoscientists British Columbia members.

The Engineers and Geoscientists Act
Bylaws
Code of Ethics

Code of Ethics

https://www.egbc.ca/getmedia/e8d858f5-e175-4536-8834-34a383671c13/APEGBC-Code-of-Ethics.pdf.aspx
The purpose of the code of ethics is to give general statements of the principles of ethical conduct in order that members and licensees may fulfill their duty to the public, to the profession and their fellow members and licensees. Members and licensees shall act at all times with fairness, courtesy and good faith to their associates, employers, employees and clients, and with fidelity to the public needs. They shall uphold the values of truth, honesty and trustworthiness and safeguard human life and welfare and the environment. In keeping with these basic tenets, members and licensees shall:
1) Hold paramount the safety, health and welfare of the public, the protection of the environment and promote health and safety within the workplace;
2) Undertake and accept responsibility for professional assignments only when qualified by training or experience;
3) Provide an opinion on a professional subject only when it is founded upon adequate knowledge and honest conviction;
4) Act as faithful agents of their clients or employers, maintain confidentiality and avoid a conflict of interest but, where such conflict arises, fully disclose the circumstances without delay to the employer

or client;
5) Uphold the principle of appropriate and adequate compensation for the performance of engineering and geoscience work;
6) Keep themselves informed in order to maintain their competence, strive to advance the body of knowledge within which they practice and provide opportunities for the professional development of their associates;
7) Conduct themselves with fairness, courtesy and good faith towards clients, colleagues and others, give credit where it is due and accept, as well as give, honest and fair professional comment;
8) Present clearly to employers and clients the possible consequences if professional decisions or judgments are overruled or disregarded;
9) Report to their association or other appropriate agencies any hazardous, illegal or unethical professional decisions or practices by members, licensees or others; and
10) Extend public knowledge and appreciation of engineering and geoscience and protect the profession from misrepresentation and misunderstanding.

Engineers Without Borders

https://www.ewb.ca/en/

At Engineers Without Borders Canada, we strive to unlock human potential.
We unlock human potential in Sub-Saharan Africa by investing in forward-thinking social enterprises. We support local innovators to accelerate their impact and apply their innovations on a global scale, to the benefit of millions.

We unlock human potential in Canada by fostering a community of leaders—supporting a network of established thought leaders while developing the next generation of pioneers.

We unlock human potential globally—collaborating with innovators across boundaries, consolidating our similarities, and learning from our differences. This enables people to contribute individually and as a collective, and to challenge the national and global policies, systems and institutions that contribute to the flawed status quo.

Evolving Engineering

https://www.ewb.ca/en/showcase/evolving-engineering/

Unlocking the higher potential of the engineering profession to contribute to society.

The engineering profession has a unique and vital role to play in ensuring we move towards the world we want to see—one with more universal equality, sustainability and wellbeing. The reason is engineers play a key role in shaping the relationship between technology and society, which will have massive implications on all aspects of humanity.

Technology holds the potential to drive economic development, tackle the sustainable development goals and grand challenges of the 21st century, and even enhance our very humanity through increased connectivity and higher creativity.

For the engineering profession to live up to its full potential and guide this relationship, we believe engineers will have to develop new skills and expand their understanding. Through increased socio-technological expertise, the engineering community can enact more impactful leadership.

What is the higher potential that we mention for the engineering profession? A global movement of engineers leveraging deep technological understanding in collaboration with diverse leaders to anticipate challenges, frame opportunities to benefit society, and deliver solutions.

As the relationship between technology and society continues to evolve, we must continuously evolve engineering to ensure we live up to our potential.

Our portfolio currently consists of a number of initiatives targeted at fostering the evolution of engineering:

Engineers at the Canadian Space Agency (CSA)

Careers in space – Engineers

http://asc-csa.gc.ca/eng/jobs/careers-in-space/engineer.asp

Engineers standing with Mars rovers
2012-01-17 – Two spacecraft engineers stand with three generations of Mars rovers. (Credit: NASA/JPL-Caltech)

Engineers are problem solvers, inventors and innovators! They find solutions to real-life problems by using science and technology. Engineers make up a large proportion of the professionals in the space sector, and for good reason: engineering is key to the success of space operations.

If you would like to turn your ideas into reality, engineering might be for you! Who knows, one of your technical accomplishments may one day be just the thing to help astronauts complete their mission.

What does an engineer in the space sector do?

Engineers in the space sector design, build and maintain systems and spacecraft. They are responsible for launching spacecraft, landing rovers on Mars, building communication satellites that allow us to use the Internet, and so much more.

To accomplish these incredible feats, engineers use math, science and technical knowledge as their tools of choice. They apply scientific principles to real-world problems and provide practical solutions, turning science into technology.

Examples of engineering solutions to problems in the space sector

Problem: Sending a probe to an asteroid takes a lot of fuel.
Solution: Calculate a trajectory that uses planets' gravities to propel the probe and save fuel.

Problem: Extreme temperatures in space damage electronic equipment
Solution: Find or create materials that can withstand the extreme temperatures of space

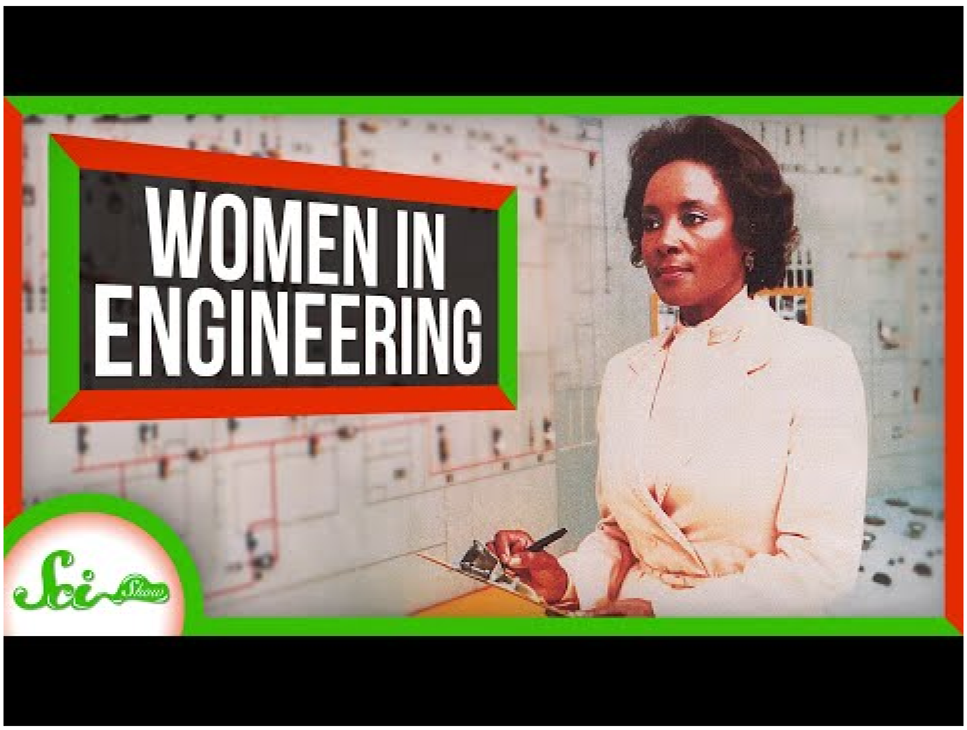
Problem: Operating a rover on Mars is very difficult because of the 15-minute communication delay.

Solution: Build an artificial intelligence system so that the rover can work autonomously.

Women in Engineering

Women are an under-represented group in the engineering profession.

Here is a great ten minute video from SciShow about five amazing women in engineering starting with Hedy Lamarr.



A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.bccampus.ca/engineeringinsociety/?p=366

Sources: Hedy Lamarr
https://www.aps.org/publications/apsn… https://people.seas.harvard.edu/~jone… https://www.theguardian.com/film/2018… https://www.womenshistory.org/educati… https://www.scientificamerican.com/ar… https://www.forbes.com/sites/shivaune… http://www.eecs.umich.edu/courses/eec… https://witestlab.poly.edu/blog/frequ… https://www.scientificamerican.com/ar…
Olive Wetzel Dennis
https://www.atlasobscura.com/articles… https://transportationhistory.org/201… https://www.baltimoresun.com/news/bs-… https://www.goucher.edu/news/olive-we… https://news.cornell.edu/stories/2015… http://www.eduborail.org/Olive-W-Denn… https://bit.ly/323J1SB

Annie Easley https://www.nasa.gov/centers/glenn/ab… https://www.nasa.gov/feature/annie-ea… https://massivesci.com/articles/annie… https://historycollection.jsc.nasa.go… https://www.salon.com/2018/12/25/meet… https://www.nsf.gov/news/mmg/mmg_disp… https://www.nasa.gov/image-feature/an… https://www.energy.gov/articles/five-… https://www.engadget.com/2015/02/13/a… https://physicstoday.scitation.org/do… http://www.livephysics.com/computatio… https://www.nasa.gov/topics/technolog… https://history.nasa.gov/SP-4230.pdf
Lynn Conway http://ai.eecs.umich.edu/people/conwa… http://ai.eecs.umich.edu/people/conwa… http://ai.eecs.umich.edu/people/conwa… https://www.ncwit.org/profile/lynn-co… https://www.computer.org/profiles/lyn… https://www.fi.edu/laureates/lynn-conway https://news.syr.edu/blog/2019/03/25/… https://www.aaas.org/sense-wonder-mot… https://www.electronicdesign.com/prod…
Treena Livingston Arinzeh
https://biomedical.njit.edu/faculty/a… https://cemb.upenn.edu/people/treena-… https://engineering.jhu.edu/magazine/… https://www.aiche.org/sbe/bio/dr-tree… https://www.nsbp.org/nsbp-news/bhm-ph… https://www.researchgate.net/scientif… https://journals.lww.com/jbjsjournal/…
Image Sources: https://bit.ly/2xrTOIj https://bit.ly/323Fdkh https://bit.ly/2XhrEu4 https://bit.ly/2J6XqGm https://bit.ly/2xqj9SL https://bit.ly/2YrdYy4 https://bit.ly/2Xopuc2 https://bit.ly/2RRl50c https://bit.ly/2J8buiC https://bit.ly/2YswR3n https://bit.ly/1PFrDc8 https://bit.ly/2Xn0g2M https://bit.ly/2KXt7ns https://bit.ly/2FO49mw https://bit.ly/2XrDCpZ https://bit.ly/2tiR4wi https://bit.ly/2J8W4L9 https://bit.ly/324xId7

Chapter 2 - Ancient Engineering

The Seven Wonders of the Ancient World

The Seven Wonders were first defined as *themata* (Greek for 'things to be seen' which, in today's common English, we would phrase as 'must sees') by Philo of Byzantium in 225 BCE, in his work *On The Seven Wonders*. Other writers on the Seven Wonders include Herodotus, Callimachus of Cyrene and Antipater of Sidon. Of the original seven, only the Great Pyramid exists today.

https://www.ancient.eu/The_Seven_Wonders/

The Seven Wonders of the Ancient World were:

- the Great Pyramid at Giza, Egypt
- the Hanging Gardens of Babylon
- the Statue of Zeus at Olympia, Greece
- the Temple of Artemis at Ephesus
- the Mausoleum at Halicarnassus
- the Colossus of Rhodes
- the Lighthouse at Alexandria, Egypt

How were they built?

As strange as it might sound to you in the year 2018, there was a strong belief that the ancients could not have made huge, complex structures that were found by Western archaeologists in the 18, 19th and 20th century. Even out of this world aliens have been proposed.

Here is a good article from 2017 from a well respected archaeological organization about this.

Racism is behind outlandish theories about Africa's ancient architecture

https://theconversation.com/racism-is-behind-outlandish-theories-about-africas-ancient-architecture-83898

Some of the most impressive buildings and cities ever made by humans can be found in Africa: the ruined city of Great Zimbabwe, Mapungubwein South Africa, Kenya's Gedi Ruins and Meroe in Sudan. Perhaps the most awe-inspiring of these are the last remaining of the Seven Wonders of the Ancient World, the Great Pyramid of Giza, in Egypt.

This should come as no surprise. Africa has an extensive archaeological record, extending as far back as 3.3 million years ago when the first-ever stone tool was made in what is today Kenya. The continent's cultural complexity and diversity is well established; it is home to the world's oldest-known pieces of art. And, of course, it is the birth place of modern humans' ancient ancestors, *Homo sapiens*.

Despite all this evidence, some people still refuse to believe that anyone from Africa (or anywhere in what is today considered the developing world) could possibly have created and constructed the Giza pyramids or other ancient masterpieces. Instead, they credit ancient astronauts, extraterestrials or time travellers as the real builders. The direct link to a video on this subject by the BBC can be found here: http://www.bbc.co.uk/history/ancient/egyptians/pyramidology_01.shtml

Great Zimbabwe in Africa - 1100-1500 CE

The Great Zimbabwe National Monument is a UNESCO heritage site.

The ruins of Great Zimbabwe – the capital of the Queen of Sheba, according to an age-old legend – are a unique testimony to the Bantu civilization of the Shona between the 11th and 15th centuries. The city, which covers an area of nearly 80 ha, was an important trading centre and was renowned from the Middle Ages onwards.

http://whc.unesco.org/en/list/364

Here is a good article by the well respected Guardian newspaper from 2016 exploring the engineering of this African city and the changing attitudes around who might have built it.

https://www.theguardian.com/cities/2016/aug/18/great-zimbabwe-medieval-lost-city-racism-ruins-plundering

Designated a Unesco World Heritage Site in 1986, the preservation of Great Zimbabwe – led by the National Museums and Monuments of Zimbabwe organisation – is now challenged by uncontrolled growth of vegetation, which threatens the stability of its dry stone walls. The spread of *lantana*, an invasive flowering shrub introduced to Zimbabwe in the early 20th century, has put added of strain on the preservation work.

The Historic Town of Gedi , Kenya, Africa - 1500 CE

It is on the tentative list to be a UNESCO heritage site. http://whc.unesco.org/en/tentativelists/5501/

Description

Gedi lies on the coastal region of Kenya, 94 km north of Mombasa town, another historic town. Gedi was a small town built entirely from rocks and stones, which was inhabited by Swahili people of East Africa. This historic town date back from the 15th century, and through careful preservation most of the original foundations can still be seen today. In 1927, the Gedi historic town, which occupy an area of 44 hectares of land, were declared a historic monument and much excavation and preservation work carried out such that large areas of this ancient town are now revealed, including the pillar tombs, the palace and a great mosque.

The historic town of Gedi occupied a very large area and had two walls around it. The inner wall was where the rich lived. The outer wall enclosed 18 hectares which also included farm and plantation land with quite a number of mud and wattle houses for the middle class. Outside the walls is where the peasants lived.

There is a dated coral tomb with beautiful Arabic script engraved with the date 1399. From the dated tomb, one can see the Great Mosque. A spectacular 50m deep well, known as the "Well of the Great Mosque" which must have been used for ablutions is still discernible. On the other side of the mosque stands the Octagonal pillar tomb of the Imam or priest. Further into the forest, one can see the 15th century palace where the king held court and addressed women with marital problems. Chambers which had no windows or doors are believed to have been used by the noblemen to store their gold and jewels. The only way to gain entrance was through a secret door from the roof.

Over the historic town, the shallow coral rag soil has grown a lowland semi-deciduous forest, maintained by a rainfall of around 1,100 mm/year. The 44 hectares site, surrounded by farmland, is entirely fenced, and contains around 35 hectares of coastal forest, traversed by narrow paths that wind between the excavated buildings. At least 50 indigenous tree species occur, including *Gyrocarpus americanus* and *Sterculia appendiculata*.

It is not quite clear why the town was eventually deserted. Several theories have been put across:

1. One of the theories is that it was overcome by an army from Mombasa on its way to attack Malindi around 1530 AD.

2. Another theory suggests that the Galla people who were raiding southwards around 1600 AD made life unbearable.

3. It is also theorized that lack of water (drying of the wells) except the one which was outside the walls contributed to its abandonment.

Whatever theory is true, one thing is clear, the nobles did not flee; they had time to empty their gold and precious stones in their secret vaults since none of this type of wealth has ever been found.

Meroe in Sudan - 750 BCE to 350 CE

https://www.ancient.eu/Meroe/

Meroe was a wealthy metropolis of the ancient kingdom of Kush in what is today the Republic of Sudan. It was the latter day capital of the Kingdom of Kush (c. 1069 BCE-c.350 CE) after the earlier captial of Napata was sacked in c. 590 BCE. Prior to that date, Meroe had been an important administrative centre south of Napata. The city was located at the crossroads of major trade routes and flourished from c. 750 BCE to 350 CE.

Here is a link to a BBC video about the pyramids in Meroe

http://www.bbc.com/news/av/world-africa-38994176/the-forgotten-pyramids-of-sudan

More than 200km (124 miles) from the Sudanese capital, Khartoum, the remains of an ancient city stand in the desert.

The Nubian pyramids in Meroe are smaller than the more famous ones in Egypt but there are many more of them.

Pyramids and the Sphinx - Giza in Egypt - 2500 BCE

If you want to learn more about pyramids in general, please visit this link https://www.ancient.eu/pyramid/

The three great pyramids of Giza in Egypt were one of the Seven Wonders of the Ancient World https://www.ancient.eu/giza/

The Great Pyramid of Khufu (also known as the pyramid of Cheops, the king's name in Greek) is the last remaining of the ancient Seven Wonders of the World and rises to a height of 481 feet (147 metres). The pyramid of Khafre is 471 feet tall(144 metres) and that of Menkaure rises to 213 feet (65 metres). The Great Sphinx sits on the eastern side of the plateau apart from the pyramids but it is thought it once was an important part of the pyramid complex which covered the area. The head of the Sphinx is believed by Egyptologists to be that of the king Khafre though others contend that represents Khufu. Further on, the great solar barge of Khufu, which is the oldest intact ship extant, was found buried in a pit near the Great Pyramid in 1954 CE. Dating from 2500 BCE, the ship is 143 feet (43 metres) long and 19 feet (5.9 metres) wide. Near the Pyramid complex there are a number of smaller structures known as the Queens Pyramids. It is uncertain who was buried beneath these pyramids but evidence suggests they were the tombs of Hetepheres I (Khufu's mother), Meretites (Khufu's wife) and a later queen named Henutsen.

BBC

Here is a link to a video by the BBC on what we know about the building of this great pyramid by leading structural engineer and designer Cecil Balmond. The BBC goes beyond the well known histories of three celebrated monuments: Stonehenge, the Taj Mahal and the Great Pyramid, to reveal the hidden geometry at their cores. At each iconic structure he examines a fundamental form: at Stonehenge – the circle: the Taj Mahal – the square and the Great Pyramid – the triangle.

Through the abstraction of these forms Cecil reveals the secrets that lie within their iconic design and discovers what these basic shapes can tell us about the sacred and religious, the spiritual and transcendent intentions of the buildings' architects. On a global journey across structure and shape, Cecil also explores how these simple forms influence our lives. From the earliest of times to our present culture, they have shaped our thinking in science, mathematics and design.

http://www.bbc.co.uk/programmes/p00jy6cj

Here is a link to a BBC video about a void discovered in 2017. A hidden void has been uncovered under the Great Pyramid in Giza. Using a new technique using muons which are a by-product of cosmic rays from the Universe. Explorers have visualized what they think could be a large void at least 30 metres long above the Great Gallery in the 4500 year old Pharaoh Khufu's Pyramid.

https://www.bbc.co.uk/programmes/w3csvrgq

Taj Mahal in India - 1634 CE

The Taj Mahal, Agra, India. Built in 1634 CE by Shah Jahan as a mausoleum for his favourite wife Mumtaz Mahall.

https://www.ancient.eu/image/3837/

BBC documentary about the Taj Mahal

Leading structural engineer and designer Cecil Balmond goes beyond the well known histories of three celebrated monuments: Stonehenge, the Taj Mahal and the Great Pyramid, to reveal the hidden geometry at their cores.

http://www.bbc.co.uk/programmes/p00jszvb

Stonehenge in England - 2500 BCE

Stonehenge

http://www.english-heritage.org.uk/visit/places/stonehenge/

EARTHWORK ENCLOSURE

The first major construction at Stonehenge was a circular ditch, with an internal bank and a smaller external bank, built about 3000 BC. Today the ditch and inner bank are visible as low earthworks in the grass, but the outer bank has largely been ploughed away. The ditch on the eastern side is deeper because this half was excavated in the 1920s.[1]

There were two original entrances to the enclosure – a wide one to the north-east and a smaller one on the southern side. There are many more causeways and gaps in the circuit today, mostly the result of later tracks which once crossed the monument.

Set just inside the bank were 56 pits, known as the Aubrey Holes.[2] About half of these have been excavated, and were marked in the 1920s with white concrete circles.

SARSEN TRILITHONS AND CIRCLE

The stones of the central cluster, brought to the site about 2500 BC, are of two types – the larger sarsens and the smaller bluestones. The sarsens were erected in two concentric arrangements.

The inner one is horseshoe of five trilithons (two vertical stones capped by a horizontal lintel). Of these, three complete trilithons still stand (one fell in 1797 and was re-erected in 1958), and two are partly fallen. Near the centre is the Altar Stone, which is mostly buried beneath the fallen stone of the tallest trilithon.

Around the horseshoe are the remains of the outer sarsen circle, capped with lintels. There were probably once 30 stones in this circle, but many have fallen and most of the lintels and a few uprights are missing from the site.

Documentary by a BBC engineer

From the BBC, here is a link to a video documentary by leading structural engineer and designer Cecil Balmond, He goes beyond the well known histories of three celebrated monuments: Stonehenge, the Taj Mahal and the Great Pyramid, to reveal the hidden geometry at their cores.

At each iconic structure he examines a fundamental form: at Stonehenge – the circle: the Taj Mahal – the square and the Great Pyramid – the triangle.Through the abstraction of these forms Cecil reveals the secrets that lie within their iconic design and discovers what these basic shapes can tell us about the sacred and religious, the spiritual and transcendent intentions of the buildings' architects. On a global journey across structure and shape, Cecil also explores how these simple forms influence our lives.

http://www.bbc.co.uk/programmes/p00jnf0j

Great Wall of China - 700 BCE to 1600 CE

The Great Wall of China (??) is an impressive engineering feat. It runs for more than 8000 kilometres from east to west from Mount Hu near Dandong, in Liaoning province, to Jiayu Pass west of Jiuquan in the northwester Gansu province. It is a series of fortification made of stone, brick, tamped earth, wood and other material.

https://www.britannica.com/topic/Great-Wall-of-China

The Great Wall of China at Jinshanling taken in June 2013 by Severin Stalder CC-BY 3.0 https://commons.wikimedia.org/wiki/File:The_Great_Wall_of_China_at_Jinshanling-edit.jpg

It was built to protect the Chinese states and empires against the raids and invasions of the various nomadic groups of the Eurasian Steppe. Several walls were being built as early as the 7th century BCE, these were later joined together and made bigger and stronger, are collectively referred to as the Great Wall.

Especially famous is the wall built in 220–206 BC by Qin Shi Huang, the first Emperor of China. Little of that wall remains. The Great Wall has been rebuilt, maintained, and enhanced over various dynasties; the majority of the existing wall is from the Ming Dynasty (1368–1644 CE)

https://en.wikipedia.org/wiki/Great_Wall_of_China

It is one of the largest building-construction projects ever undertaken. The Great Wall actually consists of numerous walls—many of them parallel to each other—built over some two millennia across northern China and southern Mongolia. The most extensive and best-preserved version of the wall dates from the Ming Dynasty (1368-1644). This wall often traces the crests of hills and mountains as it snakes across the Chinese countryside. About one-fourth of its length consists solely of natural barriers such as rivers and mountain ridges. Nearly all of the rest (about 70 percent of the total length) is actual constructed wall, with the small remaining stretches being ditches or moats. Although lengthy sections of the wall are now in ruins or have disappeared completely, it is still one of the more remarkable structures on Earth.

Chapter 3 Engineering Disasters

https://en.wikipedia.org/wiki/Engineering_disasters

Shortcuts in engineering design can lead to **engineering disasters**. Engineering is the science and technology used to meet the needs and demands of society.[1] These demands include buildings, aircraft, vessels, and computer software. In order to meet society's demands, the creation of newer technology and infrastructure must be met efficiently and cost-effectively. To accomplish this, managers and engineers have to have a mutual approach to the specified demand at hand. This can lead to shortcuts in engineering design to reduce costs of construction and fabrication. Occasionally, these shortcuts can lead to unexpected design failures.

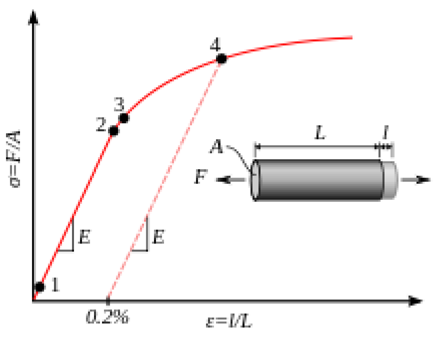
Importance of safety

In the field of engineering, the importance of safety is emphasized. Learning from past engineering failures and infamous disasters such as the Challenger explosion brings the sense of reality to what can happen when appropriate safety precautions are not taken. Safety tests such as tensile testing, finite element analysis (FEA), and failure theories help provide information to design engineers about what maximum forces and stresses can be applied to a certain region of a design. These precautionary measures help prevent failures due to overloading and deformation.[2]

Background of failure

Failure occurs when a structure or device has been used past the limits of design that inhibits proper function.[3] If a structure is designed to only support a certain amount of stress, strain, or loading and the user applies greater amounts, the structure will begin to deform and eventually fail. Several factors contribute to failure including a flawed design, improper use, financial costs, and miscommunication.

Failure due to static loading



Stress–strain curve showing typical yield behavior for ductile metals. Stress (σ) is shown as a function of strain (ϵ). Stress and strain are correlated through Young's Modulus: $\sigma=E\epsilon$ where E is the slope of the linear section of the plot.

Static loading is when a force is applied slowly to an object or structure. Static load tests such as tensile testing, bending tests, and torsion tests help determine the maximum loads that a design can withstand without permanent deformation or failure. Tensile testing is common when calculating a stress-strain curve which can determine the yield strength and ultimate strength of a specific test specimen.

The specimen is stretched slowly in tension until it breaks, while the load and the distance across the gage length are continuously monitored. A sample subjected to a tensile test can typically withstand stresses higher than its yield stress without breaking. At a certain point, however, the sample will break into two pieces. This happens because the microscopic cracks that resulted from yielding will spread to large scales. The stress at the point of complete breakage is called a material's ultimate tensile strength.[4] The result is a stress-strain curve of the material's behavior under static loading. Through this tensile testing, the yield strength is found at the point where the material begins to yield more readily to the applied stress, and its rate of deformation increases.[5]

Failure due to fatigue

When a material undergoes permanent deformation from exposure to radical temperatures or constant loading, the functionality of the material can become impaired.[6][7] This time–dependent plastic distortion of material is known as creep. Stress and temperature are both major factors of the rate of creep. In order for a design to be considered safe, the deformation due to creep must be much less than the strain at which failure occurs. Once the static loading causes the specimen to surpass this point the specimen will begin permanent, or plastic, deformation.[7]

In mechanical design, most failures are due to time-varying, or dynamic, loads that are applied to a system. This phenomenon is known as fatigue failure. Fatigue is known as the weakness in a material due to variations of stress that are repeatedly applied to said material.[8] For example, when stretching a rubber band to a certain length without breaking it (i.e. not surpassing the yield stress of the rubber band) the rubber band will return to its original form after release; however, repeatedly stretching the rubber band with the same amount of force thousands of times would create micro-cracks in the band which would lead to the rubber band being snapped. The same principle is applied to mechanical materials such as metals.[5]

Fatigue failure always begins at a crack that may form over time or due to the manufacturing process used. The three stages of fatigue failure are:

- 1.) Crack initiation- when repeated stress creates a fracture in the material being used
- 2.) Crack propagation- when the initiated crack develops in the material to a larger scale due to tensile stress.
- 3.) Sudden fracture failure- caused by unstable crack growth to the point where the material will fail

Note that fatigue does not imply that the strength of the material is lessened after failure. This notion was originally referred to a material becoming "tired" after cyclic loading.[5]

Failure due to miscommunication

Engineering is a precise discipline and in order to be precise, communication among project developers is pertinent for a successful product. There are several forms of miscommunication that can lead to a flawed design in a system. There are various fields of engineering that have to intercommunicate when working toward a mutual goal. These fields include civil, electrical, mechanical, industrial, chemical, biological, and environmental engineering. When creating a modern automobile, electrical engineers, mechanical engineers, and environmental engineers are required to work together to produce a fuel-efficient, durable product for consumers. If engineers do not adequately communicate among one another, a potential design could have flaws and be unsafe for consumer purchase. **Engineering disasters** can be a result of such miscommunication. Such disasters include the 2005 levee failures in Greater New Orleans, Louisiana during Hurricane Katrina, the Space Shuttle Columbia disaster, and the Hyatt Regency walkway collapse.[9][10][11]

Failure due to software

Software has played a role in many high-profile disasters.

- Ariane 5 Flight 501
- Mars probe
- Denver International Airport – Automated baggage system
- TAURUS — UK share settlement system and dematerialised central share depository.
- Therac-25 — A radiation therapy machine responsible for six overdoses due to faulty software.
- Airbus A320 —[*citation needed*] The Airbus A320, while was controversial in software engineering circles, being the first civilian Fly-by-wire aircraft. In the Airbus flight control systems, the computer has the final say on all decisions, meaning the safety of passengers depends upon the accuracy of the software specification, and the competence of the engineering teams producing the (multiple, independent) software stacks. The Strasbourg A320 crash of Jan 21, 1992is partially related to software in that poor user interface design was a contributing factor.
- Failure at Dharan — Patriot Missile clock issue.

Infamous disasters in engineering

Engineering products and inventions are utilized everyday including computers, microwaves, and elevators. A broken microwave can have limited consequences; however, when larger projects such as infrastructures and airplanes fail, multiple people can be affected which leads to an **engineering disaster**. A disaster is defined as a calamity that results in significant damage which may include the loss of life.[12] Large-scale engineering disasters are recorded in the history books. Just like any other mistake, these disasters become reminders and guidelines of how to improve and not repeat the same mistakes. In-depth observations and post-disaster analysis have been documented to a large extent to help prevent similar disasters from occurri

Infrastructure Disaster - Tay Bridge Disaster 1879

https://en.wikipedia.org/wiki/Tay_Bridge_disaster

The **Tay Bridge disaster** occurred during a violent storm on Sunday 28 December 1879 when the first Tay Rail Bridge collapsed while a train was passing over it from Wormit to Dundee, killing all aboard. The bridge—designed by Sir Thomas Bouch—used lattice girders supported by iron piers, with cast iron columns and wrought iron cross-bracing. The piers were narrower and their cross-bracing was less extensive and robust than on previous similar designs by Bouch.

By Unknown – Image d'une revue scannée par Poudou99, Public Domain, https://commons.wikimedia.org/w/index.php?curid=32400825

Bouch had sought expert advice on "wind loading" when designing a proposed rail bridge over the Firth of Forth; as a result of that advice he had made no explicit allowance for wind loading in the design of the Tay Bridge. There were other flaws in detailed design, in maintenance, and in quality control of castings, all of which were, at least in part, Bouch's responsibility.

Bouch died within the year, with his reputation as an engineer ruined. Future British bridge designs had to allow for wind loadings of up to 56 pounds per square foot (2.7 kPa). Bouch's design for the Forth Bridge was not used.

The bridge

A photograph of the Original Tay Bridge from the north
Taken in 1878 or 1879

Construction began in 1871 of a bridge to be supported by brick piers resting on bedrock. Trial borings had shown the bedrock to lie at no great depth under the river. At either end of the bridge, the bridge girders were deck trusses, the tops of which were level with the pier tops, with the single track railway running on top. However, in the centre section of the bridge (the “high girders”) the bridge girders ran as through trusses above the pier tops (with the railway inside them) in order to give the required clearance to allow passage of sailing ships to Perth.[1]

The bedrock actually lay much deeper than the trial borings had shown, and Bouch had to redesign the bridge, with fewer piers and correspondingly longer span girders. The pier foundations were now constructed by sinking brick-lined wrought-iron caissons onto the riverbed, and filling these with concrete. To reduce the weight these had to support, Bouch used open-lattice iron skeleton piers: each pier had multiple cast-iron columns taking the weight of the bridging girders. Wrought iron horizontal braces and diagonal tiebars linked the columns in each pier to provide rigidity and stability. The basic concept was well known, but for the Tay Bridge, the pier dimensions were constrained by the caisson. For the higher portion of the bridge, there were 13 girder spans. In order to accommodate thermal expansion, at only 3 of their 14 piers was there a fixed connection from the pier to the girders. There were therefore 3 divisions of linked high girder spans, the spans in each division being structurally connected to each other, but not to neighbouring spans in other divisions.[2] The southern and central divisions were nearly level, but the northern division descended towards Dundee at gradients of up to 1 in 73.[3]

The bridge was built by Hopkin Gilkes and Company, a Middlesbrough company which had worked previously with Bouch on iron viaducts. Gilkes, having first intended to produce all ironwork on Teesside, used a foundry at Wormit to produce the cast-iron components, and to carry out limited post-casting machining. Gilkes were in some financial difficulty; they ceased trading in 1880, but had begun liquidation in May 1879, before the disaster.[4] Bouch’s brother had been a director of Gilkes,[note 1] and on his death in January 1876, Bouch had inherited Gilkes shares valued at £35,000 but also owed for a guarantee of £100,000 of Gilkes borrowings and been unable to extricate himself.[5]

The change in design increased cost and necessitated delay, intensified after two of the high girders fell when being lifted into place in February 1877. The first engine crossed the bridge in September, 1877. A Board of Trade inspection was conducted over three days of good weather in February 1878; the bridge was passed for use by passenger traffic, subject to a 25 mph speed limit. The inspection report noted:

> When again visiting the spot I should wish, if possible, to have an opportunity of observing the effects of high wind when a train of carriages is running over the bridge.[6]

The bridge was opened for passenger services on 1 June 1878. Bouch was knighted in June 1879 soon after Queen Victoria had used the bridge.

Infrastructure Disaster - Tacoma Narrows Bridge 1940

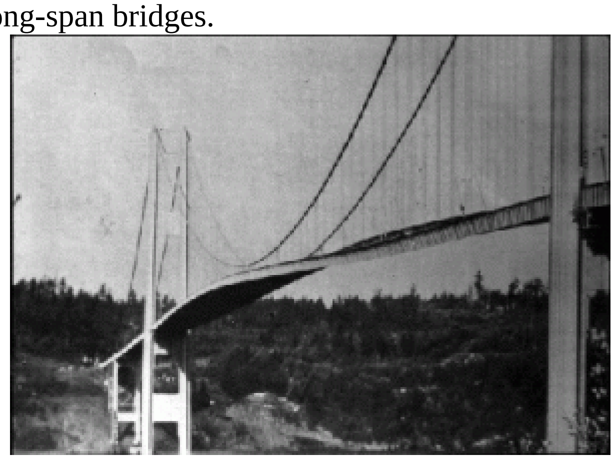
https://en.wikipedia.org/wiki/Tacoma_Narrows_Bridge_(1940)

The **1940 Tacoma Narrows Bridge**, the first Tacoma Narrows Bridge, was a suspension bridge in the U.S. state of Washington that spanned the Tacoma Narrows strait of Puget Sound between Tacoma and the Kitsap Peninsula. It opened to traffic on July 1, 1940, and dramatically collapsed into Puget Sound on November 7 of the same year. At the time of its construction (and its destruction), the bridge was the third-longest suspension bridge in the world in terms of main span length, behind the Golden Gate Bridge and the George Washington Bridge.

Construction on the bridge began in September 1938. From the time the deck was built, it began to move vertically in windy conditions, which led to construction workers giving the bridge the nickname **Galloping Gertie**. The motion was observed even when the bridge opened to the public. Several measures aimed at stopping the motion were ineffective, and the bridge's main span finally collapsed under 40-mile-per-hour (64 km/h) wind conditions the morning of November 7, 1940.

Following the collapse, the United States' involvement in World War II delayed plans to replace the bridge. The portions of the bridge still standing after the collapse, including the towers and cables, were dismantled and sold as scrap metal. Nearly 10 years after the collapse, a new Tacoma Narrows Bridge opened in the same location, using the original bridge's tower pedestals and cable anchorages. The portion of the bridge that fell into the water now serves as an artificial reef.

The bridge's collapse had a lasting effect on science and engineering. In many physics textbooks, the event is presented as an example of elementary forced resonance; the bridge collapsed because high speed winds produced aeroelastic flutter that matched the bridge's natural frequency.[1] The collapse boosted research into bridge aerodynamics-aeroelastics, which has influenced the designs of all later long-span bridges.



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Infrastructure Disaster - Hyatt Regency Hotel 1981

https://en.wikipedia.org/wiki/Hyatt_Regency_walkway_collapse

On the night of July 17, 1981, in Kansas City, Missouri, United States, two suspended walkways of the Hyatt Regency Hotel collapsed, killing 114 people and injuring 200 more. During this calamity, the hotel was hosting a dance competition. There were numerous competition attendants and observers standing and dancing on the suspended walkways when connections supporting the ceiling rods that hoisted both the second and fourth floor walkways across the atrium failed and collapsed onto the crowded first floor atrium below.[13]

During investigation after the walkway collapse, architectural engineer Wayne G. Lischka noticed a substantial alteration of the original design. The fabricator constructed a double-rod support system rather than the originally designed single-rod system without approval of the engineering design team. In doing so, the created support beams doubled the loading on the connector which resulted in the failure of the walkway. It was documented that even the single-rod system would have barely supported the expected load and would not have met Kansas City Building Code standards.[13]

The final analysis of the damage had several conclusions reported including:

- The maximum load capacity of the fourth floor walkway was only 53% the maximum load capacity of Kansas City Building Code standards
- The fabrication alterations from the original design doubled the load that was received by the fourth floor walkway
- The deformation and distortion of the fourth floor hanger rods support the notion that the collapse began at that point
- No evidence that the quality of construction or material selection played a role in the walkway collapse.[9]

By Dr. Lee Lowery, Jr., P.E.
Public Domain, https://commons.wikimedia.org/w/index.php?curid=6370077

Aeronautical Disaster - Space Shuttle Challenger 1986

The American Society of Civil Engineers (ASCE) Published this ethics case study at YouTube on November 18, 2015

If you want to learn more about the ASCE you can access this award winning video "ASCE The Voice of the Civil Engineering Profession

< https://www.youtube.com/watch?v=iI8ZoFgrrHY >

In the video shown below, Allan J. McDonald, former director of the Space Shuttle Solid Rocket Motor Project for Morton Thiokol, discusses the events surrounding the destruction of the Space Shuttle Challenger

< https://www.youtube.com/watch?v=QbtY_Wl-hYI >

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.bccampus.ca/engineeringinsociety/?p=49

For more background on this disaster, you can access the following links:

https://en.wikipedia.org/wiki/Space_Shuttle_Challenger_disaster

Shuttle Challenger Explosion photograph from NASA http://grin.hq.nasa.gov/ABSTRACTS/GPN-2004-00012.html Public Domain, https://commons.wikimedia.org/w/index.php?curid=530754

On January 28, 1986, the Space Shuttle Challenger and her seven-member crew were lost when a ruptured O-ring in the right Solid Rocket Booster caused an explosion soon after launch. This photograph, taken a few seconds after the accident, shows the Space Shuttle Main Engines and Solid Rocket Booster exhaust plumes entwined around a ball of gas from the External Tank. Because shuttle launches had become almost routine after twenty-four successful missions, those watching the shuttle launch in person and on television found the sight of the explosion especially shocking and difficult to believe until NASA confirmed the accident.

Space Shuttle orbiter *Challenger* (OV-099) (mission STS-51-L) broke apart 73 seconds into its flight, leading to the deaths of its seven crew members.

Aeronautical Disaster - Space Shuttle Columbia 2003

https://en.wikipedia.org/wiki/Space_Shuttle_Columbia_disaster

The Space Shuttle Columbia disaster occurred on February 1, 2003, while reentering Earth's atmosphere over Louisianaand Texas. The shuttle unexpectedly disintegrated, resulting in the death of all seven astronauts on board. The cause was later discovered to be damage to thermal shielding tiles from impact with a falling piece of foam insulation of an external tank during launch. It was the seventh known instance of this particular piece breaking free during launch.[14] As the shuttle re-entered Earth's atmosphere at a speed of Mach 23 (23 times faster than the speed of sound), the wing experienced temperatures of 2,800 °F (1,540 °C). The damage from the insulation strike experienced during launch proved fatal as the shuttle disintegrated during the mission return.[11] NASA's investigation team found melted aluminum on the thermal tiles and inside edges of the left wing of the spacecraft, supporting the notion that the Columbia's destruction was due to hot gases that penetrated the damaged spot on the wing.[15]

Roger L.M. Dunbar of New York University and Raghu Garud of Pennsylvania State University procured a case description of what missteps NASA had taken that led to the Columbia spacecraft catastrophe. Mission control deemed that foam shedding was a not a safety factor prior to launch, believed damage of the shuttle panels were not a significant issue which in-turn delayed analysis on damages as of January 17, 2003, and denied mission action request between January 18 and 19. It was not until January 24, 2003, that mission control had classified the damage as a problematic issue. These missteps in communication between mission control and the debris assessment team inhibited a proper examination of the damages to the spacecraft.[11]

Photo: Columbia lifting off on its final mission.

The light-colored triangle visible at the base of the strut near the nose of the orbiter is the left bipod foam ramp

Nautical Disaster - Steamboat Sultana 1865

https://en.wikipedia.org/wiki/Engineering_disasters#Steamboat_Sultana_(1865)

https://en.wikipedia.org/wiki/Sultana_(steamboat)

On the night of April 26, 1865, the passenger steamboat Sultana exploded on the Mississippi River seven miles north of Memphis, Tennessee. This maritime disaster is categorized as the worst in United States history. The explosion resulted in the loss of 1,547 lives, surpassing the total number of deaths caused by the sinking of the *Titanic*. The Sultana was overcrowded due to a soldier prisoner exchange towards the end of the United States Civil War. The overcrowding contributed significantly to the high death toll. Another reason for the high number of deaths is that the steamer was made mostly of wood, which was documented to have been completely engulfed in flames approximately seven minutes after the explosion. The explosion happened around midnight which was when the Mississippi River was at flood stage. It was documented that the single metal lifeboat on board the Sultana was thrown from the upperdeck landing on several people swimming from the steamer resulting in further deaths.[16]

The disaster was believed to be the result of a repaired boiler explosion that led to the explosion of two of the three other boilers. The boiler had been previously found to have had a leak and was improperly repaired by boilermaker R.G. Taylor due to orders from Captain J. Cass Mason because of time constraints in Vicksburg, Mississippi. While chief engineer Nathan Wintringer approved the repaired boiler, Taylor stated that the boiler could not be considered safe since the boiler appeared to be burned from being worked on with too little water.[16] Traveling along the Mississippi River, the boiler exploded causing fire to spread throughout the steamer. The fire on board led to the collapse of both of the Sultana's smokestacks, killing many passengers.[17]

Photo: Whole plate tintype, which appears to be a period enlargement made from a carte de visite of the Sultana taken at Helena, AR, on April 26, 1865, a day before she was destroyed. The view captures a large crowd of paroled Union prisoners packed tightly together on the steamboat's decks. The original image is credited to Thomas W. Bankes, Helena, AR

Source: Cowan's Auction.

Nautical Disaster - Liberty Ships in World War II 1940

https://en.wikipedia.org/wiki/Engineering_disasters#Liberty_ships_in_WWII

https://en.wikipedia.org/wiki/Liberty_ship

Early Liberty ships suffered hull and deck cracks, and a few were lost to such structural defects. During World War II, there were nearly 1,500 instances of significant brittle fractures. Three of the 2,710 Liberties built broke in half without warning. In cold temperatures the steel hulls cracked, resulting in later ships being constructed using more suitable steel.

SS John W. Brown is one of only two surviving operational Liberty ships.
Photograph taken in 2000
Source is Projet Liberty Ship
http://www.liberty-ship.com/

Infrastructure Disaster - Quebec Bridge 1907

https://en.wikipedia.org/wiki/Quebec_Bridge#Collapse_of_August_29.2C_1907

First design and collapse of August 29, 1907

Wreckage of the 1907 collapse

The Quebec Bridge was included in the National Transcontinental Railway project, undertaken by the federal government. The Quebec Bridge Company was first incorporated by Act of Parliament under the government of Sir John A. Macdonald in 1887,[2] later revived in 1891,[3] once again revived for good in 1897 by the government of Wilfrid Laurier,[4] who granted them an extension of time in 1900.[5] In 1903, the bond issue was increased to $6,000,000 and power to grant preference shares was authorised, along with a name change to the Quebec Bridge and Railway Company (QBRC).[6] An Act of Parliament the same year was necessary to guarantee the bonds by the public purse.[7] Laurier was MP for Quebec Eastriding, while the president of the QBRC, Simon-Napoleon Parent, simultaneously was Premier of Quebec from 1900 to 1905, and was Quebec City's mayor from 1894 to 1906.[*citation needed*]

Edward A. Hoare was selected as Chief Engineer for the Company throughout this time,[8] while Collingwood Schreiber was the Chief Engineer of the Department of Railways and Canals in Ottawa.[9] Hoare had never worked on a cantilever bridge structure longer than 300 ft.[8][10] Schreiber was assisted until July 9, 1903 by Department bridge engineer R.C. Douglas, at which time Douglas was deposed for his opposition to the calculations that were submitted by the contractors.[11] Schreiber subsequently requested the support of another qualified bridge engineer, but was effectively overruled by the Cabinet on August 15, 1903. Thereafter, QBRC consulting engineer Theodore Cooper was completely in charge of the works,[12] and on July 1, 1905,[9] Schreiber was demoted and replaced as deputy minister and chief engineer by MJ Butler.[9][13]

By 1904, the southern half of the structure was taking shape. However, preliminary calculations made early in the planning stages were never properly checked when the design was finalized, and the actual weight of the bridge was far in excess of its carrying capacity. The dead load was too heavy. All went well until the bridge was nearing completion in the summer of 1907, when the QBRC site engineering team under Norman McLure began noticing increasing distortions of key structural members already in place.[*citation needed*]

McLure became increasingly concerned and wrote repeatedly to QBRC consulting engineer Theodore Cooper, who at first replied that the problems were minor. The Phoenix Bridge Company officials claimed that the beams must already have been bent before they were installed, but by August 27 it had become clear to McLure that this was wrong. A more experienced engineer might have telegraphed Cooper, but McLure wrote him a letter, and then went to New York to meet with him on August 29, 1907. Cooper then agreed that the issue was serious, and promptly telegraphed to the Phoenix Bridge Company: "Add no more load to bridge till after due consideration of facts." The two engineers then went to the Phoenix offices.[*citation needed*]

However, the message had not been passed on to Quebec before it was too late. Near quitting time that same afternoon, after four years of construction, the south arm and part of the central section of the bridge collapsed into the St. Lawrence River in just 15 seconds. Of the 86 workers on the bridge that day, 75 were killed and the rest were injured,[14] making it the world's worst bridge construction disaster. Of these victims, 33 (some sources say 35) were Mohawk steelworkers from the Kahnawake reserve near Montreal; they were buried at Kahnawake under crosses made of steel beams.[15]

On August 30, 1907, a Royal Commission of inquiry into the disaster was provisionally appointed by the Deputy Minister in charge of the Department of Railways and Canals (Butler), with the concurrence of the Minister. The Royal Commission, which was granted by Edward VII by advice of his Governor General, Albert Grey, on August 31, 1907, consisted of three members, who were all engineers of good standing: Mr. Henry Holgate, of Montreal, Mr. JGG Kerry, of Campbellford, Ontario also an instructor at McGill University, and Professor John Galbraith, then dean of the Faculty of Applied Science and Engineering at the University of Toronto. The Commission document conferred upon the commissioners full powers to summon witnesses and documents, and to express "any opinion they may see to express thereon". The Commissioners presented their Report in full on February 20, 1908, issued 15 conclusions, and included the hindsight work of consulting bridge engineer C.C. Schneider, of Philadelphia (a fulfillment of the 1903 request of Schreiber, supra).[16]

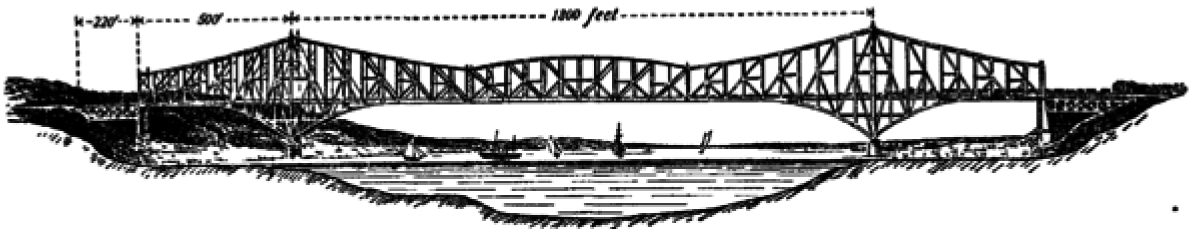
The Commissioners found responsibility for the failure to lie at the feet of two men, consulting engineer Theodore Cooper and Peter L. Szlapka, Chief Designing Engineer for Phoenix Bridge Company:

> (c) The design of the chords that failed was made by Mr. P.L. Szlapka, the designing engineer of the Phoenix Bridge Company
>
> (d) This design was examined and officially approved by Mr. Theodore Cooper, consulting engineer of the Quebec Bridge and Railway Company.
>
> (e) The failure cannot be attributed directly to any cause other than errors in judgment on the part of these two engineers.

Cooper escaped penal sanction.[17] It is presumed that Szlapka escaped as well. The Commissioners also found that:

> (k) The failure on the part of the Quebec Bridge and Railway Company to appoint an experienced bridge engineer to the position of chief engineer was a mistake. This resulted in a loose and inefficient supervision of all parts of the work on the part of the Quebec Bridge and Railway Company.

The abortive construction of the Quebec Bridge spanned the careers of two Ministers of Railways and Canals, and one temporary replacement, who was on the job for five months immediately preceding the disaster. A popular myth is that the iron and steel from the collapsed bridge, which could not be reused for construction, was used to forge the early Iron Rings worn by graduates of Canadian engineering schools starting in 1925.[18]



Drawing of the original design of Quebec Bridge

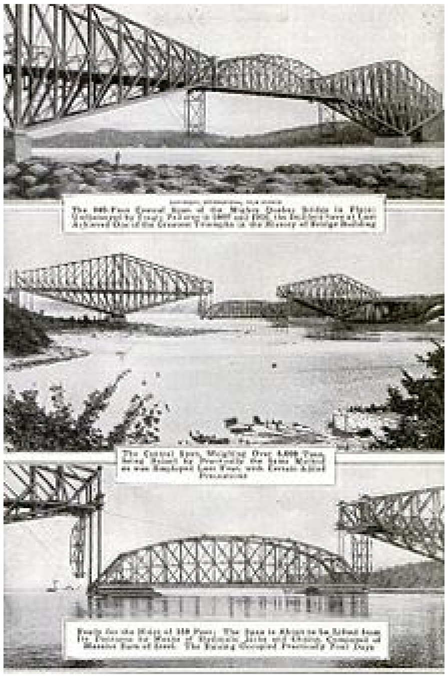
Second design and collapse of September 11, 1916[edit]

September 11, 1916 Quebec Bridge Collapse

After a Royal Commission of Inquiry into the collapse, construction started on a second bridge. Three engineers were appointed: H. E. Vautelet, a former engineer for the Canadian Pacific Railways, Maurice FitzMaurice from Britain, who worked on the construction of the Forth Bridge, and Ralph Modjeski from Chicago. Vautelet was President and Chief Engineer. The new design was again for a bridge with a single long cantilever span, but a much more massive one.

On September 11, 1916, when the central span was being raised into position, it fell into the river, killing 13 workers.[14] The chief engineer was made aware of the problem six weeks before the collapse by the engineer that was responsible for the construction of the centre section, Frants Lichtenberg. Frants Lichtenberg was also working as an inspector for the federal government of Canada at the time.[19][20] Immediately, fears of German sabotage were reported but it was soon clear that another tragic construction accident had befallen the structure (a problem with the hoisting devices). Reconstruction began almost immediately after the accident and special permission granted for the bridge builders to acquire the steel that was in high demand because of the War effort. The fallen central span still lies at the bottom of the river. After the bridge’s completion in 1917, special passes were required for those wanting to cross the structure. Armed soldiers, and later Dominion Police, guarded the structure and checked passes until the end of the War.

Completion[edit]



Lifting the centre span in place was considered to be a major engineering achievement. Photo caption from *Popular Mechanics* magazine, December 1917

Construction was ultimately completed in August 1919, at a total cost of $25 million and 88 bridgeworkers' lives. On December 3, 1919, the Quebec Bridge opened for rail traffic, after almost two decades of construction. Its centre span of 549 metres (1800 ft) remains the longest cantilevered bridge span in the world and is considered a major engineering feat.

Engineering Failures - Florida University Overpass Collapse 2018

March 15 2018

Six people died

Cause: Faulty design where strength was overestimated.

https://en.wikipedia.org/wiki/Florida_International_University_pedestrian_bridge_collapse

Chapter 4 - British Columbia Engineering Failures

1958 - BC Infrastructure Disaster - Ironworkers Memorial Bridge - Vancouver 1958

https://en.wikipedia.org/wiki/Ironworkers_Memorial_Second_Narrows_Crossing

The **Ironworkers Memorial Second Narrows Crossing**, also called the **Ironworkers Memorial Bridge** and **Second Narrows Bridge**, is the second bridge constructed at the Second (east) Narrows of Burrard Inlet in Vancouver, British Columbia, Canada. Originally named the Second Narrows Bridge, it connects Vancouver to the north shore of Burrard Inlet, which includes the District of North Vancouver, the City of North Vancouver, and West Vancouver. It was constructed adjacent to the older Second Narrows Bridge, which is now exclusively a rail bridge. The First Narrows Bridge, better known as Lions Gate Bridge, crosses Burrard Inlet about 8 kilometres west of the Second Narrows.

The bridge is a steel truss cantilever bridge, designed by Swan Wooster Engineering Co. Ltd. Construction began in November 1957, and the bridge was officially opened on August 25, 1960. It cost approximately $15 million to build. Tolls were charged until 1963.

The bridge is 1,292 metres (4,239 ft) long with a centre span of 335 metres (1,099 ft). It is part of the Trans-Canada Highway (Highway 1).

Collapse on June 17, 1958

On June 17, 1958, as a crane stretched from the north side of the new bridge to join the two chords of the unfinished arch, several spans collapsed. Seventy-nine workers plunged 30 metres (100 ft) into the water. Eighteen were killed either instantly or shortly thereafter, possibly drowned by their heavy tool belts. A diver searching for bodies drowned later, bringing the total fatalities for the collapse to 19. In a subsequent Royal Commission inquiry, the bridge collapse was attributed to miscalculation by bridge engineers. A temporary arm, holding the fifth anchor span, was deemed too light to bear the weight.[2]

Renaming

The bridge was renamed the **Ironworkers Memorial Second Narrows Crossing** in 1994 to honour the 19 workers who died in the collapse, along with four others who also died during the construction process.[3]

I attended the official opening of the artwork along the new Convention Centre in Vancouver that honoured people injured or killed in the line of duty. This is a picture of me with one of the survivors of the Bridge Collapse.

One of the survivors of the Ironworker's Bridge Collapse and Jennifer Kirkey. Picture taken in 2009 at the opening of the art work to commemorate injured workers.

In popular culture

Stompin' Tom Connors paid a musical tribute to the fallen ironworkers with the song "The Bridge Came Tumbling Down" on his 1972 album *My Stompin' Grounds*. (This tune also appears on several later compilations one of which was performed by Les Claypool's Duo de Twang). Jimmy Dean's 1962 song "Steel Men" is a ballad about the Second Narrows bridge disaster. Gary Geddes' 2007 book of poetry, entitled *Falsework*, is based on the collapse of the bridge.

Engineering students might find it interesting that on February 2, 2009 several University of British Columbia engineering students were arrested while attempting to suspend the shell of a Volkswagen Beetle under the bridge as part of an "Engineering Week" tradition.

There were many inquiries held after the collapse. The official commission can be accessed at https://search-bcarchives.royalbcmuseum.bc.ca/commission-on-second-narrows-bridge

There is a complete lesson from the BC Labour History Project. It can be accessed https://teachbcdb.bctf.ca/permalink/resource695

WorkSafe BC made a tribute video on the 50th Anniversary in 2009.

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.bccampus.ca/engineeringinsociety/?p=81

1988 Station Square Collapse aka Save-on Foods Collapse aka Cave-in-Foods

The **Station Square collapse**, also known as the **Save-On-Foods collapse or "Cave-in-Foods"**, was a major structural failure of a new supermarket and parking facility in Burnaby, British Columbia, Canada. On April 23, 1988, within minutes of the grand opening of a new Save-On-Foods store, a 6,400 square foot (590 m^2) portion of the roof collapsed sending the rooftop parking deck and 20 automobiles crashing into the produce section below.

There were no fatalities and 21 people were treated in hospital, In the years following the collapse of the roof, recommendations from a commission of inquiry resulted in significant changes to the practice of architecture and engineering throughout British Columbia

The roof top parkade of Save-on-Foods collapsed in Burnaby in 1988

Professional negligence

In 1989 the four engineers from the two engineering firms (Tammy Tacy and Associates, MSS

Engineering (Structural) Ltd.) involved in the collapse were found guilty of incompetence, negligence or professional misconduct by a five-member panel of the professional engineers governing body. The panel noted inadequate design of the roof structure, including the support beams, failure to inspect the construction of the roofs assembly, and failure to direct or check the work on the project of the engineer in training who was directly managing the project. The panel also found that the engineers' code of ethics had been breached by one of the firm's partners signing and applying his professional seal to plans and specifications that he had not prepared or supervised. Also faulted were the engineers for inadequately reviewing the structure before the collapse, including not noticing that lateral supports were missing.

https://en.wikipedia.org/wiki/Station_Square_collapse

Here is a link to the formal Commissioner Inquiry held by the British Columbia Legislature
http://www.llbc.leg.bc.ca/public/pubdocs/bcdocs/43459/commissionerinquirystationsquare.pdf

2012 and 2016 - Engineering Design Problems - Port Mann Bridge Surrey 2012 and 2016 - ice bombs

There was a design failure of the "new" Port Mann bridge when due to ice falling off the cables many cars were damaged.

https://en.wikipedia.org/wiki/Port_Mann_Bridge

2014 - Mt. Polley Tailings Pond Collpase

The **Mount Polley mine disaster** is an environmental disaster in the Cariboo region of central British Columbia, Canada, that began 4 August 2014 with a breach of the Imperial Metals-owned Mount Polley copper and gold mine tailings pond, releasing its water and slurry with years worth of mining waste into Polley Lake. The spill flooded Polley Lake, its outflow Hazeltine Creek, and continued into nearby Quesnel Lake and Cariboo River. By 8 August the four-square-kilometre (1.5 sq mi) sized tailings pond had been emptied of the majority of supernatant (process water) that sits atop the settled solids (mining waste, or 'tailings'). Water tests showed elevated levels of selenium, arsenic and other metals similar to historical tests before the disaster. The cause of the dam break has been investigated with a final report published 31 January 2015. Imperial Metals had a history of operating the pond beyond capacity since at least 2011.

https://en.wikipedia.org/wiki/Mount_Polley_mine_disaster

Disciplinary Actions against BC Engineers and Geoscientists - details

The *Engineers and Geoscientists Act* authorizes Engineers and Geoscientists British Columbia to regulate the practice of professional engineering and professional geoscience in British Columbia. The Provincial Government has given this authority to the association to protect the public.

In order to protect the public, the association investigates complaints against members and licensees for failure to meet their professional and ethical obligations as set out in the *Act*, the association Bylaws, and the Code of Ethics. Further information on members' and licensees' ethical obligations may be found in the Code of Ethics Guidelines.

The BC association of Engineers and Geoscientists maintains a list of disciplinary actions against its members. You can find the details here.

https://www.egbc.ca/Complaints-Discipline/Discipline-Notices

Chapter 5 - Case Studies

Texas A&M University Case Studies Collection

https://ethics.tamu.edu/nsf-report/

THE CASES

The more than 30 cases address a wide range of ethical issues that can arise in engineering practice. There is no easy way to categorize the cases. So they are presented in alphabetical order by case name. There are some broad categories in terms of which many of the cases can be arranged. However, it should be noted that many cases fall into several of these categories; and many cases raise issues for which no special category is listed below. It is best for readers to view the listings below simply as suggestive.

TEACHING ENGINEERING ETHICS: A CASE STUDY APPROACH

Michael S. Pritchard

The Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (EAC/ABET) now requires accredited engineering programs in the United States to make serious efforts to foster in their students "an understanding of the ethical characteristics of the engineering profession and practice."2 In cooperation with the College of Engineering and Applied Sciences, Western Michigan University's Center for the Study of Ethics in Society undertook a three year project to develop case studies that can be used in meeting this EAC/ABET requirement. This project is one of several funded by the National Science Foundation's Ethics and Values in Science program in order to improve ethics education in engineering. What follows is an introduction to the project–its background and rationale, and guidelines for its use.

https://ethics.tamu.edu/case-studies/

NASA and the Kennedy Space Centre Space Shuttle Case Study Collection

https://www.nasa.gov/offices/education/centers/kennedy/technology/scsc.html

Welcome to NASA KSC's newest educational resource – the Shuttle Case Study Collection! In an effort to capture and share knowledge gained from the Space Shuttle Program's 30-year history, the KSC Education Programs and University Research Division has developed the Shuttle Case Study Collection, or SCSC. Designed especially for educators and students to gain behind the scenes access into the Space Shuttle System, the SCSC is a great resource for engineering and pre-engineering curriculum. This collection is designed to provide unique content for educators to incorporate into the classroom and aid in the teaching of good engineering practices and the enhancement of critical thinking, decision making, and problem-solving skills.

Our formally reviewed collection contains cases in a variety of technical areas related to the Space Shuttle System. Our reports are perfect tools for classroom discussion, group activities, and research projects. Supply your students with real world experiences of NASA engineers, contractors, and other industry professionals. Enhance your engineering curriculum by introducing students to the unique decision making processes related to Shuttle maintenance, processing, and launch. Challenge your students to think like official NASA team members. We invite you to browse our collection now!

Engineers without Borders

One of the best places to find case studies is from Engineers Without Borders.

Case studies are the basis of assignments and projects that connect people to Africa. They give students a sense of the issues people are facing in Africa and around the world.

http://my2.ewb.ca/library/collection/41/case-studies/

Appropriate Technology - Fog collection at El Tofo in Chile

You can find the case study from Engineers Without Borders
http://my2.ewb.ca/library/collection/41/case-studies/

Here is a link to the original article used in that case study.
https://www.idrc.ca/en/article/collecting-fog-el-tofo
From the International Development Research Centre of Canada
This article is in the Public Domain as it was posted on a Government of Canada web site.
Stephen Dale

In the early 1990s, the global news media became entranced by a small town in northern Chile that started drinking the fog. Newspaper reporters and television cameras were drawn by the site of the giant mesh collectors that trapped droplets of fog drifting in from the coast. Those droplets — which coalesced as an average of 15,000 litres of water a day — were piped down from the El Tofo mountain for use in the formerly parched community of Chungungo.

The technology worked well and the increased water supply helped to transform the town. In fact, the project served as a prototype and there are now fog catchers or collectors providing water to communities in other areas of the world. But, more than 10 years later, in El Tofo, the nets are in a total state of disrepair. What caused the community of Chungungo to abandon the project that had brought it abundant water and high hopes for the future? And what can be learned from the El Tofo experience? These are questions that people close to the project are now grappling with.

Water and a community transformed

One reason the media reported so frequently on this project, may be because the impact was so direct and easy to see. In 1992, Canada's *Globe and Mail* reported: "Residents in this impoverished coastal region, who for the first time have a steady supply of clean water, call it a miracle." A resident told CNN the same year: "Now I can wash every day. Before I had to watch every drop. You really suffer without water."

By 1995, the *Economist* was still marveling at the sight of a vibrant community where "gardens thrive on land that was once barren. Fisherman whistle and joke as they compare potatoes, peppers, cabbages, and maize." Pure and plentiful water, the *Economist* correspondent wrote, had produced not only vegetable gardens but better health and a new sense of optimism among Chungungo's citizens.

There was hope that this "miracle" could be transplanted. "The new technology — which is cheap to build, easy to maintain, and requires no power — could alleviate water shortages in thousands of rural communities in arid and semi-arid communities around the world," suggested *The Toronto Star*, in a 1993 feature.

Ten years later, a good deal of that promise has been realized. The technology that was perfected at El Tofo — where researchers experimented with different materials and designs — has now either been adopted or is under study in 25 different countries. Recently, for instance, new fog collection projects have become operational in Yemen and central Chile, while other projects are at the evaluation stage in Guatemala, Haiti, and Nepal.

Ironically, though, the prototype project in Chungungo has fallen into disrepair and disuse. By the summer of 2002, only nine of the 94 mesh collectors that once blanketed the mountaintop at El Tofo were still hanging. Cables and meshes had been carted off for use elsewhere, and the operator's house on the site had been dismantled. Most of the town's water supply is now hauled in, at much greater expense, by truck.

Conflicting visions of community development

In a report prepared for the International Development Research Centre (IDRC), Chilean consultant Carolina de la Lastra reported that municipal politicians in La Higuera (the larger jurisdiction of which Chungungo is a part) have begun to lobby for a pipeline that would bring water to the community from the Los Choros river, 20 km away. The officials have taken this approach because they "regard water from fog as an unreliable, irregular, and insufficient source for providing drinking water for Chungungo," she writes. It is nonetheless true that fog catchers continue to function well in other parts of Chile, where they bring water to agricultural and reforestation projects.

IDRC project officer Chris Smart says the community's new desire for piped water may be an indication of a once-common problem where alternative technologies — like solar and wind power — suffer from a lack of local prestige.

Often in developing countries, he explains, "people have certain visions of what it means to be developed, and one of them is that water should be brought to you by the state, and you should never have to think about it." Water that comes from a local source, through a system that has to be maintained by a local committee, may therefore be regarded as second-rate.

The call for piped water

Ironically, this feeling that the community was ready for piped water arose partly because of the Chungungo fog collectors' earlier, stunning success. Although the community, a former mining town, had been steadily losing inhabitants since the mine closed in 1970s, the arrival of fog water led to a tripling of the population. Summer homes and tourist facilities were built nearby. The collectors' success also seemed to breed a new economic and political momentum: Chungungo's new profile and global renown allowed officials to lobby successfully for electricity and telephone service.

Beyond contributing to the community's ambition to move to a higher technological plateau, success also gave rise to practical problems. With 900 inhabitants in the town — rather than 300 — the original number of fog-collectors could not supply as much water to each household as it once had. Even more unsettling, periods without fog meant depleted reservoirs and occasional drought in the community. Fog collectors came to be seen as an unreliable source of water.

The road not taken

Robert Schemenauer — one of the original designers of the Chungungo project and the current-day president of FogQuest, a nongovernmmental organization (NGO) that helps bring fog technology to arid regions — says the simplest solution to the supply problem would have been to expand the grid of fog collectors.

"It's no different from any other kind of water supply system. If the community grows, you have to increase the supply," says Schemenauer, who is now working on a proposal to revive the El Tofo site.

"The most logical response would have been to simply increase the number of fog collectors, and increase the size of the water reservoir. Then you'd have more water, and a larger buffer capacity to get this larger community through the times when there is no fog. There's essentially no limit to the number of fog collectors you can put up there. You can put ten times, twenty times, fifty times what there is now."

Community leaders, however, clearly preferred the idea of a pipe bringing a steady flow of water from Los Choros — even though this project would come with an estimated price tag of one million US dollars.

The question of community involvement

The fact that there was so little long-term commitment to keeping the fog collectors functional, says University of Guelph rural extension professor Jorge Nef, is an indication that not enough preparatory work was done to determine if the community had the right mindset to sustain this type of technology, and how much they were willing to contribute to keep the fog collectors running. [See related sidebar: Taking a Multidisciplinary Approach]

In his report on what went wrong at El Tofo, Nef recounts that "villagers were not involved in any significant way in [the project's] origins and development" and that there was very little study of their underlying attitudes and aspirations. This meant that they were inadequately informed about the economics of water supply and were unprepared to commit to the fog collectors' long-term functioning.

But Schemenauer believes that any deficiencies in preparing the social ground for the arrival of this new technology, arose because of the project's unusual evolution. The original goals of the project, he explains, were to perfect the technology, construct an array of collectors as a pilot project and then to use the water to feed seedlings for a trial reforestation project on the mountain. The project was not initially designed or funded as a water project for a community. It was only after intensive lobbying by the community that funders reluctantly agreed to provide additional support to have the water diverted down the mountainside to the community.

Switching gears midstream

"El Tofo is not a typical situation," he says. "We worked on the top of the mountain for five years before there was any push to put a pipeline down the mountain. Normally, we work with local NGOs that have a long history in the community and put a strong emphasis on the social side." He adds that — even though there was little formal research into the social character of the community — community members were involved in planning through public meetings.

In Nef's estimation, changing the purpose of the project in mid-course also helped create a management structure that was unclear and unstable.

The project began as a collaboration between IDRC, Chile's National Forestry Corporation (CONAF), and Catholic University. Yet when the project's goal became the provision of drinking water, CONAF (which had no jurisdiction over consumable water) shifted its responsibility to the municipality and to various national and regional bureaucracies.

This created something like organizational chaos. With up to eight stakeholders involved at one time, "there was no single authority looking over the whole system," writes Nef. Within an atmosphere of jurisdictional dispute and uncertainty (contributed to, for instance, by events such as the privatization of the state's rural water agency) the local committee charged with running and maintaining the fog collectors was unable to develop the necessary expertise or to function efficiently. The local committee could collect sufficient fees to pay for routine maintenance of the system but not for increased demands made by regional water agencies or for major repairs.

Lessons from El Tofo

Those who have followed the roller-coaster ride of fog collecting at El Tofo draw some clear lessons from the experience.

One is that fog collecting works. Proof of this can be found in the work of a new network of specialists who have taken this technology to arid areas across the globe.

The other lesson is that understanding social conditions and securing the involvement and commitment of local people — a factor apparently given short shift here because of special circumstances — is always vital to the long-term viability of a development project.

"I think the main message," says Smart, "is that the technology may be absolutely wonderful — and in this case the technology works brilliantly — but there's always a social setting, and that's going to demand as much attention as the technical questions."

Taking a Multidisciplinary Approach

For many researchers, the traditional, monodisciplinary approach to science has outlived its usefulness — particularly with respect to research in the developing world.

Increasingly, the approach to research is more fluid: applied, cross-disciplinary, heterogeneous, and non-hierarchical. In practice, this means researchers problem-solve around an issue rather than through a rigid code of practice associated with a specific scientific discipline. It also means they may work in multidisciplinary teams.

"Imagine that you're trying to improve production in a village wood lot," says Tim Dottridge, Director of IDRC's Special Initiatives Division. "In addition to foresters, you might have a social anthropologist and — since men and women have different interests in the wood lot — socio-economic and gender specialists on your team."

IDRC's shift in programing

For the first 25 years of its existence, IDRC conducted its programs along fairly traditional sectoral lines. In fact, by the early 1990s, it had 55 separate sub-programs delivered by seven program divisions and six regional offices — all with separate budgets. By 1995, however, the shift towards a multidisciplinary approach was complete, and the Centre has never looked back.

"A lot of organizations have tried to embrace a cross-cutting approach without changing their internal structures," says Dottridge. "We went further, and truly attempted to transform the organization. Our approach helps ensure that we practice what we preach. We expect Southern researchers to take a multidisciplinary approach, and we're organized in multidisciplinary teams ourselves to assess the proposal properly."

While IDRC has been influenced by international trends in research, its unique experience and circumstances have also been a motivating factor in the shift towards multidisciplinary teams.

The role of evaluation

The first seeds were planted back in 1978 with the creation of an Office of Planning and Evaluation, and the subsequent integration of those functions with the work of the program divisions. By 1986, the accumulated evaluation work, along with analysis of the external context, led to the first policy shift. A strategic review stressed the "connectedness" of the various elements of development, along with the need for greater coherence in programming.

The review reflected the Board of Governors' ongoing concern about the open-ended nature of programming. Still, while IDRC tried to draw up divisional objectives in 1986, programs received budget allocations without the requirement of a multi-year plan or any specific objectives. And in the 1990s, while IDRC was describing its programs in terms of sustainable development — especially after the Earth Summit in Rio in 1992 — program delivery was essentially unchanged. Meanwhile, evaluations could not conclusively demonstrate that disparate projects added up to more than the sum of their parts.

In 1995, the Government of Canada made widespread cuts to its programs, including IDRC's work. In response, the Centre decided to cut staff and concentrate on fewer research areas. It produced a plan for a more focused program that would lead to measurable results — a decision that led to the creation of Program Initiatives (PIs) as the primary vehicles to fund Southern researchers and research institutions.

Program initiatives

Instead of focussing on single disciplines or sectors such as economics, fisheries, or earth sciences to solve problems, PIs first look at the problem, and then consider what knowledge is necessary to solve it. When Southern researchers and research institutions submit funding proposals, for example, PI teams review them to see how closely they fit with the PIs' objectives and priorities. Often, the initial proposal is sketchy and the PI team encourages the applicant to take a more integrated approach. The team also strives to expand the networks to include members of civil society, policy makers, and extension agents who can help define the problem and set the research agenda.

"The government cuts may have been the final push, but IDRC was already moving in the direction of a true multidisciplinary approach," says Dottridge. "What's remarkable about the transition is that we were effectively undertaking three major changes at once. We were downsizing our operations by cutting staff. We were restructuring our operations. And we were reorienting our thinking. Many organizations have made these changes individually. Few have attempted them at the same time.

"It hasn't been an easy transition, and the system is not perfect. There is always room to improve how we assess and manage projects. But we've positioned ourselves to be a model for a way of working. When we insist on a cross-disciplinary approach to research in the field, we're walking the talk."

Stephen Dale is a freelance writer based in Ottawa.

https://en.wikipedia.org/wiki/Fog_collection

Fog collection refers to the collection of water from fog using large pieces of vertical canvas to make the fog-droplets flow down towards a trough below the canvas, known as a fog fence.

Through a process known as condensation, atmospheric water vapour from the air naturally condenses on cold surfaces into droplets of liquid water known as dew. The phenomenon is most observable on thin, flat, exposed objects including plant leaves and blades of grass. As the exposed surface cools by radiating its heat to the sky, atmospheric moisture condenses at a rate greater than that of which it can evaporate, resulting in the formation of water droplets.

Contents

Historical origin

The organized collection of dew or condensation through natural or assisted processes is an ancient practice, from the small-scale drinking of pools of condensation collected in plant stems (still practised today by survivalists), to large-scale natural irrigation without rain falling, such as in the Atacama and Namib desert. Several man-made devices such as antique stone piles in Ukraine, medieval "dew ponds" in southern England or volcanic stone covers on the fields of Lanzarote have all been thought to be possible dew-catching devices.

Modern methods

In the mid-1980s, the Meteorological Service of Canada (MSC) began constructing and deploying large **fog collecting** devices on Mount Sutton in Quebec. These simple tools consisted of a large piece of canvas (generally 12 m long and 4 m high) stretched between two 6 m wooden poles held up by guide wires, with a long trough underneath. Water would condense out of the fog onto the canvas, coalesce into droplets, and then slide down to drip off of the bottom of the canvas and into the collecting trough below.

Chilean project

The intent of the Canadian project was simply to use fog collection devices to study the constituents of the fog that they collected. However, their success sparked the interest of scientists in Chile's National Forest Corporation (CONAF) and Catholic University of Chile to exploit the camchanca or garúa clouds which blanket the northern Chile coast in the southern hemisphere winter. With funding from the International Development Research Centre (IDRC), the MSC collaborated with the Chileans to begin testing different designs of collection facilities on El Tofo Mountain in northern Chile. Once perfected, approximately 50 of the systems were erected and used to irrigate seedlings on the hillside in an attempt at reforestation. Once vegetation became established, it should have begun collecting fog for itself, like the many cloud forests in South America, in order to flourish as a self-sustaining system.

However, the success of the reforestation project is unclear, but approximately five years after the beginning of the project, the nearby village of Chungungo began to push for a pipeline to be sent down the mountain into the town. Though this was not in the scope of CONAF, which pulled out at this point, it was agreed to expand the collection facility to 94 nylon mesh collectors with a reserve tank and piping in order to supply the 300 inhabitants of Chungungo with water.

The project, completed in 1992, initially achieved a spectacular success, with an average production of 15,000 litres of water per day (peaking at 100,000 liters) that could be stored or piped to the village for use in drinking, bathing and irrigating. The accomplishment achieved high publicity, with frequent quotes from the townspeople, for whom water was dangerously scarce before, calling the collectors a "miracle."[*citation needed*]

Unfortunately, the IDRC reports that ten years later in 2002, only nine of the devices remained and the system overall was in very poor shape. On the other hand, the MSC oddly states in its article that the facility was still fully functional in 2003, but provides no details behind this statement. In June 2003 the IDRC reported that plans existed to revive the site on El Tofo.

The reason for the failure of this project to achieve sustainability can be attributed to many factors. Because the project started off on a different path, the final route that it took was disorganized and lacked clear objectives once the facilities were built. The villagers of Chungungo formed a committee to see to the maintenance and repair of the collectors, funded by collections from the village households, but, ironically, the new water supply caused the population of the village to triple and the committee was unable to acquire the supplementary funds to expand the array of collectors and the reservoir, which would have solved any new water shortage problems easily and cost effectively. It is also suggested that this and other methods of water supply are shunned by the people of Chungungo and towns in other developing countries, who feel that collecting one's own water lacks prestige and think that the state should pay for such services. In fact, this is exactly what the people of Chungungo wanted as of 2003 – a pipeline costing around US$1 million to be built from Los Choros river, 20 km away.

However, current evidence suggests the failure has been mended, and operations are successful.[*citation needed*]

Dar Si Hmad

In March 2015 Dar Si Hmad (DSH), a Moroccan NGO, built the world's largest fog-collection and distribution system in the Anti-Atlas Mountains.[1] The region DSH worked in is water-poor, but abundant fog drapes the area 6 months out of the year.[2] DSH's system also included technology that allowed reporting and monitoring of the water system via SMS message. These capabilities were crucial in dealing with the effects Fog Collection had on the social fabric of these rural areas.[3] According to

MIT researchers, the Fog Collection methods implemented by DSH have "improved the fog-collecting efficiency by about five hundred per cent."[4]

International use

Despite the apparent failure of the fog collection project in Chungungo, the method has already caught on in various localities around the world.[4][5][6] Nowadays the International Organization for Dew Utilization organization is working on foil-based effective condensers for regions where rain or fog cannot cover water needs throughout the year. Shortly after the initial success of the project, researchers from the various participating organizations formed the nonprofit organization FogQuest, which has set up operational facilities in Yemen and central Chile, while still others are under evaluation in Guatemala, Haiti, and Nepal, this time with much more emphasis on the continuing involvement of the communities in the hopes that the projects will last well into the future. Villages in a total of 25 countries worldwide now operate fog collection facilities. There is also still potential for the systems to be used to establish dense vegetation on previously arid grounds. Overall, it appears that the inexpensive collectors will continue to flourish.

Appropriate Technology - Cook Stoves in Mali - from EWB (Engineers Without Borders)

Summary: You have been assigned to help rural communities in the Kidal region of Mali adopt more efficient cook-stoves in an effort to reduce the labour and health risks of cooking and protect an already damaged environment.

http://my2.ewb.ca/library/view/108/

And the basis of this case study is from the IMF or the International Monetary Fund in 2013.

https://www.imf.org/external/pubs/ft/scr/2013/cr13111.pdf

Bridge to Mwazna - EWB

: This case study explores the design of a bridge in a rural community that loses road access in the rainy season due to flooding and leads students through an analysis of whether the social context is right to build the bridge.

http://my2.ewb.ca/library/view/139/

Shea Nut Economics

Summary: Students look at increasing production of a shea nut cooperative by analyzing pump designs and then investigate whether installing a pump will change the economics of the shea nut market for the better or for the worse of the co-op.

http://my2.ewb.ca/library/view/143/

EWB - Monitoring, Evaluating and Adapting to Failure

This report from EWB published in 2014 shows the role of failure in engineering.

https://www.ewb.ca/wp-content/uploads/2017/01/2014_EWB_Failure_Report.pdf

INTRODUCTION: FAILURE AS MEDICINE By Dr. Ernesto Sirolli, Sustainable Development expert, founder of the Enterprise Facilitation approach.

> ” This is why I applaud the small-but-mighty Engineers Without Borders Canada for openly publishing stories of their failure for the world to see. In his introduction to the 2012 Failure Report, co-founder George Roter stated that failure makes us stop and reconsider, “forcing [us] to ask whether we succeeded or not, and to make changes if the answer is ‘not’.” This report is certainly not an attempt to sensationalize or glamourize failure – as in my personal experience, there is nothing sensational or glamorous about it! Rather, this is a collection of testimonies by people that are brave enough to announce to the world that they were going about it wrong. This is a challenging thing to do, but they do it because they believe in the power of opening up these difficult conversations. The stories in this report are about failure. But they are not about defeat. They are about experiences that have shaped these individuals and, through extension, the organization of which they’re a part. By challenging their work, they are challenging chronic and pervasive problems in the international development sector. They are making themselves vulnerable because they recognize that in sharing their experiences they can educate others about the realities of development on the ground. And finally, they realize that by admitting their failures – particularly those of a more personal nature – they are making a sincere and valiant effort to learn from their own mistakes. They have the foresight to realize that this failure, painful as it may be, can be a wonderful gift if they choose to take their hard earned lesson and act on it in a meaningful way. “

Case Study - Space Shuttle Challenger

Please see the earlier section in this textbook that gives more background on this disaster.

Introduction to the Case

On January 28, 1986, seven astronauts were killed when the space shuttle they were piloting, the Challenger, exploded at just over a minute into the flight. The failure of the solid rocket booster O-rings to seal properly allowed hot combustion gases to leak from the side of the booster and burn through the external fuel tank. The failure of the O-ring was attributed to several factors, including faulty design of the solid rocket boosters, insufficient low-temperature testing of the O-ring material and of the joints that the O-ring sealed, and lack of proper communication between different levels of NASA management.

Here are a list of case studies relating to this incident

Engineering.com

posted this case study in The Engineer on October 24, 2006
https://www.engineering.com/Library/ArticlesPage/tabid/85/ArticleID/170/The-Space-Shuttle-Challenger-Disaster.aspx
Adapted from material by the Department of Philosophy and Department of Mechanical Engineering at Texas A&M University NSF Grant Number DIR-9012252

Key Issues

How does the implied social contract of professionals apply to this case?
What profressional responsibilities were neglected, if any?
Should NASA have done anything differently in their launch decision procedure?

Texas A&M Univerisity Case Studies
https://ethics.tamu.edu/case-studies/

American Society for Engineering Education Case 2014 Study

https://www.asee.org/file_server/papers/attachment/…/2013-Paper-ASEE-Shuttle.pdf

The Challenger Disaster: A Case of Subjective Engineering from the IEEE

From the IEEE archives: NASA's resistance to probabilistic risk analysis contributed to the Challenger disaster

https://spectrum.ieee.org/tech-history/heroic-failures/the-space-shuttle-a-case-of-subjective-engineering

Chapter 6 - Sustainability

United Nations Principles for Responsible Investment (PRI) and ESG

https://www.unpri.org/

As it says on the United Nation's website, the committee on PRI (Principles for Responsible Investment)

> "We work to understand how environmental, social and governance (ESG) issues – such as climate change, human rights and tax avoidance – impact investments, and we support our international network of investor signatories in incorporating these factors into their investment and ownership decisions.
>
> The PRI acts in the long-term interests of its signatories, of the financial markets and economies in which they operate and ultimately of the environment and society as a whole."

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What is responsible investment?

https://www.unpri.org/pri/what-is-responsible-investment

Responsible investment is an approach to investing that aims to incorporate environmental, social and governance (ESG) factors into investment decisions, to better manage risk and generate sustainable, long-term returns.

Why invest responsibly?

The global momentum around responsible investment is driven by:

- recognition in the financial community that ESG factors play a material role in determining risk and return;
- understanding that incorporating ESG factors is part of investors' fiduciary duty to their clients and beneficiaries;
- concern about the impact of short-termism on company performance, investment returns and market behaviour;
- legal requirements protecting the long-term interests of beneficiaries and the wider financial system;

- pressure from competitors seeking to differentiate themselves by offering responsible investment services as a competitive advantage;
- beneficiaries becoming increasingly active and demanding transparency about where and how their money is being invested;
- value-destroying reputational risk from issues such as climate change, pollution, working conditions, employee diversity, corruption and aggressive tax strategies in a world of globalisation and social media.

What are environmental, social and governance (ESG) factors?

Examples of environmental, social and governance (ESG) factors are numerous and ever-shifting. They include:

Environmental

- climate change
- greenhouse gas (GHG) emissions
- resource depletion, including water
- waste and pollution
- deforestation

Social

- working conditions, including slavery and child labour
- local communities, including indigenous communities
- conflict
- health and safety
- employee relations and diversity

Governance

- executive pay
- bribery and corruption
- political lobbying and donations
- board diversity and structure
- tax strategy

United Nations "Our Common Future" or "The Brundtland Report" on Sustainable Development

http://www.un-documents.net/wced-ocf.htm

Our Common Future, also known as the **Brundtland Report**, from the United Nations World Commission on Environment and Development (WCED) was published in 1987.

Its targets were multilateralism and interdependence of nations in the search for a sustainable development path. The report sought to recapture the spirit of the Stockholm Conference – which had introduced environmental concerns to the formal political development sphere. *Our Common Future* placed environmental issues firmly on the political agenda; it aimed to discuss the environment and development as one single issue.

Sustainability from APEGBC

https://www.egbc.ca/Practice-Resources/Sustainability

SUSTAINABILITY

Sustainability is the concept of utilizing our physical, natural and social resources to meet our needs and aspirations without compromising the well-being of future generations and the global ecosystem. Since the early 1990s, Engineers and Geoscientists British Columbia has consistently supported and encouraged its members to adapt sustainable principles within the practice of professional engineering and geoscience.

Members of Engineers and Geoscientists BC, through the Sustainability Committee, advise Council on these matters on an ongoing basis.

SUSTAINABILITY AND APEGBC PROFESSIONALS

WHAT IS SUSTAINABILITY?

A sustainable society meets the needs of people in a resilient economy without compromising the planet's ecological integrity or the needs of future generations. Sustainability has three pillars that must be integrated in a balanced way:

a) environmental: to stay within the biophysical carrying capacity of our region/country/planet (e.g. minimize resource use, minimize waste, protect nature from degradation);

b) social: to maintain and protect quality of life and the values that we aspire to live by; and

c) economic: to ensure that an adequate material standard of living is provided for all members of society.

The most widely quoted definition of sustainability and sustainable development was given by the United Nations' Brundtland Commission on March 20, 1987:

> "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Since that time, the definition and scope of sustainability has expanded to encompass all aspects of human activities. Sustainability requires us to be smart about managing our resources and impacts, with the long term in mind. In other words,

we need to think about the way we use our natural, social, and economic capital so that we don't use them up too fast or make conditions worse for others while we benefit ourselves ("others" can mean those in different places around the world or future generations).

How Does it Relate to Professional Engineering and Geoscience?

This preamble emphasizes the relevance of the Sustainability Guidelines to the scope of an APEGBC professional's task and work responsibilities. APEGBC professionals must consider these Sustainability Guidelines in their work; the application of the Sustainability Guidelines is, however, a matter of judgment. The concept of sustainability in the practice of professional engineering and geoscience is not new. Sustainability is already a key element to our professional practice where we carry out our roles considering ethical, environmental, social and economic challenges. By continually gathering new knowledge, developing new materials and technologies, and using more sophisticated decision-making methods, we deliver economic benefits, minimize negative environmental impacts and improve societal wellbeing. APEGBC professionals already have an explicit mandate to protect public welfare and the environment.

The first principle of our Code of Ethics states:

> "Professional Engineers and Geoscientists shall hold paramount the safety, health and welfare of the public, the protection of the environment and promote health and safety within the workplace."

1.0 HOW DOES IT RELATE TO PROFESSIONAL ENGINEERING AND GEOSCIENCE?

APEGBC professionals have a significant role to play in the development of
a sustainable society through their professional practice. Our actions directly and indirectly shape the world we live in, including the resources we use, as well as the health, safety, environment, and wellbeing of the public. APEGBC professionals make decisions and provide leadership to our colleagues, clients, employers, decision-makers and the public in the development, implementation, operational life spans, and decommissioning of engineering and geoscience projects, products, processes, or systems. We have a responsibility to the public, consistent with the APEGBC Code of Ethics (the "Code of Ethics"), to provide sustainable solutions that adhere to the basic pillars of sustainability
(environmental, social and economic). This requires that we consider the long-term consequences that flow directly and indirectly from our actions. APEGBC professionals must not make promises of results for sustainable solutions as this will probably negate their professional liability insurance coverage. These APEGBC Sustainability Guidelines are an update of APEGBC's former Guideline on Sustainability, originally adopted in 1995. APEGBC professionals are encouraged to view their work through the "lens of sustainability", using these Sustainability Guidelines to assist them where appropriate. Sector-specific guidelines for sustainable engineering and geoscience practice are also available on the APEGBC website.

2.0 THE SUSTAINABILITY GUIDELINES

Within their scope of professional practice, APEGBC professionals have a responsibility to:

2.1 GUIDELINE 1: MAINTAIN A CURRENT KNOWLEDGE OF SUSTAINABILITY

Maintain a level of competence on matters of sustainability related to the APEGBC professional's area of expertise, and seek additional expertise as necessary. The knowledge, concepts and opportunities for sustainable solutions are rapidly evolving and APEGBC professionals should strive to keep skills up to date, and advance the understanding of sustainability in their field of practice.

2.2 GUIDELINE 2: INTEGRATE SUSTAINABILITY INTO PROFESSIONAL PRACTICE

Integrate sustainability considerations into professional practice, reflecting the APEGBC Code of Ethics' requirements to hold paramount the safety, health and welfare of the public and the protection of the environment. APEGBC professionals must consider the combined environmental, social and economic aspects that take into account the direct and indirect impacts over the full project life-cycle.

2.3 GUIDELINE 3: COLLABORATE WITH PEERS AND EXPERTS FROM CONCEPT TO COMPLETION

At key stages of the project life-cycle, collaborate with peers and experts
across disciplines to identify appropriate alternatives and new opportunities for sustainable results.

2.4 GUIDELINE 4: DEVELOP AND PREPARE CLEAR JUSTIFICATIONS TO IMPLEMENT SUSTAINABLE SOLUTIONS

Discuss opportunities and document decisions made related to the integration of environmental, social and economic metrics. These discussions should occur early enough to enable the client or employer to make informed decisions about how to implement an appropriate level of sustainability considerations in the task or projects, products, processes, or systems.

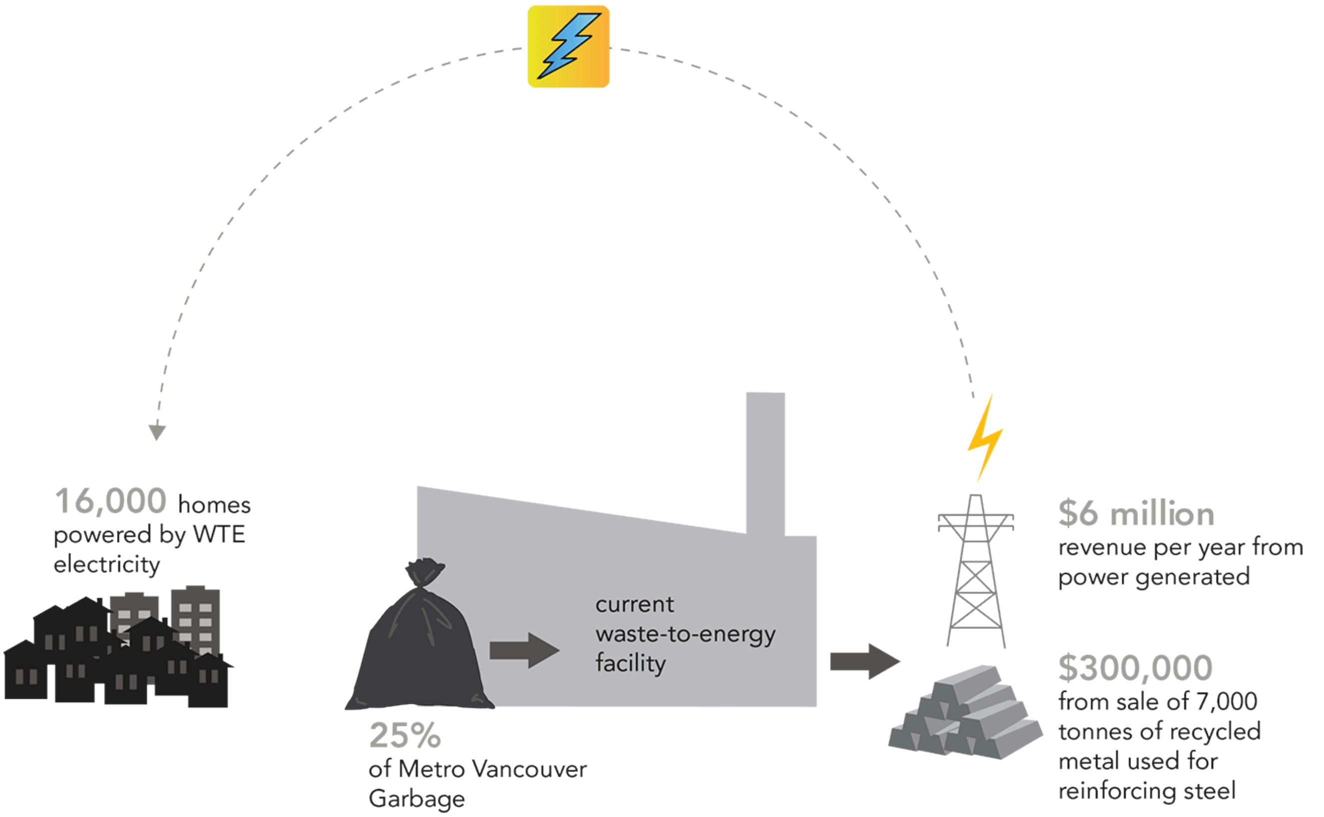
2.5 GUIDELINE 5: ASSESS SUSTAINABILITY PERFORMANCE AND IDENTIFY OPPORTUNITIES FOR IMPROVEMENT

Identify opportunities to improve knowledge and professional practice related to sustainability, where best practice is to assess actual performance of implemented solutions against the original design goals and metrics. An amplification of each guideline is provided in Appendix I.

Appendix I link here: https://www.egbc.ca/Practice-Resources/Sustainability

Metro Vancouver Waste Incinerator "Waste-to-Energy Facility"

One of the topics we covered in our course in June 2019 was Metro Vancouver's Waste to Energy Facility. Here is a graphic from the Metro Vancouver's fact sheet.



Waste to Energy Facility in Metro Vancouver, BC Canada — CC0 license as it comes from a government funded website http://www.metrovancouver.org/services/solid-waste/garbage-recycling/waste-to-energy-facility/about/Pages/default.aspx

In an attempt to nail down the costs, Jennifer Kirkey used the contact email address. Here is the reply from Sarah Wellman, P.Eng. **Senior Engineer,** Solid Waste Operations. "Thank you for your interest in Metro Vancouver's Waste-to-Energy Facility. Please see the following link for the Waste-to-Energy Facility 2018 financial report. Please contact me if you have any other questions, or if you are interested in a tour of the facility." Sarah.Wellman@metrovancouver.org

http://www.metrovancouver.org/services/solid-waste/SolidWastePublications/Waste-to-EnergyFacility-2018FinancialUpdate.pdf

Here is a summary of the 2018 numbers
The cost to operate the facility was $20,497,223.
Please note that disposing of the fly ash was $1,385,142 of that cost.
The facility made $5,584,341 by selling the electricity it made.

That works out to a cost of disposal of $58.16 per tonne. Please note that it is a metric tonne = 1000 kg = 2204 pounds.

Here is a link to the facility web page.
https://www.covanta.com/Our-Facilities/Covanta-Burnaby

You can take a virtual tour here.
https://www.covanta.com/Covanta-Map/Virtual-Tour

Here is a photo of the facility from the Covanta web page.

Waste to Energy Facility operated by Covanta in Metro Vancouver. This image was accessed from the facility web page on June 7 2019 https://www.covanta.com/Our-Facilities/Covanta-Burnaby

A timely issue is that of the 26 containers of garbage that will be burnt there. This is an international scandal and will be handled here in Burnaby, BC, Canada. The ethics of recycling.
https://www.cbc.ca/news/canada/british-columbia/philippines-garbage-canada-1.5149645

Chapter 7 - Climate Change

https://www.egbc.ca/Practice-Resources/Climate

Engineers and Geoscientists British Columbia has undertaken several initiatives to explore the impact of climate change on professional engineering and geoscience practice.

Members of Engineers and Geoscientists BC, through the Climate Change Advisory Group, advise Council on these matters on an ongoing basis.

Climate Change from APEGBC

CLIMATE

Engineers and Geoscientists British Columbia has undertaken several initiatives to explore the impact of climate change on professional engineering and geoscience practice.

Members of Engineers and Geoscientists BC, through the Climate Change Advisory Group, advise Council on these matters on an ongoing basis.

On September 8, 2016 The Association of Professional Engineers and Geoscientists of British Columbia (APEGBC) released a position paper on Human-Induced Climate Change

Position

A. APEGBC accepts that there is strong evidence that human activities, in particular activities that emit greenhouse gases, are contributing to global climate change.

B. APEGBC Registrants[1] have the potential to influence greenhouse gas emissions through their professional activities, and are expected to consider the impact of their work on the climate.

Greenhouse gas emissions are changing the climate

Scientific evidence shows a global warming trend that has accelerated over the past 100 years. Further, multiple lines of evidence show that emissions of greenhouse gases—in particular carbon dioxide and methane—from human activities are the primary driver of this trend (IPCC 2014). Data from the US National Oceanographic and Atmospheric Administration show that nine of the ten warmest years on record have occurred since the year 2000 (NOAA 2015). Projections based on global climate models indicate that global temperatures will continue to rise (IPCC 2014). Climate scientists have confidence in the ability of these models to produce credible, quantitative projections of the future climate, because they are based on fundamental physical principles and have consistently been shown to reproduce observed features of the current climate and past climate changes. The scientific community has determined that in order to stabilize the climate, greenhouse gas emissions must be reduced by 40%–70% from current levels by mid-century (IPCC 2014). The Province of British Columbia has legislated targets of 33% reductions by 2020 and 80% reductions by 2050 from a 2007 baseline (Province of BC 2007). The BC Government continues to develop and refine climate change legislation and policies in consultation with a broad range of stakeholders, including local governments, professional associations such as APEGBC, and the general public. Significantly, the December 2015 Paris Climate Conference achieved a global framework agreement on climate action, with more than 190 countries recognizing that climate change represents an urgent and potentially irreversible threat to human societies and the planet, and that deep reductions in global greenhouse gas emissions will be required.

1. For the purposes of this paper, the term "APEGBC Registrants" includes: professional engineers, professional geoscientists, provisional members, licensees, limited licensees, engineers-in-training, and geoscientists-in-training.

Engineers and geoscientists can contribute to mitigating human-induced climate change through their professional activities

At its core, climate change mitigation includes actions to reduce the quantity of greenhouse gas emissions released into the atmosphere, in particular carbon dioxide from the combustion of fossil fuels. Mitigation will require moving toward a low-carbon economy and replacing fossil fuels with renewable energy, where possible. Mitigation can also refer to sequestering carbon dioxide from the atmosphere, or finding ways to store carbon dioxide (or other greenhouse gases) that would otherwise be released. The work of engineers and geoscientists can positively influence how energy and resources are produced and used in their projects, thus helping to reduce greenhouse gas emissions. APEGBC Registrants work in a wide variety of different roles—as employees, employers, researchers, academics, consultants, and in regulatory and managerial positions—and they often work on teams with other specialists. Although engineers and geoscientists may not be the implementers of strategic decisions that influence energy use and greenhouse gas emissions for the projects they work on, they are encouraged to consider how the impact of climate change may be relevant in their engineering and geoscience analysis and in the recommendations that they provide to their clients on engineering and geoscience issues. These expectations are highlighted in the APEGBC Code of Ethics and the APEGBC Professional Practice Guidelines – Sustainability (V1.1, revised 2016). In many cases, the strong links between renewable energy, energy efficiency, and greenhouse gas emissions reduction mean that there is a potential business case for solutions with lower associated climate impacts, especially when the full project life costs and benefits are accounted for.
APEGBC feedback on BC Climate Action Secretariat's Discussion Paper on the Climate Leadership Plan
Direct link:
https://www.egbc.ca/getmedia/ba992394-0171-49ff-a90d-5a41fac6436e/APEGBC-s-Feedback-on-MoE-CAS-Discussion-paper-on-CLP_14Sep2015.pdf.aspx
2016 APEGBC Position Paper on Human-Induced Climate Change
2014 APEGBC Climate Change Position Paper on evolving responsibilities for engineers and geoscientists

CLIMATE CHANGE ADVISORY GROUP

The Climate Change Advisory Group is responsible for advising Council on matters related to climate change and adaptation. This includes recommending appropriate policy development, providing input into practice guideline development and revision, and recommending appropriate responses to requests for association support.

CLIMATE CHANGE INFORMATION PORTAL

The climate change adaptation tools and resources listed in this portal aim to support professionals in incorporating a consideration of climate change into their practice.
https://www.egbc.ca/Practice-Resources/Climate/Climate-Change-Information-Portal

ENGINEERS CANADA SURVEY ON CLIMATE CHANGE

In 2007, a national survey on climate change, targeted to infrastructure engineers, was conducted by the Canadian Standards Association on behalf of Engineers Canada. The survey helped determine engineers' level of knowledge and awareness of the impacts of a changing climate on built infrastructure at the time. In 2012, a follow-up survey was conducted to understand what changes in attitudes, awareness, and actions have occurred since 2007. The 2012 survey also helps identify what engineers are doing now to adapt infrastructure to the impacts of a changing climate. The survey, conducted between December 2011 and February 2012, was targeted at professional engineers across Canada in five categories of built infrastructure: water, transportation, energy, buildings, and resource extraction/processing.

2012 Engineers Canada Survey on Climate Change Results

Supplemental Report by Jurisdiction

Vancouver's changing shoreline

A particular case can be studied due to Vancouver City. They issued a report called “Vancouver’s Changing Shoreline, preparing for sea level rise “. It can be accessed here
https://vancouver.ca/files/cov/vancouvers-changing-shoreline.pdf

Here is a link to the website for more information
https://vancouver.ca/green-vancouver/sea-level-rise.aspx

Exercises

- How old will a person be when the sea level has risen 1 metre? Assume the baby was born this year.
- Compare and contrast the two main mechanisms of sea level rise — polar ice melting and the expansion of water due to the increase in temperature

Current Technology

A survey of current technology and emergent issues.

Electric cars and autonomous cars

Electric vehicles

EVs may or may not be the wave of the future, but the challenge is the infrastructure to support electric chargers. BC Hydro has many resources on this topic.

https://www.bchydro.com/powersmart/electric-vehicles.html

Autonomous Vehicles

These are vehicles that is capable of sensing its environment and navigating without human input. The design purpose is to

a) increase safety
b) reduce traffic congestion
c) eliminate the need for insurance
d) reduce infrastructure cost
e) increase mobility
f) reduce fuel consumption

From wikipedia autonomous car

History. Experiments started in 1920, with a semi-autonomous vehicle being produced in 1977 from Japan's Tsubkuba Mechanical. 1980 at Carnegie.

Artificial Intelligence (AI) and the future of your job

Wired magazine had a good guide to AI that was published in February 2018.
https://www.wired.com/story/guide-artificial-intelligence/
Updated with more comments about the power and limits of AI was published in June 2019.
https://www.wired.com/story/power-limits-artificial-intelligence/

Here is a link to a YouTube video on the same subject from March 2017.

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.bccampus.ca/engineeringinsociety/?p=350

Social Credit system and privacy

China has recently implemented a social credit system.
https://en.wikipedia.org/wiki/Social_Credit_System

It has had a huge effect, including preventing millions of people from buying airplane tickets.
https://www.cbc.ca/radio/thecurrent/the-current-for-march-7-2019-1.5046443/how-china-s-social-credit-system-blocked-millions-of-people-from-travelling-1.5046445

CBC radio show Spark has a fascinating article on this where your social credit can determine your financial loans.
https://www.cbc.ca/radio/spark/episode-327-working-less-social-credit-scores-and-more-1.3762032/need-a-loan-look-no-further-than-your-messaging-app-1.4124694

Other countries

An interesting discussion can centre around how easily it would be to implement this type of a system in other countries, given their privacy laws.

United States Supreme Court is adamant about constitutional rights and the recent appointments from President Trump has strengthened that. The right to privacy through the Fourth Amendment "unreasonable search and seizure" are guaranteed in the US Constitution.
https://www.whitehouse.gov/about-the-white-house/the-constitution/

Freedom of movement has been upheld under the Privileges and Immunities Clause of the United States Constitution which states, "The Citizens of each State shall be entitled to all Privileges and Immunities of Citizens in the several States."

In addition, Article 13 of the Universal Declaration of Human Rights asserts that:

- a citizen of a state in which that citizen is present has the liberty to travel, reside in, and/or work in any part of the state where one pleases within the limits of respect for the liberty and rights of others,
- and that a citizen also has the right to leave any country, including his or her own, and to return to his or her country at any time.

South Korea

In the South Korean constitution there are many clauses that would make it difficult for a social credit system to be implemented there.
The Right to Privacy is constructed as a fundamental right that is protected by the Constitution.

https://www.privacy.go.kr/eng/laws_policies_list.do

The Right to Privacy is constructed as a fundamental right that is protected by the Constitution. "It prevents the state from looking into the private life of citizens, and provides for the protection from the state's intervention or prohibition of free conduct of private living. Personal data protection laws of Korea are consisted of Personal Information Protection Act as a general law and several specific sector laws, including Act on Promotion of Information and Communications Network Utilization and Information Protection, ETC and Use and Protection of Credit Information Act."

Jennifer Kirkey's ENGR1110 assignment on BioHacking

As part of the course I am taking at Douglas College in New Westminster, British Columbia, Canada I am doing a research project. Of the topics given to me I choose Implanting Electronics into the Human Body.

Photo by Artem Kim on Unsplash Accessed on May 30 2019. CC0

Purpose

The purpose of the final research project is to examine the Engineering profession and its relationship with society. As the instructor said "Throughout this semester, this course would have provided you insight into the following topics."

- Design
- Scientists versus Engineers
- The history of the Engineering profession
- Sustainability
- Engineering and the environment
- Engineering and the betterment of the Human Condition
- Advancements in Technology

This project will be an in depth research study of Engineering issues that humanity is currently facing. Your findings will be submitted in the form of a research report and in-class presentation. As this is a research project, you will be required to research information from various books, articles, papers, website, and etc. **For this final research paper, Wikipedia is not an acceptable source of information.**

Project Details

Biohacking of 'Do-It-Yourself Biology', describes the process of making changes to your lifestyle in an attempt to alter the body's natural biology and improve the way you feel. [1,2]. The term biohacking has been traced to the late 1980's, but is biohacking a fad, or is its roots traced deeper in the realm of chemical and biological engineering? While the term biohacking has been linked to simple principles of lifestyle changes such as eliminating sugar in your diet, the expectation of this research paper is to dig deeper into large laboratory scale, big budget biohacking, based on the following topics:

1. The Use of Anabolic Steroids in Professional Sports.
2. Manipulating and Customizing DNA.
3. Implanting Electronics into the Human Body.

The expectation of this project is to formulate an argumentative research paper on one of the three topics outlined above. The research will identify critical historical discoveries, document the progression of key milestones up to today and the future outlook. The research will also include details of the role of the engineering society, the engineering and ethical issues that were encountered, as well as any pertinent policies and regulations that were developed.

Project Deliverables

The project will consist of 3 deliverables:

Project Proposal Document (Mid-Term) – June 20, 2019

The Project Proposal Document will serve as a mid-term paper that identifies the foundation of your final research paper and must include the following:

- The topic chosen.
- The basis that will eventually form your argument.
- Preliminary research.

The Project Proposal Document shall be 2-5 pages in length, written in 12-point Serif font and contain proper citation.

Final Project Research Paper – August 1, 2019

The final research paper formalizes all research in a properly formatted document and will also be written in 12-point Serif font with proper citation.

Final Presentation – August 7, 2019 (tentative)

The final presentation will be a 20-30 minute presentation of the research, followed by time for questioning by a judging panel (to be determined). The method of presentation delivery is open, but limited to the equipment available in S1720.

References

1. https://draxe.com/what-is-biohacking/
2. https://en.wikipedia.org/wiki/Do-it-yourself_biology

Draft research paper

A lot of my information comes from, or at least starts, at CBC Spark.

https://www.cbc.ca/radio/spark

As it says on their website "Spark is an ongoing conversation about our rapidly changing world… host Nora Young explores how technology, innovation and design affects our lives." It is one of my favourite radio shows and I make sure to listen it to every week.

Biohacking article from CBC Spark April 12 2012

Biophysics professor Andrew Pelling of the University of Ottawa is working to create designer organs that could communicate via Twitter. April 12 2012

https://www.cbc.ca/player/play/2247601568

Biohacking article from CBC Spark May 13 2012

"A few weeks ago on Spark, we heard how scientists at the University of Ottawa were working to create designer organs (the kind in our bodies!) that could communicate via Twitter. This kind of bio-tinkering seems an awful lot like what's going on in the DIY-bio movement. Yes, Do-it-yourself bio-hackers do exist, and they say if you're an actual scientist, you can't be in the club."

https://www.cbc.ca/radio/spark/bio-hacking-1.1734292

Biohacking article from December 1 2018 – Swedes with RFID implanted under their skin

https://www.cbc.ca/radio/spark/416-1.4927730/sweden-s-digital-culture-is-making-implanted-microchips-more-common-1.4927740

In Sweden, electronic devices implanted under the skin are becoming more common and useful for everyday things. The devices, which use RFID (radio frequency identification) technology similar to what allows key fobs or debit cards to be tapped, have been implanted into 4,000 Swedes, 700 having been done in the first 6 months of 2018.

Per Söderström is a consultant and biohacker in Sweden, who is able to use his device to enter his office and gym in Stockholm. He can even buy snacks at vending machines. Last year, Staten Järnsväger (SJ), the state owned railway, began allowing customers to confirm their tickets through their implanted chips.

"Stuff we use daily that have chips in them, could be a chip that's under your skin," Soderstrom said, speaking to Spark host Nora Young

Biohacking article from CBC Spark March 24, 2019

Exploring Silicon Valley's obsession with longevity and bio-hacking

CBC Spark asks if there is a problem with Silicon Valley's obsession with agelessness and living forever. The interview is focused on James Strole who states that he "plans to live forever". At the biological age of 70, he has spent his entire life trying to find a cure for aging, and ultimately death, optimizing his body through techniques like cleanses, fasts, blood transfusions and even skin patches that claim to help reverse aging at a cellular level. In the interview he states "Let's put it this way: I'd do anything that I feel safe with."

Strole, who appears lean and energetic and sports a full head of greyish-white hair, is the director of the Coalition for Radical Life Extension, an organization that brings together scientists, entrepreneurs and enthusiasts who are passionate about physical immortality. Their overall aim, Strole said, is to conquer aging and eventually death.

https://www.cbc.ca/radio/spark/spark-431-1.5058858/from-extreme-fasting-to-radical-life-extension-the-dark-side-of-body-optimization-1.5058860

In that episode two things really stood out for me, in context of this research paper.

Arwa Mahdawi said she also spoke to people who consider themselves "biohackers," which are those who measure certain markers in their bodies and experiment on themselves using various techniques with the goal of optimizing their health.

"Some of them will go and they'll get special glucose implants in their skin, so they can test their glucose, and that's something that diabetics normally have," Mahdawi explained. "These people are not diabetics. They just want to check."

These behaviours, Mahdawi said, are troubling. "They are basically treating themselves like computers: If I don't eat, how does my blood sugar react? If I eat this, how … did my metabolic markers change? And that degree of obsession, really, I think can be quite problematic."

Unintended consequences

James Horton, an evolutionary biologist at the University of Bath, has also written about the darkside of this obsession with body optimization and longevity.

In his article "Silicon Valley's quest for immortality – and its worrying sacrifices", he argues that there is a real danger to some of these practices that certain tech companies are touting.

"Some are great," Horton said. "They're basically just encouraging us to live healthy lives and you know, if that brings us extra longevity and lifespan, healthspan, that's fantastic."

Legislation – 2019 – Nevada bill would outlaw electric microchips

The disastrous Nevada bill that would outlaw elective microchip implants (AB226) shows that some policymakers simply do not understand augmentative technology and the importance of bodily autonomy.

At the invitation of State Senator Melanie Scheible (who has been absolutely amazing throughout this process), we're going to hold a Cyborg & Transhumanist Forum at the Nevada State Capitol to educate policymakers, staffers, the media, and the public on these technologies and topics. We'd love to see you there if you're able to make it! If not, we hope you'll share this with anyone who may be able to attend and support. If you're interested in participating in this event in any official capacity, please get in touch!

Facebook event on May 15 2019 : https://www.facebook.com/events/911340172531413/Event organized by the U.S. Transhumanist Party, Future Grind, & Anastasia Synn.

Grindhouse Wetware

Grindhouse Wetwares was founded January 2012, by what was then a rag tag group of programmers, engineers, and enthusiasts, according to their web page. In the short five months that followed, Grindhouse evolved from a group of highly driven individuals on the biohack.me forums, to a dedicated team working towards a common goal – augmenting humanity using safe, affordable, open source technology. All hardware can be purchased from the Grindhouse website, and all schematics for our implants and cyberware are open source. "What would you like to be today?"

Here is a short video from their YouTube channel. Here is an update on this implanted red LEDs Northstar from April 2019.

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.bccampus.ca/engineeringinsociety/?p=235

Canadian Health Regulations

In Canada, The Therapeutic Products Directorate (TPD) applies the Food and Drug Regulations and the Medical Devices Regulations under the authority of the Food and Drugs Act to ensure that the pharmaceutical drugs and medical devices offered for sale in Canada are safe, effective and of high quality. The TPD also administers fee regulations for drugs and medical devices under the authority of the Financial Administration Act. All Federal Acts and associated Regulations are available on the Justice Canada Web site.

https://www.canada.ca/en/health-canada/services/drugs-health-products/medical-devices/legislation-guidelines.html

https://www.canada.ca/en/health-canada/services/drugs-health-products/medical-devices/licences/medical-devices-active-licence-listing.html

The same evidence requirements apply to 3D printed devices as those for non-3D printed devices in terms of their characterization and evidence of safety and effectiveness, including physical and mechanical bench testing, biocompatibility testing, software validation and clinical evidence.

As part of the evidence to demonstrate the safety and effectiveness of a Class III or IV 3D printed device, manufacturers should submit the additional information outlined in this guidance document with their application. Failure to submit the additional information with an application could result in a request for additional information under subsection 35(1) of the Regulations at any time during the review (i.e., during either the screening or review phase).

In keeping with international standards, the guidance document adopts definitions developed by the International Medical Device Regulators Forum (IMDRF) with respect to Definitions for Personalized Medical Devices.

Healthcare facilities which manufacture 3D printed implantable medical devices under their own name and distribute them outside of their own corporate entity, qualify as a manufacturer, and will be subject to all the requirements of the Regulations.

Footnote Reference: https://www.canada.ca/en/health-canada/services/drugs-health-products/medical-devices/application-information/guidance-documents/3d-licensing-requirements/document.html

Canadian article about implants from 2016
https://www.ctvnews.ca/sci-tech/biohacking-how-a-tiny-implant-can-unlock-doors-with-the-wave-of-a-hand-1.2913912

“Anywhere from 10,000 to 20,000 people across the globe are estimated to have the RFID implants in their hands, according to Amal Graafstra, who owns a U.S. company that sells the chips.”

”

Medicine vs. convenience

Back at the doctor’s office, Landy points out that technologies similar to the RFID chip have become part of many doctors’ 21st century “tool kit.” For instance, cardiologists can now use tiny implants placed near a patient’s heart to detect heartbeat abnormalities and relay them back to a doctor using radio frequencies.

“So these things exist both for convenience and for what I’ll call conventional medical application,” Landy said. “And I’m sure the berth between those things is going to be growing smaller as time goes by.”

Still, Landy insisted that getting a non-medical implant outside a medical environment “does not strike me as a safe idea.”

Dangerous Things Company
https://dangerousthings.com

Canadian regulations on the frequency used for medical and non-medical implants
https://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09826.html

One example of what can be found there is ” This device may not interfere with stations operating in the 400.150-406.000 MHz band in the meteorological aids, meteorological-satellite, and earth exploration-satellite services, and must accept any interference received, including interference that may cause undesired operation.” Another example is “The maximum average e.i.r.p. for MICS transmitters is 25 microwatts.”

TED talk

The technology stuff starts at 500 minutes in and PH model = Potato Head model “plug and play senses” at 7 minutes in. 10:40 in is where he talks about sensory substitution for the deaf which is what he does in the lab. 17:38 ” we not longer have to wait for Mother Nature on her time scales.” All of his stuff is wearable, but you can tell the next frontier is to embed.

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.bccampus.ca/engineeringinsociety/?p=235

The Future Scope and Regulation of Implantable Technologies

from Wikipedia
https://en.wikipedia.org/wiki/Cyborg

Given the technical scope of current and future implantable sensory/telemetric devices, these devices will be greatly proliferated, and will have connections to commercial, medical, and governmental networks. For example, in the medical sector, patients will be able to login to their home computer, and thus visit virtual doctor's offices, medical databases, and receive medical prognoses from the comfort of their own home from the data collected through their implanted telemetric devices.[107] However, this online network presents huge security concerns because it has been proven by several U.S. universities that hackers could get onto these networks and shut down peoples' electronic prosthetics.[107] These sorts of technologies are already present in the U.S. workforce as a firm in River Falls, Wisconsin called Three Square Market partnered with a Swedish firm called Biohacks Technology to implant RFID microchips in the hands of its employees (which are about the size of a grain of rice) that allow employees to access offices, computers, and even vending machines. More than 50 of the firms 85 employees were chipped. It was confirmed that the U.S. Food and Drug Administration approved of these implantations.[108] If these devices are to be proliferated within society, then the question that begs to be answered is what regulatory agency will oversee the operations, monitoring, and security of these devices? According to this case study of Three Square Market, it seems that the FDA is assuming the role in regulating and monitoring these devices.

References

List of references

Wikipedia's strength and weakness is that it is open source. It can be a useful route to finding original sources of information.
https://en.wikipedia.org/wiki/Cyborg

The Cyborg Foundation
" IS AN ONLINE PLATFORM FOR THE RESEARCH, DEVELOPMENT AND PROMOTION OF PROJECTS RELATED TO THE CREATION OF NEW SENSES AND PERCEPTIONS BY APPLYING TECHNOLOGY TO THE HUMAN BODY. OUR MISSION IS TO HELP PEOPLE BECOME CYBORGS, PROMOTE CYBORG ART AND DEFEND CYBORG RIGHTS"
https://www.cyborgfoundation.com/

Retrieved June 12 2019
https://www.nytimes.com/2016/02/23/health/a-do-it-yourself-revolution-in-diabetes-care.html

Retrieved June 12 2019
https://hackernoon.com/biohack-your-intelligence-now-or-become-obsolete-97cdd15e395f
https://hackernoon.com/im-32-and-spent-200k-on-biohacking-became-calmer-thinner-extroverted-healthier-happier-2a2e846ae113

Retrieved June 12 2019
June 5 2018 by Faye Flam "it is not illegal to experiment on yourself FDA"
https://www.bloomberg.com/opinion/articles/2018-06-05/biohackers-experimenting-on-themselves-new-drugs-old-technique
Bloomberg: Warning: Don't Try This Biohacking At HomeEarly this year, a 28-year-old self-described biohacker named Aaron Traywick injected himself with an alleged herpes vaccine prepared by fellow amateur medical researchers. The injection, which was broadcast on Facebook Live, brought on a volley of criticism and ethical concerns. Only a few months earlier, a colleague at the company Traywick founded, Ascendance Biomedical, injected himself with an alleged gene therapy for HIV. It's unlikely either of these treatments worked, but they succeeded in proving how easy it's become for amateurs to experiment with infectious agents and other biological materials that were once restricted to trained professionals. While it's illegal to sell biohacked therapies or vaccines, or to test them on human subjects, so far at least, the FDA does not explicitly forbid experimenting on yourself.
Brain interfaces for paralyzed patients since 2006
https://www.nytimes.com/2006/07/13/science/13brain.html
New England Journal of Medicine

Fully Implanted Brain–Computer Interface in a Locked-In Patient with ALS https://www.nejm.org/doi/full/10.1056/NEJMoa1608085

July 7 2013 Retrieved on June 14 2019
https://io9.gizmodo.com/what-you-need-to-know-about-getting-magnetic-finger-imp-813537993

Hacklab Toronto Retrieved June 13 2019
https://hacklab.to/

Eric Boyd Cyborg – Canadian
https://ca.linkedin.com/in/eric-boyd-2b5ab83

http://makerfestival.ca/team/eric-boyd/

Eric Boyd is the founder of Sensebridge, an electronic jewelry company. Born and raised in Ontario Canada, on a small chicken farm, Eric went to Queens University for engineering, graduating in 2003, but not before co-founding StumbleUpon.com. After graduating, he lived and worked in Silicon Valley at a high tech startup, designing and installing industrial sensors. Eric is currently based in Toronto Canada, where he is President of Hacklab.to, a technology community space and a trustee of the Awesome Foundation. At Sensebridge, Eric works on a variety of devices which are intended to augment the user, turning them into a cyborg. These devices include North Paw, a compass anklet that gives users a sense of direction, and Heart Spark, a heart-beat flashing pendant which broadcasts the wearers emotions. A man of diverse interests, his other hobbies include Quantified Self, DIYbio and Guerrilla Gardening.

Neil Harbisson had an antenna implanted into his skull so he could see colours.

https://www.cnn.com/videos/tech/2014/09/02/spc-make-create-innovate-neil-harbisson-cyborg.cnn

Cyborg images in popular culture

One of the reasons I chose this topic was because of my interest in science fiction and cyborgs. Here is a collection of cyborg images in popular culture.

Historic image from Italy in the year 1569. An unknown artist used the copper engraving technique to produce this image which was photographed and shared via Wikipedia.

Created in 1569, this is an Italian artist's conception of a part human, part machine. Photo credit from Wikipedia. This is a public domain image as the artist has been dead for more than 100 years. https://commons.wikimedia.org/wiki/File:Unknown_engraver_-_Humani_Victus_Instrumenta_-_Ars_Coquinaria_-_WGA23954.jpg

Ethics - British Columbia and Canadian Cases

Code of Ethics from Engineers and Geoscientists, BC

https://www.egbc.ca/About/Governance/The-Act,-Bylaws-and-Code-of-Ethics

THE ACT, BYLAWS AND CODE OF ETHICS

The *Engineers and Geoscientists Act*, the professions' governing legislation, as well as the Bylaws and Code of Ethics, guide the association and its members and licensees in performing their duties.

THE PURPOSE OF THE *ACT*, BYLAWS AND CODE OF ETHICS IS TO:

- Define the association's mandate;
- Outline its governing powers with respect to members and non-members alike; and
- Provide general statements regarding principles of ethical conduct to prepare professional engineers and geoscientists for the fulfillment of their duty to the public, the profession and fellow Engineers and Geoscientists British Columbia members.

The Engineers and Geoscientists Act
Bylaws
Code of Ethics

Code of Ethics

https://www.egbc.ca/getmedia/e8d858f5-e175-4536-8834-34a383671c13/APEGBC-Code-of-Ethics.pdf.aspx
The purpose of the code of ethics is to give general statements of the principles of ethical conduct in order that members and licensees may fulfill their duty to the public, to the profession and their fellow members and licensees. Members and licensees shall act at all times with fairness, courtesy and good faith to their associates, employers, employees and clients, and with fidelity to the public needs. They shall uphold the values of truth, honesty and trustworthiness and safeguard human life and welfare and the environment. In keeping with these basic tenets, members and licensees shall:
1) Hold paramount the safety, health and welfare of the public, the protection of the environment and promote health and safety within the workplace;
2) Undertake and accept responsibility for professional assignments only when qualified by training or experience;
3) Provide an opinion on a professional subject only when it is founded upon adequate knowledge and honest conviction;
4) Act as faithful agents of their clients or employers, maintain confidentiality and avoid a conflict of interest but, where such conflict arises, fully disclose the circumstances without delay to the employer

or client;
5) Uphold the principle of appropriate and adequate compensation for the performance of engineering and geoscience work;
6) Keep themselves informed in order to maintain their competence, strive to advance the body of knowledge within which they practice and provide opportunities for the professional development of their associates;
7) Conduct themselves with fairness, courtesy and good faith towards clients, colleagues and others, give credit where it is due and accept, as well as give, honest and fair professional comment;
8) Present clearly to employers and clients the possible consequences if professional decisions or judgments are overruled or disregarded;
9) Report to their association or other appropriate agencies any hazardous, illegal or unethical professional decisions or practices by members, licensees or others; and
10) Extend public knowledge and appreciation of engineering and geoscience and protect the profession from misrepresentation and misunderstanding.

Ironworker's Memorial Bridge collapse

Ethics – Ironworkers Memorial Bridge

- Investigation into the collapse revealed that the temporary supports were inadequately designed, the webs of the temporary beams were too thin.
- Calculation error in the temporary support by Assistant Field Engineer
- Lack of checking by Field Engineer
- Both the field engineer and his assistant perished in the collapse

Information from

Andrews, G.C., "Canadian Professional Engineering and Geoscience – Practice and Ethics" Fifth Edition, Copyright 2014, 2009

https://www.egbc.ca/News/Articles/Never-before-seen-Footage-Documents-Second-Narrows

Site C Dam

Site C is a large hydroelectric project in Fort St. John, British Columbia, Canada. Overseen by BC Hydro.
https://www.bchydro.com/energy-in-bc/projects/site_c.html

Site C Dam artist's rendition from BC Hydro web site https://www.bchydro.com/energy-in-bc/projects/site_c.html Accessed July 9 2019

Here is a link to the official web site of the project for more details.
https://www.sitecproject.com/
Here is a link from an environmental group that opposes the dam.
https://www.wildernesscommittee.org/sitec

There are many ethical concerns about this project in particular around the first part of the code "1) Hold paramount the safety, health and welfare of the public, the protection of the environment and promote health and safety within the workplace".

- concerns about the amount of land being flooded
- concerns about lack of consultation with the First Nations community

Ethical concerns under code 2. "Undertake and accept responsibility for professional assignments only when qualified by training or experience." Concerns

- BC Hydro overseeing the design
- BC Utilities Commissions in Early 1980's rejected the Site C proposal
- Poor forecasting of energy demand
- Clean Energy Act of 2010 meant that Site C dam was exempt from further review

Ethical concerns under 7 “Conduct themselves with fairness, courtesy and good faith towards clients, colleagues and others, give credit where it is due and accept, as well as give, honest and fair professional comment,”

- BC Hydro
- BC Utilities Commission
- Stakeholders – Environmentalists and Indigenous People

Consequences from terminating projects identified by the Liberal Party

Bike Lanes in Vancouver

Engineers design things that put one or more people at risk. Try to minimize risk where possible.

https://bc.ctvnews.ca/caught-on-cam-bicycle-crushed-by-tanker-truck-in-east-vancouver-1.4001733

Vancouver has a plan, including engineering solutions, for having safer roads.
https://vancouver.ca/streets-transportation/transportation-safety.aspx

Biomedical issues and Ethics Genome Editing

Is it ethical to be manipulating DNA?

Materials and bioengineering

Stainless steel and titanium wire meshes expand to make stents. Here is a link to the American Heart Association.

https://www.heart.org/-/media/data-import/downloadables/pe-abh-what-is-a-stent-ucm_300452.pdf

Genome Editing and CRISPR

https://royalsociety.org/topics-policy/projects/genetic-technologies/what-are-genetic-technologies/

A nice short video from The Royal Society explaining this

A YouTube element has been excluded from this version of the text. You can view it online here: *https://pressbooks.bccampus.ca/engineeringinsociety/?p=340*

British girl treated for leukemia using gene therapy

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.bccampus.ca/engineeringinsociety/?p=340

One year later, still in remission. By Russ Logan January 2018. https://www.express.co.uk/news/uk/760024/Great-Ormond-Street-Hospital-cancer-cure-leukaemia-children-gene-editing

What is leukemia you ask? https://www.llscanada.org/leukemia

CRISPR

Explained by the Mayo Clinic https://interestingengineering.com/video/the-mayo-clinic-explains-crispr-in-a-way-you-can-understand https://www.sciencealert.com/scientists-have-figured-out-how-to-inject-human-eyes-with-night-vision

For a humourous take on this, John Oliver did a segment on CRISPR during his 2018 Last Week Tonight

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.bccampus.ca/engineeringinsociety/?p=340

SNC Lavalin and the Prime Minister of Canada

Engineering ethics might have a huge impact on the 2019 Federal Election. Two different ethical concerns.

Here are two articles by the CBC that summarize the original bribes which is the start of this case. From February 2015 "The RCMP laid fraud and bribery charges yesterday against three divisions of the company for work done in Libya between 2001 and 2011, alleging the subsidiaries paid $47.7 million in bribes and defrauded the people of the dictatorship ("Great Socialist People's Libyan Arab Jamahiriya") of $129.8 million."

You can access the whole article here: https://www.cbc.ca/news/business/snc-lavalin-bribery-case-threatens-billions-in-federal-contracts-1.2964018

An update from February 2019 detailing other issues at SNC Lavalin.
https://www.cbc.ca/news/canada/snc-lavalin-corruption-fraud-bribery-libya-muhc-1.5010865

Another summary of the SNC Lavalin case in the courts from June 2019
https://www.cbc.ca/news/canada/montreal/snc-lavalin-trial-corruption-bribery-judge-1.5193975

In August 2019, Prime Minister Trudeau says "I take responsibility" after the release of the report by the Federal Conflict of Interest and Ethics Commissioner Mario Dion who states the the Prime Minister inappropriately tried to influence Jody Wilson-Raybould when she was Attorney-General and Justice Minster of Canada.
https://www.cbc.ca/news/politics/trudeau-snc-ethics-commissioner-violated-code-1.5246551
https://www.cbc.ca/news/politics/trudeau-snc-ethics-commissioner-violated-code-1.5246551
https://www.cbc.ca/news/politics/trudeau-snc-ethics-commissioner-violated-code-1.5246551

Becoming a Professional Engineer in British Columbia

https://www.egbc.ca/Become-a-Member

Key Competencies

https://www.egbc.ca/Become-a-Member

34 Competencies

The Engineers and Geoscientists BC Competency Experience Reporting System is now competencyassessment.ca.

You can find the list of all 34 key competencies here
https://competencyassessment.ca/Indicators-Report?indicatorTypeId=5

2.1 Oral

3.3 Manage expectations in light of available resources
Course exercise: Design an object with design constraints such as
a) only donated materials, a budget of zero dollars
b) Maximum weight of the final project

4 – Team Effectiveness
4.1 – Work respectfully
Course exercise: groups were assigned randomly in the team research design project

6 – Safeguards
Course Exercise: Sea Level Change assignment.

Professional Societies

Provincial Regulators

Each Canadian province and territory has its own regulatory body to license engineers who meet the profession's high standards, and to govern the engineering profession. The associations listed below provide additional information about licensure and certification and offer professional training, education and networking opportunities.

Association of Professional Engineers and Geoscientists of British Columbia (APEGBC)
Association of Professional Engineers and Geoscientists of Alberta (APEGA)
Association of Professional Engineers and Geoscientists of Saskatchewan (APEGS)
Association of Professional Engineers and Geoscientists of the Province of Manitoba (APEGM)
Professional Engieers Ontario (PEO)
Ordre des ingénieursdu Québec (OIQ)
Association of Professional Engineers and Geoscientists of New Brunswick (APEGNB)
Engineers Nova Scotia (APENS)
Engineers PEI (APEPEI)
Professional Engineers and Geoscientists Newfoundland and Labrador (PEG-NL)
Association of Professional Engineers of Yukon (APEY)
Northwest Territories and Nunavut Association of Professional Engineers and Geoscientists (NAPEGG)

Engineering societies

Although they are not involved in the licensing of engineers in Canada, engineering societies play a key role in helping engineers learn about new theories, advanced techniques and modern equipment through their conference, seminars or publications.

Professional societies are a means to demonstrate a certain level of experience and competency, through a process of validation.

https://www.prepareforcanada.com/career-pathways/engineering/engineering-associations-in-canada/#.XUDblZNKg1A

Here is a list of some of the societies in Canada

Canadian Academy of Engineering (CAE)
Canadian Dam Association
Canadian Federation of Engineering Students (CFES)
The Canadian Medical and Biological Engineering Society

Canadian Society for Bioengineering
Canadian Society for Chemical Engineering
Canadian Society for Civil Engineering
Canadian Society for Engineering Management
Canadian Society for Mechanical Engineering
The Chemical Institute of Canada
Consulting Engineers of New Brunswick
Consulting Engineers of Manitoba
Engineering Institute of Canada (EIC)
Generation-E (Engineering Career Awareness site)
Institute of Electrical and Electronics Engineering

Appendix A APEGBC Engineers and Geoscientists of British Columbia

ABOUT APEGBC

https://www.egbc.ca/

Engineers and Geoscientists British Columbia is the business name of the Association of Professional Engineers and Geoscientists of the Province of British Columbia. Engineers and Geoscientists BC regulates and governs these professions under the authority of the *Engineers and Geoscientists Act*.

The association is charged with protecting the public interest by setting and maintaining high academic, experience, and professional practice standards for all 34,000 members. Individuals licensed by Engineers and Geoscientists BC are the only persons permitted by law to undertake and assume responsibility for engineering and geoscience projects in BC.

We are a not-for-profit organization governed by a council of elected members, licensees and government appointees. Council is accountable to the public through the Ministry of Advanced Education for both the governance and management of the association.

OUR VISION

Engineering and geoscience professionals creating a better future for all.

OUR MISSION

To serve the public interest as a progressive regulator that supports and promotes the engineering and geoscience professions.

OUR VALUES

In our governance, administration and delivery of service, we are guided by the following values:

- Integrity: We mean and do what we say,
- Accountability: We are responsible for our actions, and
- Innovation: We will explore new ideas to make things better.

WorkSafe BC or Worker's Compensation Board

https://www.worksafebc.com/en/about-us/who-we-are/mission-vision-values

WorkSafe BC is committed to creating a province free from workplace injury or illness, and to providing service driven by their core values of integrity, accountability, and innovation. By partnering with workers and employers, it helps British Columbians come home from work safe every day.

https://www.worksafebc.com/en/about-us/shared-data

In 2016, people in B.C. missed 2.6 million days of work and 144 people lost their lives due to work-related incidents and disease.

Engineering Humour - Engineer's Guide to Cats

Two professional engineers illustrate the proper care and practical benefits of cats. None of the cats, humans, or engineers were mistreated in the making of this film. They were however, slightly annoyed. T-shirts and other goodies available.

https://www.youtube.com/watch?v=mHXBL6bzAR4

Engineering Humour - Cooking for Engineers®

Have an analytical mind? Like to cook? This is the site to read!
http://www.cookingforengineers.com