

Engineering and Technology in Society - Canada

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Jennifer Kirkey and Sahar Bani Soltan



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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. <https://www.coupland.com/> Photography was encouraged. CC BY 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

Corequisites ENGL 1130 or CMNS 1135 must be completed prior to OR at the same time as this course.

Equivalencies Not Specified

Maximum Class Size: 36

PLAR: No

COURSE CURRICULUM

Learning Outcomes After 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 Content Students 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\Materials Students 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 Assessment Evaluation 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, Djoser](#), 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 Station](#) represents 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. Airplane
4. Water supply and distribution
5. Electronics
6. Radio and television
7. Agriculture mechanization
8. Computers
9. Telephone
10. Refrigeration and air conditioning
11. Highways
12. Spacecraft
13. Internet
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

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/Complaints-Discipline/Code-of-Ethics/Code-of-Ethics>

The Engineers and Geoscientists Act

The [*Engineers and Geoscientists Act*](#), the professions' governing legislation, guide the association and its members and licensees in performing their duties.

As it stated on the EGBC web site as of March 20 2022, The Code of Ethics required under the *Professional Governance Act*, S.B.C. 2018, c. 47 and created in the Bylaws of Engineers and Geoscientists BC provides a set of principles that all registrants are required to follow.

Code of Ethics

A registrant must adhere to the following Code of Ethics:

Registrants must act at all times with fairness, courtesy and good faith toward all persons with whom the registrant has professional dealings, and in accordance with the public interest. Registrants must uphold the values of truth, honesty, and trustworthiness and safeguard human life and welfare and the environment. In keeping with these basic tenets, registrants must:

1. hold paramount the safety, health, and welfare of the public, including the protection of the environment and the promotion of health and safety in the workplace;
2. practice only in those fields where training and ability make the registrant professionally competent;
3. have regard for the common law and any applicable enactments, federal enactments, or enactments of another province;
4. have regard for applicable standards, policies, plans, and practices established by the government or Engineers and Geoscientists BC;
5. maintain competence in relevant specializations, including advances in the regulated practice and relevant science;
6. provide accurate information in respect of qualifications and experience;
7. provide professional opinions that distinguish between facts, assumptions, and opinions;
8. avoid situations and circumstances in which there is a real or perceived conflict of interest and ensure conflicts of interest, including perceived conflicts of interest, are properly disclosed and necessary measures are taken so a conflict of interest does not bias decisions or recommendations;
9. report to Engineers and Geoscientists BC and, if applicable, any other appropriate authority, if the registrant, on reasonable and probable grounds, believes that:

1. the continued practice of a regulated practice by another registrant or other person, including firms and employers, might pose a risk of significant harm to the environment or to the health or safety of the public or a group of people; or
 2. a registrant or another individual has made decisions or engaged in practices which may be illegal or unethical;
10. present clearly to employers and clients the possible consequences if professional decisions or judgments are overruled or disregarded;
 11. clearly identify each registrant who has contributed professional work, including recommendations, reports, statements, or opinions;
 12. undertake work and documentation with due diligence and in accordance with any guidance developed to standardize professional documentation for the applicable profession; and
 13. 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.

Frequently Asked Questions

<https://www.egbc.ca/Complaints-Discipline/Code-of-Ethics/Frequently-Asked-Questions>

Why does the Organization have a Code of Ethics that applies to all its registrants?

There are two essential aspects of being an accredited professional engineer or professional geoscientist through registration with a professional organization such as Engineers and Geoscientists BC.

The first is the ability to assure the public that by virtue of your professional qualification you possess a level of expertise, knowledge, and experience appropriate to activities and undertakings that potentially carry significant risks to public health and safety and to the physical and natural environment. The second is the ability to assure the public that you are governed not only by legal and regulatory requirements and standards, but also by an additional higher standard of ethics and integrity—set out in the organization's [Code of Ethics](#) — that places on you the paramount duty to uphold the values of truth, honesty, and trustworthiness, and to safeguard human life and welfare and to protect the environment.

The Code of Ethics is a condition of acceptance into and continued registration with the organization. It sets a high standard of conduct that is binding on and applies consistently to all registrants of Engineers and Geoscientists BC.

What is the difference between the legal or regulatory standards requirements and ethical standards?

Generally speaking, laws and regulations establish the thresholds and formal boundaries that set the minimum requirements or standards necessary, acceptable, and permissible to balance and protect competing interests in society.

Complying or operating in conformity with laws and regulations is the first step in ethical practice,

but merely asking “what is necessary to comply with the law or regulation” is not the same as asking the ethics question “what is right?”

Ethical standards go beyond what is required to comply with the law to address what is necessary to ensure honesty, integrity, respect, responsibility, trustworthiness, and concern for others in all actions and decisions. As a registrant with Engineers and Geoscientists BC, your conduct must meet the higher ethical standards outlined in the [Code of Ethics](#) over and above what is required by law.

Why are the standards in the Code of Ethics higher than those required by law?

Generally speaking, laws and regulations establish the thresholds and formal boundaries that set the minimum requirements or standards necessary, acceptable, and permissible to balance and protect competing interests in society.

Complying or operating in conformity with laws and regulations is the first step in ethical practice, but merely asking “what is necessary to comply with the law or regulation” is not the same as asking the ethics question “what is right?”

Ethical standards go beyond what is required to comply with the law to address what is necessary to ensure honesty, integrity, respect, responsibility, trustworthiness, and concern for others in all actions and decisions. As a registrant with Engineers and Geoscientists BC, your conduct must meet the higher ethical standards outlined in the [Code of Ethics](#) over and above what is required by law.

Why am I expected to uphold ethical standards in the profession beyond my own work responsibility?

As a registrant with Engineers and Geoscientists BC, you are governed by the [Code of Ethics](#) that requires you to act at all times with fairness, courtesy, and good faith to your associates, employers, employees, and clients and with fidelity to the public needs.

The Code also places on you the duty to uphold the values of truth, honesty and trustworthiness and to safeguard human life and welfare and protect the environment. As a consequence, you have professional responsibilities under the Code that extend beyond the immediate scope of your own conduct and work, particularly and especially with respect to matters that affect or potentially affect public health and safety and protection of the environment.

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 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 and Under-Represented Individuals in Engineering

Women are an under-represented group in the engineering profession. As stated by Engineers Canada at <https://engineerscanada.ca/diversity/women-in-engineering>

Women make up more than half of the Canadian population but are significantly underrepresented in engineering education and in the engineering profession. Over the past decades, the number of women enrolled in post-secondary engineering programs has risen, as has the number of women in the engineering profession. Yet despite steady increases in the representation of women, men still vastly outnumber women in engineering.

In the [Engineers Canada Strategic Plan, 2019-2021](#), the Engineers Canada Board made the [recruitment, retention](#), and [professional development](#) of women in the engineering profession one of four strategic priorities for the organization, and directed Engineers Canada to develop [goals and action plans](#) for all three of these areas. Engineers Canada consulted regulators and 30 by 30 Champions on the three areas and published an [Environmental Scan](#) on the current state and context of the 30 by 30 initiative. This work is primarily carried out through Engineers Canada's [30 by 30](#) initiative, which has as its goal raising the percentage of newly licensed engineers who are women to 30 per cent by the year 2030. Thirty per cent is held as the tipping point for sustainable change—reaching 30 by 30 will help drive cultural change in the engineering profession, supporting even greater involvement of women in the profession.

There are many organizations working to increase diversity in engineering. CCWESTT or the Canadian Coalition of Women in Engineering, Science, Trades and Technology is just one of them. <https://www.cwestt.org/>

International Women in Engineering Day

Every year on June 23, Engineers Canada joins individuals and organizations around the world in celebrating [International Women in Engineering Day](#). While Engineers Canada and others work year-round to increase the representation of women in engineering, International Women in Engineering Day is an opportunity to shine a spotlight on the achievements of women in engineering, share our successes, and bring even more attention to the need to continue this important work throughout the year.

National Day of Remembrance and Action on Violence Against Women

It has been over 30 years since the murder of 14 young women, most of whom were engineering students, at Polytechnique Montréal (December 6, 1989). This act of violent misogyny shook our country and led the Canadian Parliament to designate December 6 as The National Day of Remembrance and Action on Violence Against Women. <https://women-gender-equality.canada.ca/en/commemorations-celebrations/16-days/national-day-remembrance.html>

As we mourn their loss and remember their lives, we reaffirm our commitment to fight the hatred that led to this tragedy, and the misogyny that still exists today. In Canada and around the world, women,

girls, 2SLGBTQIA+ (two-spirit, lesbian, gay, bisexual, transgender, queer, questioning, intersex, asexual, plus) and gender diverse individuals face unacceptable violence and discrimination.

The National Day of Remembrance and Action on Violence Against Women is about remembering those who have experienced gender-based violence and those who we have lost to it. It is also a time to take action. Achieving a Canada free from gender-based violence requires everyone living in this country to educate themselves and their families and communities on gender-based violence, centre the voices of survivors in our actions and speak up against harmful behaviours.

Mentorship – an example from the University of Alberta

Inspired by the Lean-In movement whose mission is to “help women achieve their ambitions and work to create an equal world.” You can learn more about lean-in here: <https://leanin.org/>

The University of Alberta (UA) is located in Edmonton, Alberta, Canada. <https://www.ualberta.ca/index.html> It has a UA-WiSE/WISER Mentorship Program which aims to connect women and under-represented individuals in STEM fields with mentors who can help foster professional development and personal discovery.

You can get more information here: <https://wiseredmonton.ca/mentorship-program-2021-2022/>

This is part of the WISEST group at the University of Alberta, Canada. Women in Scholarship, Engineering, Science, & Technology (WISEST) focuses on creating effective programs to empower women (and other underrepresented groups) to pursue, impact, and succeed in the fields of science, engineering, and technology. You can get more information here: <https://www.ualberta.ca/women-in-scholarship-engineering-science-technology/index.html>

Five Amazing Women in Engineering

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

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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](#), [Mapungubwe](#) in 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, extraterrestrials 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 capital 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/>



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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 northwestern 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.

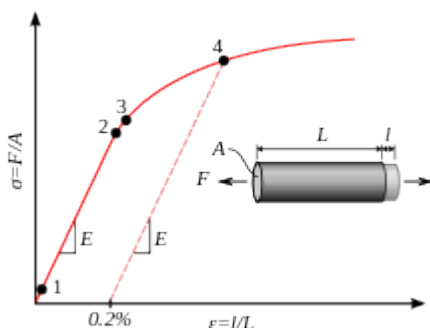
Importance of safety

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, 1992](#) is 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 occurring.

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_\(1940\)](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.



Opening day of the Tacoma Narrows Bridge, Tacoma, Washington, July 1, 1940 Photographer: Unknown Subjects (LCSH): Tacoma Narrows Bridge (Tacoma, Wash. : 1940) Bridges—Washington (State)—Tacoma Narrows Automobiles—Washington (State)—Tacoma Crowds—Washington (State)—Tacoma Tacoma Narrows (Tacoma, Wash.) Straits—Washington (State)—Tacoma Digital Collection: Tacoma Narrows Bridge Collection content.lib.washington.edu/farquharsonweb/index.html Item Number: FAR008 Persistent URL: content.lib.washington.edu/u?/farquharson,13 Visit Special Collections reproductions and rights page for information on ordering a copy. University of Washington Libraries. Digital Collections content.lib.washington.edu/

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.

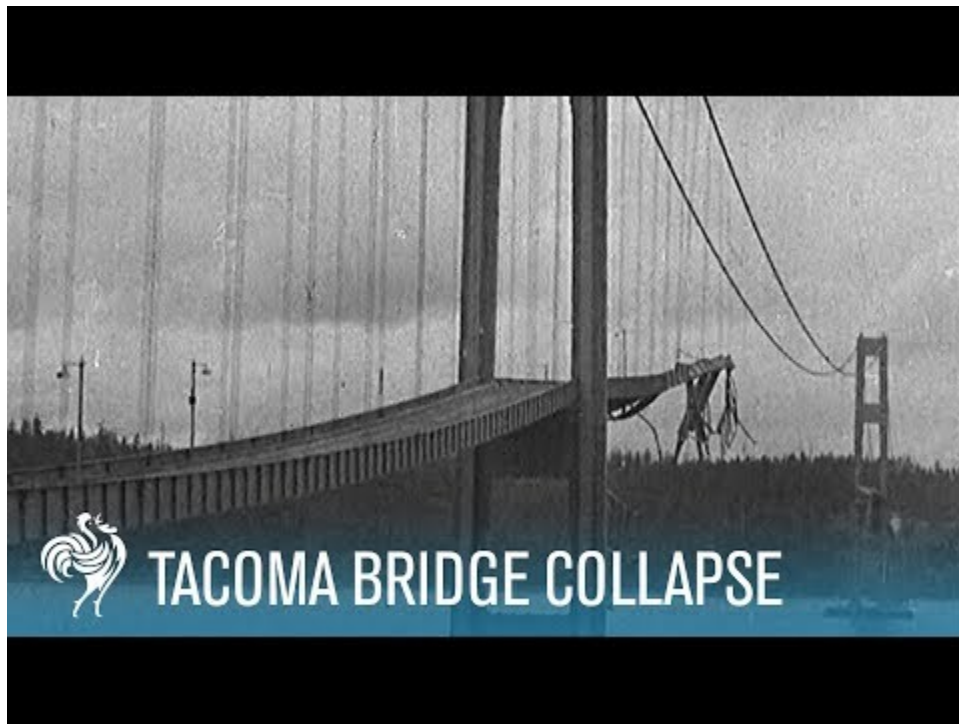
Following the collapse, the United States' involvement in [World War II](#) delayed plans to replace the bridge. The portions of the bridge still standing after the collapse, including the towers and cables, were dismantled and sold as scrap metal. Nearly 10 years after the collapse, a [new Tacoma Narrows 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.

Here is some footage from British Pathé

<https://www.britishpathe.com/>



A YouTube element has been excluded from this version of the text. You can view it online here:

<https://pressbooks.bccampus.ca/engineeringinsociety/?p=38>

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 [Louisiana](#) and [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 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

By NASA – <http://grin.hq.nasa.gov/ABSTRACTS/GPN-2003-00080.html>
Public Domain, <https://commons.wikimedia.org/w/index.php?curid=259978>

Nautical Disaster - Steamboat Sultana 1865

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

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

Quebec City Bridge

The Quebec Bridge is a road, rail, and pedestrian bridge across the lower Saint Lawrence River between Sainte-Foy and Lévis, near Quebec City, Quebec, Canada.

The project failed twice during its construction, in 1907 and 1916, at the cost of 88 lives and additional persons injured. It took more than 30 years to complete and eventually opened in 1919.

https://en.wikipedia.org/wiki/Quebec_Bridge#First_design_and_collapse_of_August_29,_1907

First design and collapse of August 29, 1907



The twisted wreckage of the 1907 bridge. Image credit: Unknown author – Holgate, Henry; Derry, John, G. G.; Galbraith, John. (1908). Royal Commission Quebec Bridge Inquiry Report. Sessional Paper No 154. S.E. Dawson printer to the King Ottawa. Appendix 19, figure 20 ; scan found at http://matdl.org/failurecases/Bridge_Collapse_Cases/Quebec_Bridge

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 East](#) riding, 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.

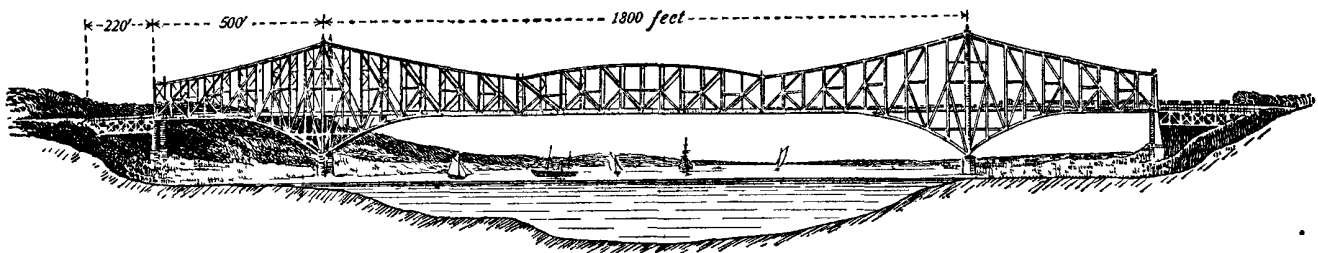
Cooper escaped penal sanction.^[17] It is presumed that Szlapka escaped as well. The Commissioners also found that:

(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.

Engineer Iron Rings Myth

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. The centre span is 1800 feet.

Second design and collapse of September 11, 1916

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.



The Quebec Bridge collapsed on 11 September 1916 a second time due to poor design work and materials, killing thirteen workers. The bridge, which was conceived to be one of the most advanced in the world, had already collapsed under similar circumstances in 1907. In that tragedy, eighty-five workers perished prompting a Dominion Royal Commission to investigate the catastrophic failure.

Lifting the centre span in place was considered to be a major engineering achievement.

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

The **Florida International University pedestrian bridge collapse** occurred on March 15, 2018, when a 175-foot-long (53 m) section of the FIU-Sweetwater University City Pedestrian Bridge collapsed while under construction. The collapse resulted in six deaths (one worker and five motorists), ten injuries (six serious and four minor), and eight vehicles being crushed underneath.

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.

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 No. 1)

Collapse on June 17, 1958



View (looking east) of new Second Narrows Bridge, 2 months after the collapse of 2 spans, Image credit: Ron Thomson, Personal Collection CC BY-SA 3.0 File:Second Narrows Bridge (Vancouver).jpg Created: 17 August 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]

Jennifer Kirkey 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. Image credit: Jennifer Kirkey CCO

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://teachbcd.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 m²) 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/commissionerinqirystationsquare.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 Hazelton 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 nongovernmental 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 camchanka 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 professional responsibilities were neglected, if any?

Should NASA have done anything differently in their launch decision procedure?

Texas A&M University 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 EGBC

<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.

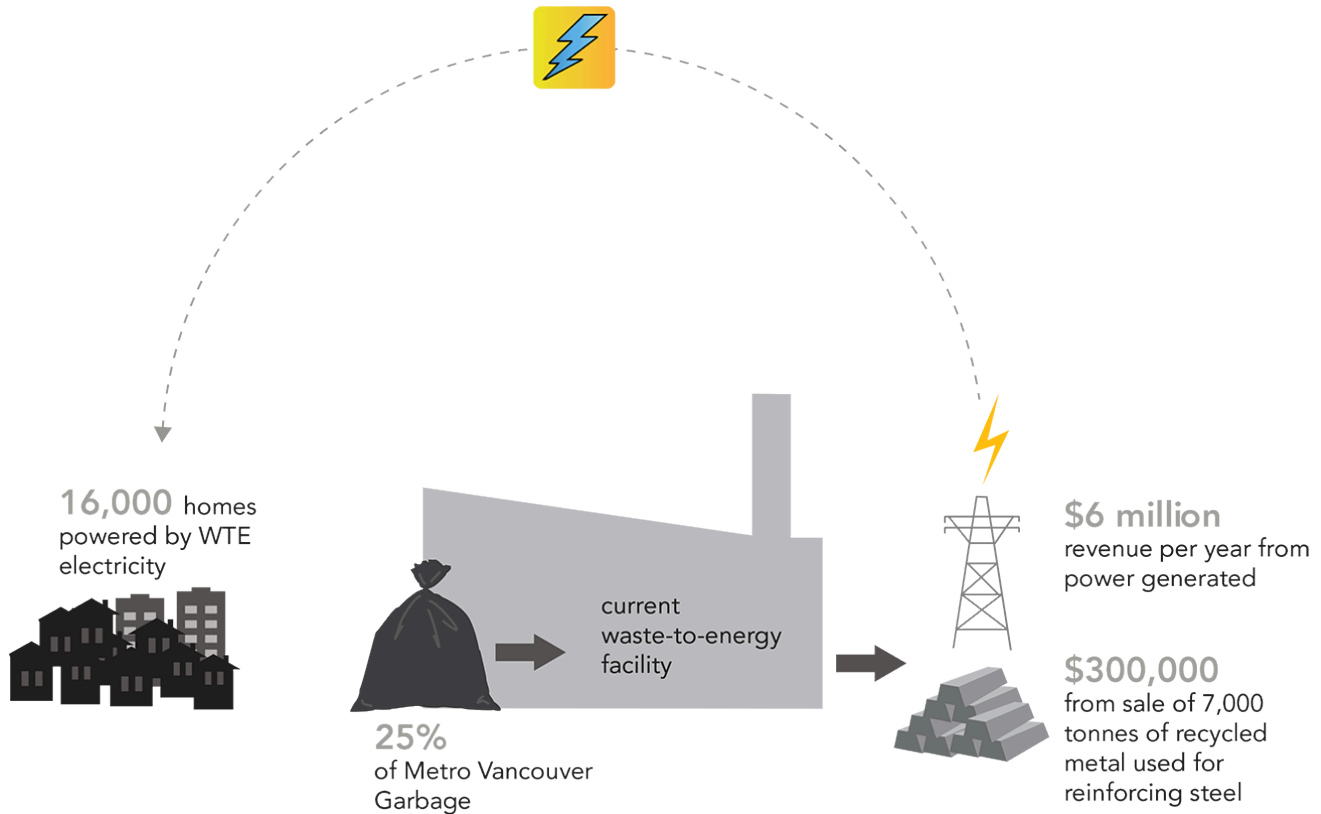
2.5 GUIDELINE 5: ASSESS SUSTAINABILITY PERFORMANCE AND IDENTIFY OPPORTUNITIES FOR IMPROVEMENT

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.



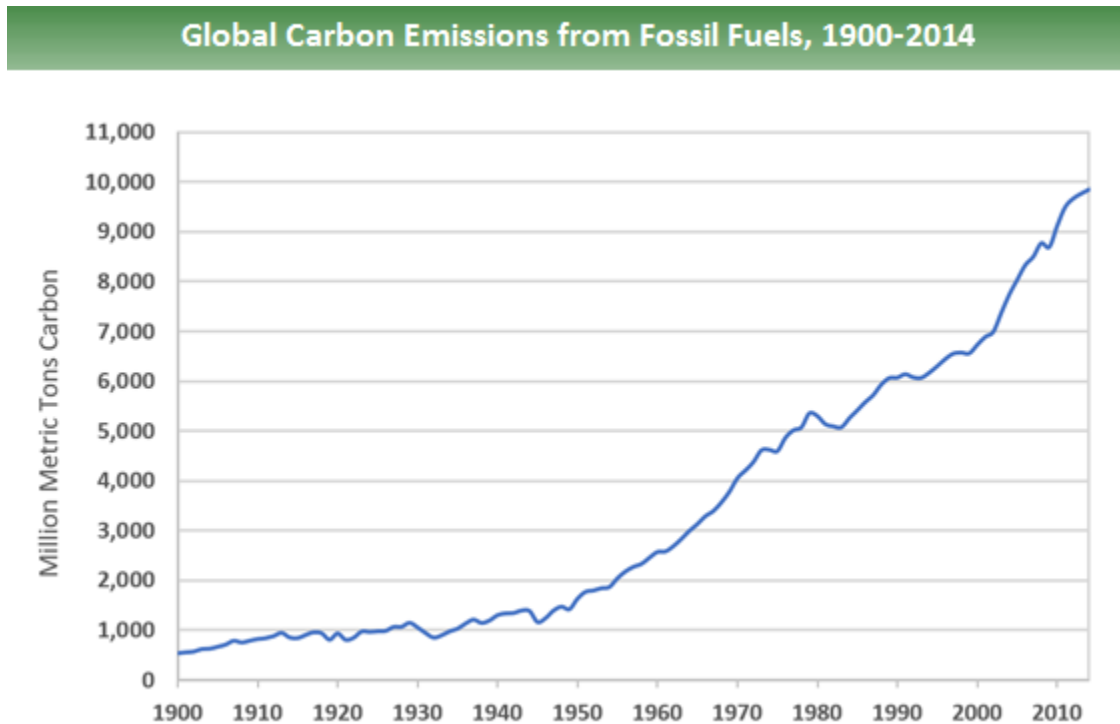
Waste to Energy Facility operated by Covanta in Metro Vancouver. This image was accessed from the facility web page on June 7 2019 <https://www.covanta.com/Our-Facilities/Covanta-Burnaby>

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>

Trends in Global Emissions

Global Carbon Emission from Fossil Fuels from 1900 – 2014



Global Carbon Emissions from 1900-2014 Source: Boden, T.A., Marland, G., and Andres, R.J. (2017). Global, Regional, and National Fossil-Fuel CO₂Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi 10.3334/CDIAC/00001_V2017.

Source: Boden, T.A., Marland, G., and Andres, R.J. (2017). Global, Regional, and National Fossil-Fuel CO₂Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi 10.3334/CDIAC/00001_V2017.

“Global carbon emissions from fossil fuels have significantly increased since 1900. Since 1970, CO₂ emissions have increased by about 90%, with emissions from fossil fuel combustion and industrial processes contributing about 78% of the total greenhouse gas emissions increase from 1970 to 2011. Agriculture, deforestation, and other land-use changes have been the second-largest contributors”.¹

1. <https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data#Reference%201>

The Climate is Changing

The IPCC is the Intergovernmental Panel on Climate Change. It is the United Nations body for assessing the science related to climate change. You can learn more about them here: <https://www.ipcc.ch/>

Here is the way that the IPCC defines climate and climate change.

Climate

“Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the *climate system* to be”

Climate Change

“Climate change refers to a change in the state of the *climate* that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external *forcings* such as modulations of the solar cycles, volcanic eruptions and persistent *anthropogenic* changes in the composition of the *atmosphere* or in *land use*. Note that the *Framework Convention on Climate Change (UNFCCC)*, in its Article 1, defines climate change as: ‘a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.’ The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes”.

2

Life Cycle Analysis (LCA)

Climate change results in a global crisis. What will be an answer to a global crisis? Sustainability and the full Life Cycle Analysis (LCA).

North American working group of the Mining and Sustainable Development, (MMSD-NA, 2002) developed “seven questions to guide sustainability assessments of the Full-Life cycle of mining projects as discussed in Gibson et al. (2005). They are related to the engaging community, people’s well-being, the integrity of the environment, the economic viability of the project and the community, acceptable

2. PCC, 2018: Annex I: Glossary [Matthews, J.B.R. (ed.)]. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press

to the community by accounting for the traditional activities of the community, project consequences, periodic reassessment of the results.

And, we need to implement LCA into our design to ensure minimizing harmful material/processes in the environment and a more sustainable design. This means (Jha, N. K. 2015):

- Design for Assembly (Mining Material Process, Product Manufacturing, Distribution)
- Design for Disassembly (Design for Recycling, Design for Reuse, Design for Disposal)

There are a couple of LCA tools available at this time

- Sphera (Gabi) Database <https://gabi.sphera.com/databases/gabi-databases/>
- Simapro Database <https://simapro.com/>
- Emissions Impact Dashboard for Microsoft
- https://www.microsoft.com/en-us/sustainability/emissions-impact-dashboard?activetab=pivot_2%3aprimar12
- Life cycle initiative <https://www.lifecycleinitiative.org/>
- U.S. Life Cycle Inventory Database: <https://www.nrel.gov/lci/>

As the industry is responding to the call from the public/policymakers, they develop some platforms to integrate the LCA aspects into the modeling. For example, Solidworks uses “The GaBi environmental LCA database and a set of environmental impacts obtained through a combination of scientific experimentation and empirical results obtained in the field. (Solidwork Sustainability 2022)”. They are using four key environmental indicators (carbon footprint, total energy consumed, air acidification, and water eutrophication) indicators.

Some related information:

- Carbon footprint:
<https://www.newsteelconstruction.com/wp/the-carbon-footprint-of-steel/>
- Water
https://www.researchgate.net/publication/5494047_Mechanisms_and_Assessment_of_Water_Eutrophication
- Air Acidification
<https://www.sciencedirect.com/topics/engineering/acidification-potential>
- Total Energy Consumed
https://www.researchgate.net/publication/336227431_The_Material_Indices_Method_in_the_Sustainable_Engineering_Design_Process_A_Review

The above indicators are related to product developments. However, for some projects such as mining projects we need other indicators. Overall sustainable development (SD) indicator is defined (Martinho (n.d.)) as the average of social summary measure (Soc), economic summary measure (Eco), and environmental summary measure (Env).

List of Resources

- Boden, T.A., Marland, G., and Andres, R.J. (2017). Global, Regional, and National Fossil-Fuel CO₂Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi 10.3334/CDIAC/00001_V2017.

Retrieved from <https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data> on Feb 19, 2022

- Bob Gibson, Selma Hassan, James Tansey. Sustainability Assessment Criteria and Processes. Routledge; 2005. Accessed February 20, 2022.

[https://search.ebscohost.com/](https://search.ebscohost.com/login.aspx?direct=true&AuthType=ip,sso&db=nlebk&AN=142635&site=eds-live&scope=site)

[login.aspx?direct=true&AuthType=ip,sso&db=nlebk&AN=142635&site=eds-live&scope=site](https://search.ebscohost.com/login.aspx?direct=true&AuthType=ip,sso&db=nlebk&AN=142635&site=eds-live&scope=site)

- Intergovernmental Panel on Climate Change (2008) “Climate Change 2007 Synthesis Report” Retrieved from

https://www.ipcc.ch/site/assets/uploads/2018/02/ar4_syr_full_report.pdf on Feb 19, 2022

- Imperatives (1987) Report of the World Commission on Environment and Development: Our Common Future

- Jha, N. K. (2015). Integration of Green Design and Manufacturing for Sustainability in Undergraduate Engineering Curriculum.

- Martinho M. (N.D.) “Integrating social, environmental and economic dimensions into a monitoring framework” Retrieved from <https://slideplayer.com/slide/4509562/> on March 10th

- MMSD-NA, Mining, Minerals and Sustainable Development Project North America, Task 2 Work Group (2002) Seven Questions to Sustainability: How to Assess the Contribution of Mining and Minerals Activities, Winnipeg, IISD

- Mining, Minerals and Sustainable Development North America, MMSD (2002) https://www.iisd.org/pdf/2002/mmsd_sevenquestions.Pdf

- Pacific Climate Impact Consortium (2012) <http://www.plan2adapt.ca/tools/planners?pr=0&ts=8&toy=16>

- Solidworks (2022) Retrieved it from <https://www.solidworks.com/solutions/what-life-cycle-assessmentlca#:~:>

[text=SOLIDWORKS%C2%AE%20Sustainability%20provides%20actionable,as%20well%20as%20of](https://www.solidworks.com/solutions/what-life-cycle-assessmentlca#:~:)fering%20alternatives On March 12, 2022

- UN (1987) Our Common Future Retrieved from https://www.are.admin.ch/dam/are/en/dokumente/nachhaltige_entwicklung/dokumente/bericht/our_common_futurebrundtlandreport1987.pdf Retrieved On March 14, 2022

Chapter 7 - Climate Change

<https://www.egbc.ca/Practice-Resources/Programs-Resources/Climate-Sustainability>

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.

<https://www.egbc.ca/Practice-Resources/Programs-Resources/Climate-Sustainability>

Climate Change from EGBC

CLIMATE

Excerpts from: <https://www.egbc.ca/Practice-Resources/Programs-Resources/Climate-Sustainability>

Climate & Sustainability

Climate

Engineers and Geoscientists BC is committed to providing registrants with support in incorporating a consideration of climate change into their practice. We have undertaken several initiatives to explore the impact of climate change on professional engineering and geoscience practice.

Registrants, through the Climate Change Advisory Group, advise Council on these matters on an ongoing basis.

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 regulatory support.

Climate Change Action Plan

The Climate Change Advisory Group developed a [Climate Change Action Plan](#) that gives Engineers and Geoscientists BC an appropriate and methodical approach to addressing climate change issues related to the practice of professional engineering and geoscience.

This plan provides a framework for how Engineers and Geoscientists BC can better support its registrants in their professional practice and allow Engineers and Geoscientists BC to respond to climate change issues proactively rather than reactively. The “[What We Heard Report](#)” summarizes the feedback we heard from registrants on the development of the Climate Change Action Plan.

Position Statements

- [Engineers and Geoscientists BC feedback on the CleanBC Preparing Together Engagement Opportunity](#)
- [Engineers and Geoscientists BC feedback on BC Climate Action Secretariat’s Discussion Paper on the Climate Leadership Plan](#)

- [2016 Engineers and Geoscientists BC Position Paper on Human-Induced Climate Change](#)
- [2014 Engineers and Geoscientists BC Climate Change Position Paper on evolving responsibilities for engineers and geoscientists](#)

2017 Climate Change Awareness Survey Findings

The 2017 Climate Change Survey was developed by Engineers and Geoscientists BC's Climate Change Advisory Group to better assess how the organization can support registrants to consider the impact their work has on the climate, as well as the impact of climate on their professional activities.

Sustainability

Sustainability is the concept of employing 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 BC has consistently supported and encouraged its registrants to adapt sustainable principles within the practice of professional engineering and geoscience.

Here is the link to the sustainability guidelines, retrieved March 2022

<https://www.egbc.ca/getmedia/3686f97d-f6cf-41a1-9ca2-b99f298f15cf/APEGBC-Sustainability-Guidelines.pdf.aspx>

Climate Change Implication in BC Projects

Two major modelings that have been used in BC projects are

Plan2adapt: <https://services.pacificclimate.org/plan2adapt/app/>

IDF-CC : <https://www.idf-cc-uwo.ca/>

Climate change will cause the sea level rise (SLR) which is expected to impact the BC communities. Therefore, some flood hazard modelings have been performed to understand the effect of the SLR in Metro Vancouver:

<http://floodplain.ca/Vancouver-Floodplain-Map.htm>

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/vancouver-s-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

Chapter 8 - Current Technology and Emergent Issues

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.”

Chapter 9 - 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 humorous 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 Minister 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>

Chapter 10 - 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 Engineers Ontario](#) (PEO)

[Ordre des ingénieurs du 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](#)

Chapter 11 - Canadian Engineers

An incomplete list of historical and current engineers of note, in Canada.

For more information the best place to start looking is at

<https://engineerscanada.ca/awards-and-honours/awards/past-recipients-awards>

Olivia Poole - inventor - Jolly Jumper - First Indigenous Woman in Canada to Patent an Invention

Olivia Poole and the Jolly Jumper – First Indigenous Woman in Canada to Patent an Invention

Susan Olivia Davis Poole, inventor (born 18 April 1889 in Devils Lake, North Dakota; died 10 October 1975 in Ganges, BC). Olivia Poole was raised on the [Ojibwe](#) White Earth Reservation in Minnesota. There, she was inspired by the traditional practice of using a bouncing [cradleboard](#) to soothe babies. In 1957, she patented her invention of the baby jumper, under the name Jolly Jumper, making her one of the first [Indigenous](#) women in Canada to patent and profit from an invention.

For more information on Olivia Poole:

<https://www.thecanadianencyclopedia.ca/en/article/olivia-poole>

To see a video of the Jolly Jumper in action from 1957 please visit CBC:

<https://www.cbc.ca/archives/the-jolly-jumper-a-new-canadian-creation-in-1957-1.4776616>

The company is still based in Ontario, Canada

<https://www.jollyjumper.com/pages/about-us>

Indigenous thinkers reinvigorate STEM with traditional knowledge

CBC Unreserved Episode from October 29, 2021

“Indigenous knowledge is more than beads, drums and sweetgrass — it’s also science, technology, engineering and math (STEM). On this episode of *Unreserved*, we talk to several people reintegrating traditional knowledge into scientific discourse.”

You can listen to the whole episode here:

<https://www.cbc.ca/radio/unreserved/indigenous-thinkers-reinvigorate-stem-with-traditional-knowledge-1.6225338>

ABOUT THE SHOW

<https://www.cbc.ca/radio/unreserved>

Unreserved is the radio space for Indigenous community, culture, and conversation. Host Falen Johnson takes you straight into Indigenous Canada, from Halifax to Haida Gwaii, from Shamattawa to Ottawa, introducing listeners to the storytellers, culture makers and community shakers from across the country. The *Unreserved* team offers real talk from the people behind the headlines, with a soundtrack from the best in Indigenous music.

ABOUT THE HOST

Rosanna Deerchild (she/her) is Cree, from the community of O-Pipon-Na-Piwan Cree Nation.

Bjarni Tryggvason - Engineer and Astronaut

Bjarni Tryggvason

Born in Iceland on September 21, 1945

Died on April 6 2022

He one of the original six Canadian astronauts selected in December 1983. He flew aboard Space Shuttle *Discovery* on August 7, 1997, as a payload specialist. He spent over 11 days in space, where he successfully operated a Canadian technology he helped develop: the Microgravity Vibration Isolation Mount. Designed to isolate payloads from vibrations, this technology would later be adapted for the Canadian Microgravity Vibration Isolation Subsystem. He had a Bachelor of Applied Science in Engineering Physics and did postgraduate work in engineering with specialization in applied mathematics and fluid dynamics.

<https://www.canada.ca/en/space-agency/news/2022/04/the-canadian-space-agency-remembers-bjarni-tryggvason.html>

<https://asc-csa.gc.ca/eng/astronauts/canadian/former/bio-bjarni-tryggvason.asp>

Chris Hadfield - Engineer and Astronaut

Chris Hadfield

Was the first Canadian to

<https://www.asc-csa.gc.ca/eng/astronauts/canadian/former/bio-chris-hadfield.asp>

Born August 29, 1959, in Sarnia, and raised in Milton, Ontario.

Education: Graduated as an Ontario Scholar from Milton District High School in 1977; Received a bachelor's degree in mechanical engineering (with honours), Royal Military College, Kingston, Ontario, Canada, in 1982; Conducted post-graduate research at the University of Waterloo, Ontario in 1982; Received a Master of Science in aviation systems at the University of Tennessee in 1992.

Experience: In June 1992 Chris Hadfield was selected to become one of four new Canadian astronauts from a field of 5330 applicants.

Space flights

In November 1995 Hadfield served as Mission Specialist 1 on [STS-74](#), NASA's second space shuttle mission to rendezvous and dock with the Russian Space Station Mir.

In April 2001 Hadfield served as Mission Specialist 1 on [STS-100](#) International Space Station (ISS) assembly Flight 6A. The crew of Space Shuttle Endeavour delivered and installed Canadarm2, the new Canadian-built robotic arm, as well as the Italian-made resupply module Raffaello.

In September 2010, Chris Hadfield was assigned to [Expedition 34/35](#). On December 19, 2012 he launched aboard the Russian Soyuz, enroute to becoming the second Canadian to take part in a long-duration spaceflight aboard the ISS. On March 13, 2013 he became the first Canadian to command a spaceship as Commander of the ISS during the second portion of his five-month stay in space. On May 13, Hadfield, Tom Marshburn and Roman Romanenko landed in Kazakhstan after travelling almost 99.8 million kilometres while completing 2,336 orbits of Earth. The trio spent 146 days in space, 144 of which were aboard the station.

Julie Payette - Engineer and Astronaut

Julie Payette

You can learn much more about her career from the Canadian Space Agency web site at

<https://www.asc-csa.gc.ca/eng/astronauts/canadian/former/bio-julie-payette.asp>

Personal Profile: Born October 20, 1963, in Montreal, Quebec

Education: Attended primary and secondary school in Montreal. International Baccalaureate (1982) from the United World College of the Atlantic in Wales, UK. Bachelor of Engineering, Electrical (1986) cum laude from McGill University. Master of Applied Science – Computer Engineering (1990) from the University of Toronto.

Experience: Before joining the space program, Ms. Payette conducted research in computer systems, natural language processing and automatic speech recognition. In June 1992, the Canadian Space Agency (CSA) selected Ms. Payette from 5330 applicants to become one of four astronauts. After her basic training in Canada, she worked as a technical advisor for the Mobile Servicing System, an advanced robotics system contributed by Canada to the International Space Station (ISS).

Space Flight Experience: Julie Payette flew on Space Shuttle Discovery from May 27 to June 6, 1999, as a crewmember of [STS-96](#). During the mission, the crew performed the first manual docking of the Shuttle to the International Space Station, and delivered four tons of supplies to the Station. Ms. Payette served as a mission specialist, was responsible for the Station's systems, supervised the spacewalk and operated the Canadarm robotic arm. The [STS-96](#) mission was accomplished in 153 orbits of the Earth, travelling more than six million kilometres in 9 days, 19 hours and 13 minutes. Ms. Payette was the first Canadian to participate in an ISS assembly mission and to board the Space Station.

From July 15 to 31, 2009, Julie Payette served as the flight engineer on the crew of [STS-127](#) aboard Space Shuttle Endeavour on the 29th Shuttle mission to the International Space Station. Robotics technology was used almost every day on this assembly mission and Ms. Payette operated all three robotic arms – the Shuttle's Canadarm, the Space Station's Canadarm2, and a special-purpose Japanese arm on Kibo. A record 13 astronauts of 5 different nationalities were together on board while the Shuttle was docked to the ISS. It was also the first time two Canadians were in space at the same time, Robert Thirsk was the other one.

On July 13, 2017, it was officially announced that Ms. Payette would become [Canada's 29th Governor General](#). Her installation took place on October 2, 2017.

Robert Thirsk - Engineer and Astronaut

Robert (Bob) Thirsk

There is a Douglas College, New Westminster, Canada connection to Bob Thirsk. He became an honorary fellow of the College in the Winter of 2019. At his speech he explained why that the reason he became both an engineer and a medical doctor was that at the time when he was in school there was no such thing as a degree in bio-engineering.

<https://www.douglascollege.ca/current-students/enrolment-services/graduation/honorary-fellows>

You can read much more about him here:

<https://www.asc-csa.gc.ca/eng/astronauts/canadian/former/bio-robert-thirsk.asp>

Birthdate and birthplace: August 17, 1953, New Westminster, British Columbia.

Education: Bob attended primary and secondary schools in British Columbia, Alberta, and Manitoba. He received a Bachelor of Science in Mechanical Engineering from the University of Calgary in 1976, a Master of Science in Mechanical Engineering from the Massachusetts Institute of Technology (MIT) in 1978, a Doctorate of Medicine from McGill University in 1982, and a Master of Business Administration from the MIT Sloan School of Management in 1998.

Experience: Bob was selected in December 1983 for the Canadian astronaut corps. He began astronaut training in February 1984 and served as backup payload specialist to Marc Garneau for the October 1984 Space Shuttle Mission STS-41G.

Space flight experience:

In June and July 1996, Bob flew as a payload specialist aboard Space Shuttle Mission [STS-78](#), the Life and Microgravity Spacelab (LMS) mission.

In 2009 Bob became the first Canadian astronaut to go on a long-duration expedition aboard the ISS. He and two crewmates launched from the Baikonur Cosmodrome in Kazakhstan on May 27 aboard a Russian Soyuz spacecraft. When their Soyuz vehicle docked, the ISS became home for the first time to a permanent crew of six.

Helping us get to Mars

<https://www.ctvnews.ca/sci-tech/ex-astronaut-thirsk-to-help-define-canada-s-place-in-mars-mission-1.4233579>

Chapter 12 - BioHacking - An Example

As part of the course Jennifer Kirkey took at Douglas College in New Westminster, British Columbia, Canada in 2019, a research project was done. Of the topics, Implanting Electronics into the Human Body was the one chosen.



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

The purpose of the research project was to examine the Engineering profession and its relationship with society.

Biohacking

Research Project Details

As part of the course Jennifer Kirkey took at Douglas College in New Westminster, British Columbia, Canada in 2019, a research project was done. Of the topics, Implanting Electronics into the Human Body was the one chosen. She had to take a “pro” or a “con” position. In her opinion “pro” is easy but “con” is more fun to do and to debate so most of the research presented here is for the “con” side of the argument. She will gladly sit down and debate either side of the issue with you.

Purpose

The purpose of the final research project was to examine the Engineering profession and its relationship with society. The idea as to research something using the following insights:

- 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 was an in-depth research study of Engineering issues that humanity is currently facing. The findings were submitted in the form of a research report and maybe an in-class presentation. The expectation of this project was to formulate an argumentative research paper on one of the topics. The research had to 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 Details

Biohacking or ‘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.

References

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

Biohacking Research Results

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 dark side 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, health span, that’s fantastic.”

Legislation – 2019 – Nevada USA 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](https://www.justice.gc.ca/eng/health-canada/services/drugs-health-products/medical-devices/legislation-guidelines.html) 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>

CTV 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

As they say on their web site "We've been working with human implant technology since 2005, and we're happy to help with your upgrade."

<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 by David Eagleman on Can We Create New Senses for Humans?"

The technology stuff starts at 5:00 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 for Biohacking

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 but you need to treat with great caution. The instructor for this course, and many others, will not accept Wikipedia as the original source for any research.

<https://en.wikipedia.org/wiki/Cyborg>

1. The Cyborg Foundation

<https://www.cyborgfoundation.com/>

"The Cyborg Foundation is an online platform for the research, development and promotion of project 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"

2. New York Times article on "A Do-it-yourself revolution in Diabetes Care" Retrieved June 12 2019.

<https://www.nytimes.com/2016/02/23/health/a-do-it-yourself-revolution-in-diabetes-care.html>

<https://www.nytimes.com/2016/02/23/health/a-do-it-yourself-revolution-in-diabetes-care.html>

3. Retrieved June 12 2019 <https://hackernoon.com/biohack-your-intelligence-now-or-become-obsolete-97cdd15e395f>

4. <https://hackernoon.com/im-32-and-spent-200k-on-biohacking-became-calmer-thinner-extroverted-healthier-happier-2a2e846ae113>

5. Retrieved June 12 2019 June 5 2018 by Faye Flam "it is not illegal to experiment on yourself FDA"

6. <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 Home](#)

Early 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.

7. Brain interfaces for paralyzed patients since 2006

<https://www.nytimes.com/2006/07/13/science/13brain.html>

8. 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

9. <https://io9.gizmodo.com/what-you-need-to-know-about-getting-magnetic-finger-imp-813537993>

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

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

12. <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](#).

13. 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

Appendix A EGBC Engineers and Geoscientists of British Columbia

ABOUT EGBC

<https://www.egbc.ca/About/About-Us/Who-We-Are>

• Who We Are

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 *Professional Governance Act*.

We are charged with protecting the public interest by setting and maintaining high academic, experience, and professional practice standards for over 40,000 registrants. Only individuals and firms licensed by Engineers and Geoscientists BC are 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 registrants 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 organization.

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.

The Brand

The Engineers and Geoscientists BC brand was developed and delivered under the 2014 – 2017 Strategic Plan. Under the direction of Council, the brand was defined and brought to life, capturing the essence of the association and its members. Consultation was an integral part of this process, and included engagement with members, stakeholders, and the public.

You can watch the video on YouTube



A YouTube element has been excluded from this version of the text. You can view it online here:
<https://pressbooks.bccampus.ca/engineeringinsociety/?p=6>

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.

National Day of Mourning

Marked annually in Canada on April 28, the National Day of Mourning is dedicated to remembering those who have lost their lives, or suffered injury or illness on the job or due to a work-related tragedy.

<https://www.ccohs.ca/events/mourning/>

The most recent statistics from the Association of Workers' Compensation Boards of Canada (AWCBC) tell us that in 2019, 925 workplace fatalities were recorded in Canada. 882 were male workers, and 43 were female workers. Among these deaths were 29 young workers aged 15-24.

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>