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ENGINEERING HISTORY PAPER #40

"Recognition of Engineers and Engineering Achievements: The Hall of Fame of the Canadian Museum of Science and Technology"

by Andrew H. Wilson
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EIC HISTORY AND ARCHIVES
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Abstract

This paper presents brief biographical sketches of 16 people - engineers or directly associated with engineering achievements - who have been elected to the Hall of Fame of the Canadian Museum of Science and Technology.

Its objective is to expand the list, begun in other papers in the Cedargrove Series, of those who might be considered to be 'heroes' or 'notables' of Canadian engineering.

About this Series

Principally, the Cedargrove Series is intended to preserve some of the research, writings and oral presentations that the author has completed over the past half-century or so but has not yet published. It is, therefore, a modern-day variant of the privately-published books and pamphlets written by his forebears, such as his paternal grandfather and grandmother, and his grandfather's brother John.

About the Author

He is a graduate in mechanical engineering and the liberal arts and has held technical, administrative, research and management positions in industry in the United Kingdom and in the public service of Canada, from which he retired over 20 years ago.

He became actively interested in the history of engineering on his appointment to chair the first history committee of the Canadian Society for Mechanical Engineering in 1975, has served both CSME and the Engineering Institute of Canada in this capacity for varying periods of time until 2003, and has since provided history-related advice to EIC and the Canadian Society for Senior Engineers. He has researched, written and edited historical material for EIC and CSME organizations, and is a past president of both.

Introduction

There are a number of ways in which engineers and those directly associated with engineering achievements may receive national recognition for their contributions to the field and the profession, to the management of these, and to the development of Canada. They may, for example, be elected to the Science and Engineering Hall of Fame at the Canadian Museum of Science and Technology (CMST), designated by the Historic Sites and Monuments Board of Canada (HSMBC) as being 'persons of national historic significance,' or receive the Order of Canada. They may also be recipients of senior medals or awards from Canadian institutions, such as the Sir John Kennedy Medal of the Engineering Institute of Canada and the Gold Medal of Engineers Canada (formerly the Canadian Council of Professional Engineers). Or, spreading the net more widely still, they may be elected to the Canadian Academy of Engineering or the Royal Society of Canada. Among those so identified may be some who can be judged eligible for consideration as 'heroes' or 'notables'of Canadian engineering. This judgement, however, is being left to others.

The Canadian Museum of Science and Technology was established by the Government of Ca nada, following the recommendation by the Massey Royal Commission in 1951 that it do more to support work in the arts and sciences in this country by establishing a national museum to collect, preserve, research and interpret its technical heritage. The Canadian Science and Engineering Hall of Fame was established originally in 1991 by the Museum in partnership with the National Research Council, Industry Canada and the Association of Partners in Education to mark NRC's 75th Anniversary. Prior to1996, the Council took responsibility for the nomination, selection and induction process. The Hall then became the responsibility of the Museum, which now organizes this process for it. It is also an integral part of the *Innovation Canada* exhibit within the Museum. Basically, each nominee must have contributed in an exceptional way to the advancement of science or engineering in Canada, must have demonstrated leadership, and their contributions must have brought great benefits to society. A Selection Committee presides over the selection of nominees for induction. Unlike designation by the Historic Sites and Monuments Board, those nominated for the Hall may still be living.

This paper is not the first in the Cedargrove Series to attempt to identify notables to join Sandford Fleming, Thomas C. Keefer and Casimir S. Gzowski in a Canadian pantheon, but it is likely the last one I will do. As it happens, the three engineers just mentioned have already been designated by the Historic Sites and Monuments Board, but so far only Fleming has been included among the inductees to the Hall. The others included in this paper who belong to both are Armand Bombardier, Sir William Dawson, Reginald A. Fessenden, Wallace R. Turnbull and, I have recently discovered, Elsie Gregory MacGill.

The present (2009) membership of the Hall stands at 42, of whom 16 have been included in this paper. The biographical material about them has been arranged in alphabetical order. It is synoptic rather than definitive since, for most of the inductees, fuller biographies can be found in books, articles and through the Internet. The biographies in this paper vary in length, for a variety of reasons. Of the 16, six were members of the Engineering Institute of Canada: Fleming, MacGill, Mackenzie, McNaughton, Ouimet and Turnbull.

The Biographies

Canada must share **Alexander Graham Bell's** fame in engineering achievement with the United States. He was born in March 1847 in a third country - Scotland - in the city of Edinburgh, the second son of Alexander Melville and Eliza Bell. Both his father and grandfather were well-known practitioners of the science of phonetics and teachers of elocution.

As a young man in the late 1830s, his father had spent several years in Newfoundland escaping the damp, sooty atmosphere of Edinburgh and clearing up persistent respiratory infections. He became a strong believer in North America's healthy climate. Married in 1844, the Bells' eldest son, Melville, was born a year later, then Alec, and a third son, Edward, in 1848. Alec's interest in 'things scientific' began when he was a boy, stimulated by everyday problems he found around him and by his father's, and his brother Melville's, enthusiasm for the science of speech. Brother Edward, less so, as he was in indifferent health much of the time. Also, their mother was deaf and Alec, in particular, became expert in conveying the content of conversations to her using the manual alphabet. Alec was not enthused by his school, which followed the classical tradition of education, preferring instead activities that were related to science and to the outside of a classroom.

In the 1860s the Bells moved to London. In 1867 his brother Edward died at the age of 18. However, Alec was able to take advantage of the city to further his experience in teaching the deaf as well as his formal education and making experiments. But in late May 1970 his brother Melville died of tuberculosis at the age of 25. In July of that year the surviving Bells sailed for North America - and its healthier climate. They settled near Brantford, Ontario, Canada.

Bell's first job, however, was teaching in schools for the deaf in Boston, which became his headquarters for many years to come, although he would visit Brantford during the summers. He also began experimenting again, in the evenings in a basement workshop - and acquired a reputation for overworking himself - endangering the good health he had been brought to North America to preserve! He opened his own school in 1872 and, a year later, transferred his classes to Boston University, where he was appointed professor of vocal physiology and elocution. Among his students was Helen Keller - blind, deaf and dumb - who later credited Bell with helping humanize her life. Another was Mabel Hubbard, daughter of the prominent Boston patent lawyer, Gardiner Hubbard.

Away from his students, Bell worked in a basement laboratory on the 'harmonic' or 'multiple' telegraph and on 'electric speech' or the 'transmission of sound through telegraphy'. But he found he lacked the time and the skill to make mechanical parts for the apparatus he was developing, and sought help. He found it in Thomas Watson, who was only a few years younger than Bell himself. And so began a fruitful collaboration that would last for a very long time, result in the invention of the telephone, and bring both men fortune and renown.

Bell spent the summer vacation of 1874 at Brantford. August 10 of that year was the day, he later wrote, the idea of the telephone was conceived. The work continued. Later the following year he convinced Hubbard of the value of his invention, obtained his support, and a patent was filed in Washington, only hours before a filing by Elisha Gray, his rival in this enterprise.

At the Centennial Exhibition at Philadelphia in 1876, Bell demonstrated his invention and, with the fortuitous intervention of the Emperor of Brazil whom he had met previously in connection with his work with deaf children, he was given the Centennial Award for it by the judges in the electrical area. The following year, Bell married Mabel Hubbard and sailed for England on his wedding trip, where he took time to introduce Queen Victoria to the telephone. In 1878 the Bells returned to the United States and moved to Washington. Much of Alec's time was taken up defending his telephone patents in lawsuits. He took relatively little part in the business of promoting and selling his invention, instead establishing a laboratory and busying himself with experiments and scientific discussions. He was interested , for example, in the photoelectric cell, the iron lung, the desalination of sea water and the phonograph, where he was in competition with Edison.

During the summer of 1885, the Bells first saw Cape Breton Island and travelled on Bras d'Or Lake by steamer. The following year, negotiations were begun to purchase property on a headland across from the town of Baddeck. In 1890 a tract of land was acquired and the Bienn Bhreagh estate established. This would provide a family summer home for the rest of their lives. Bell's first experiments were on several forms and configurations of kites - and the scientific breeding of sheep. Mabel had her own research - in horticulture. The ultimate man-carrying kite was launched in December 1907, and flew steadily, carrying a passenger.

In 1907 the Bells founded, and financed, the Aerial Experimental Association to carry out a program of aeronautical research. The ideas and enthusiasm behind the AEA came from the Bells, but the work was done by a group of young engineers - Canadians Douglas McCurdy and F.W. Baldwin, and Americans Glenn Curtiss and Thomas Selfridge. AEA built several 'pusher-engined' biplanes in 1908-09, the first of which was based on a tetrahedral configuration, derived from the kites. Next was the *Red Wing*, which was flown in March 1908 by Baldwin at Hammondsport, New York - making him the first Canadian to fly a heavier-than-air aircraft. After it had made a number of flights but had crashed, this plane was rebuilt and renamed the *June Bug*, which flew in June 1908 at Hammondsport. Selfridge died while testing a plane for the Wright Brothers in September 1908, after which the AEA moved back to Baddeck. The fourth AEA machine was the *Silver Dart*, flying which Douglas McCurdy became the first Canadian to fly in Canada in February 1909. Attempts to use floats on the *June Bug* were not successful.

Later in 1909, after the AEA had been wound up, Bell's research began with the failed floats experiment. He went on to develop hydrofoils, the first of which was completed in 1911. A later hydrofoil, the *HD-4,* launched in October 1918, was the most successful. In September 1919, it established a speed record which was not broken for another 20 years. The *HD-5* was the last Bell hydrofoil, launched in September 1921.

Alec Bell continued working for another year but, on August 2, 1922, he died in Washington at the age of 75. His wife died five months later. He was inducted into the Hall by NRC, prior to 1996.

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In his ‘piece’ in the Hall of Fame website, **Joseph-Armand Bombardier** wrote:

> From the time I was young, I dreamed of inventing a machine that would conquer the snow. In those days, of course, there were no snow ploughs in rural areas, so when winter set in, people were trapped. Farmers couldn’t get outside to save stranded cattle; police cars, ambulances and fire trucks couldn’t get through the drifts; people even had difficulty getting such basics as mail and food supplies.
>
> I used to experiment at home, so when I was 15 my father gave me an old Model-T Ford to divert my attention from the family car. I promptly removed the engine, bolted it to a modified sleigh frame and attached a hand-whittled propeller to the motor’s drive shaft. I had built my first snowmobile. Unfortunately, the experiment went no further. Shortly after its first successful test run, my father forced me to dismantle the machine, fearing that the open propeller would decapitate one of my brothers or sisters.

Bombardier was born in April 1907 at Valcourt, near Sherbrooke, Québec, the eldest of eight children whose parents farmed and ran a general store. From a very young age, he showed a talent and passion for machines. At 13, for example, he built a miniature locomotive driven by clockwork, followed by tractors, boats and other mechanical toys. He built steam engines out of old sewing machine parts. He also began to develop as an entrepreneur. And, as noted above, was 15 when he built his first snowmobile.

Intended at age 14 for the priesthood, by the age of 17 he was an apprentice at a local garage, but left to work in Montréal and take night-school courses in mechanics and electrical engineering. At 19, he was employed as a garage mechanic in Valcourt. Then he opened his own small garage. It was not long before his expertise became known around the Eastern Townships. At the age of 22, he married and, with his wife, had six children. In his spare time, and making use of the then snow-bound winters, he pursued his ambition of developing and building vehicles that could save rural communities from isolation during the winter months.

In 1937, Bombardier built a seven-passenger vehicle and obtained a patent for the track-and-sprocket drive system that was incorporated into this and all his future snow vehicles. In 1940, the military took an interest in this vehicle, since it could move troops over sand and in swamps as well as over snow and ice. Several hundred of this type were built in his own factory. In 1942, he built a larger version, to hold 12 passengers, with independent suspension on each axle - the production of which continued for several decades. That same year, 1942, he incorporated himself and founded the company - Auto-Neige Bombardier Inc. As noted below, at the end of World War II he served as a civilian consultant on vehicles for the Arctic and sub-Arctic as part of Exercise Musk Ox, in which John Tuzo Wilson also participated.

When the Québec government decided to plough country roads in 1949, Bombardier lost much of his market for the B-12-type vehicles. He responded by building all-terrain tracked vehicle for oil and mining exploration and the logging industries. At the end of the 1950s, he developed an individual-use snow vehicle that became famous as the trade-marked Ski-Doo.

In doing so, Armand Bombardier fulfilled his original dream and, at the same time, gave birth to a new industry. He died in 1964 at the age of 56. By 1974, more than a million Ski-Doos were in use and the Bombardier Corporation was on its way to becoming a significant player internationally, manufacturing railway transport equipment and aeroplanes as well as recreational vehicles, having plants and representatives throughout the world and employing thousands of people. Bombardier was inducted into the Hall by the National Research Council.

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John William Dawson's principal claim to fame was as a scientist and, in particular, as a geologist. As has often been reported, he was the first Canadian-born scientist to achieve a world-wide reputation for his research and publications. His contributions to science and engineering education in Canada were also notable. The basis of his achievements in engineering stems from these contributions.

Dawson was born at Pictou, Nova Scotia, in October 1820. His education began there, at the Academy. In 1840, he went to Scotland, to the University of Edinburgh, where he studied geology. - a subject that had engaged his interest as a boy and as an avid collector - as well as taxidermy and the preparation of fossils for examination under the microscope. But, due to financial problems, he returned to Pictou in 1841 without completing a degree. Over the next few years he undertook practical work in his native province and in Lower and Upper Canada, much of it in mining, geology and mineralogy. Some of his fieldwork was published through the Geological Society of London. He also taught at Pictou Academy and Dalhousie College in Halifax. During this time he met and became friends with Charles Lyell, an internationally known geologist. They teamed up to do pioneering work in Nova Scotia.

In 1850, Dawson was appointed superintendent of education for Nova Scotia. This was also the year in which he completed his monumental work on Acadian geology, which was subsequently published in Edinburgh and London. Even without the completion of his course work, the University of Edinburgh awarded him an MA degree in 1856, partly as a result of his publications. By this time, he was an experienced educator, a prolific and popular author and a brilliant lecturer. He was also a vigorous and determined man.

Dawson was appointed by Sir Edmund Walker Head in 1853 as a member of the Commission of Inquiry into King's College in Fredericton (before it became the University of New Brunswick). The members were asked to advise on how its courses of instruction could be made more practical. This the Commission did, proposing among other things that diplomas be awarded in civil engineering and land surveying. As a result, the first regular instruction in engineering in British North America began in February 1854. The curriculum covered the elements of railway engineering and civil, mechanical and electrical engineering as they were then known. Also in 1854, Head was appointed Governor General of Canada. At his suggestion, the Council of McGill College in Montréal appointed the 35-year old Dawson to be its fifth principal. In his inaugural speech in November 1855, Dawson announced plans to initiate a course of lectures in civil engineering, with a diploma course to follow, based on the one he had helped to develop at Fredericton. At his insistence, a Department of Practical Science was formed in 1871 at McGill, and thus began in embryo the Faculty of Applied Science, founded in 1875, when the first full engineering programs in Canada with degrees in civil, mechanical and mining engineering became available. McGill went on to establish its high reputation as an engineering school, and Montréal as one of the major centres of Canadian engineering.

In 1857, Dawson had also established a Normal School at McGill and served as principal instructor in science for 13 years, teaching mainly chemistry and physics. He also oversaw the rebuilding of the McGill campus. And he built strong ties to distinguished and influential scientists and universities in the fields of geology and paleontology at home and overseas. It has been said that he built McGill and laid the foundations for the renown it gained in the 20th century and for the influence it had in Canada and abroad.

Dawson received many honours. For example, in 1854 he was elected a Fellow of the Geological Society of London and was awarded its Lyell Medal in 1881 for his outstanding research. That same year, the Governor General, the Marquis of Lorne, called on him to help establish the Royal Society of Canada, and he became its founding president. He was, in the 1880s, the only person to have held the presidencies of the American and British Societies for the Advancement of Science. He was the president of the Geological Society of America. He received honorary degrees from both McGill and Edinburgh. He was made a Commander of the Order of St. Michael and St. George (CMG) in 1881 and was knighted in 1884. Sir William remained principal of McGill until 1893. He died in Montréal in 1899. He was inducted into the Hall in 2004.

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Reginald Aubrey Fessenden is another Canadian whose fame must be shared with the United States. Born, on 6 October 1866 at East Bolton, Québec, and educated at Trinity College School at Port Hope, Ontario, and Bishop's College School and University at Lennoxville, Québec, he left the latter without a degree. Instead, for the next two years, he taught school in Bermuda.

In 1886, at the age of 20, he moved to New York, hoping - in spite of a largely classical education - to gain employment with Thomas A. Edison. With perseverence he managed this, and was employed as a semi-skilled assistant tester at the Edison Machine Works, then involved in laying underground cables in New York City. A fast learner, he was soon promoted. By late 1886 he was working for Edison at his laboratory at West Orange, New Jersey, where he tackled problems involving electricity, chemistry and metallurgy. But in 1890, facing financial problems, he and many others were let go by Edison.

Fessenden was able to find employment with a series of manufacturing companies and, in 1892, was appointed a professor in the newly formed Department of Electrical Engineering at Purdue University in Indiana. He continued to work for Westinghouse, at the 1893 World Exhibition at Chicago, after which George Westinghouse recruited hin for the position of chair of the Department of Electrical Engineering at what later became the University of Pittsburgh.

Inspired by the work of Marconi in radio, Fessenden began his own experiments in the late 1890s. In 1900, he left Pittsburgh to work for the United States' Weather Bureau to investigate the possibilities for the radio, versus telegraphic, transmission of coastal weather data, using devices he had invented. The work was done initially at Cobb Island in the Potomac River. He was successful and, in the process, developed the heterodyne principle. It was there, in December 1900, that he transmitted speech by radio for the first time, paving the way for commercially feasible transmissions of radio signals. But as a result of disputes with management over the ownership of patents, he left the Bureau in August 1902.

Fessenden, however, was able to carry on his research work with the support of two wealthy Pittsburgh businessmen, who financed the formation of the National Electric Signal Company (NESCO). The work was done at Brant Rock, Massachusetts, and involved low-power and high-power transmitters for both telegraphic and radio transmission. In January 1906 he made the first successful two-way trans-Atlantic rotary-spark transmission using Morse code. Unfortunately, this work had to be terminated when the radio tower at the Scottish end collapsed. In mid-December 1906, Fessenden demonstrated a new alternator-transmitter at Brant Rock and on Christmas Eve used it to send out a short radio program, and a second one on New Year's Eve - both of which were picked up by so few listeners that their importance was quickly downplayed and forgotten.

Unfortunately, also, the technical work of NESCO was not financially successful. Meanwhile, Fessenden himself had started a company in Montréal in 1906. But friction between him and his backers rose to the extent that Fessenden was fired in January 1911. Lawsuits followed, the end result being that the company was sold to Westinghouse in 1920 and in 1921 its assets - including important patents awarded to Fessenden - were sold to RCA. The lawsuits went too, and it was not until 1928 that he settled with RCA, receiving a large cash payment.

The work on the alternator-transmitter was continued, however, at the General Electric Company and, by 1916, the Fessenden-Alexanderson alternator was more reliable for trans-Atlantic communication than the spark apparatus. After 1920, radio broadcasting became widespread, using vacuum tube transmitters, rather than the alternator and employing continuous-wave AM signals that Fessenden had introduced in 1906.

Even before leaving NESCO in 1911, Fessenden had switched his attention to other fields. For example, he helped engineer the Niagara Falls power plant for the Hydro-Electric Power Commission of Ontario in 1904. Later, he developed the 'Fessenden oscillator' for signalling between submarines and for locating icebergs. At the outbreak of World War I he volunteered his services to the Canadian government and was sent to England, where he worked on a device for detecting submarines and enemy artillery. He patented basic ideas in seismology and invented a sonar device, television apparatus, tracer bullets, and a turbo-electric drive for ships.

After settling the RCA law-suit, Fessenden retired to a small estate in Bermuda, where he died in 1932. Over his lifetime, he held over 500 patents. He also received a number of awards for his work. For example, in 1921 the Institute of Radio Engineers presented him with its Medal of Honor and in 1922 the City of Philadelphia its John Scott Medal. In 1929 he received the Scientific American Gold Medal for his device to determine the depth of water for a submerged object.

Fessenden has been called the 'father of radio broadcasting.' For his pioneer work in radio communications and sonar devices, he was named a 'person of national historic significance' by the Historic Sites and Monuments Board of Canada in 1943. He was inducted into the CMST Hall of Fame by NRC.

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Sandford Fleming was born on the other side of Scotland's Firth of Forth from Alec Bell - at Kirkaldy - twenty years before him, in 1827. He presently shares, with Fessenden and four other members of the CMST's Hall of Fame, the HSMBC's designation as a 'person of national historic significance,' which he achieved in 1950.

Fleming came to Canada in 1845 and, having studied engineering on both sides of the Atlantic, was appointed to the staff of the Ontario, Simcoe and Huron Railway. In 1857 he was named chief engineer of its successor, the Northern Railway. The article on Fleming in Hurtig's *Canadian Encyclopedia* continues the story:

> In 1863 the Canadian government appointed Fleming chief surveyor of the first portion of the proposed railway from Quebec City to Halifax and Saint John. Subsequently built as the Intercolonial Railway, he was its chief engineer. In 1871 he was appointed engineer of the proposed new Canadian railway from Montréal to the Pacific Coast and was in charge of the major surveys across the Prairies and through the Rocky Mountains. He proposed constructing the railway along a northerly route through Edmonton and the Yellowhead Pass and then turning south to Burrard Inlet and the Pacific. Although his specific recommendations regarding the route were not followed, his extensive survey work of various routes, including the Kicking Horse Pass through which the Canadian Pacific main line was built, greatly facilitated Canadian railway construction. In the early

years of the 20th century, Canadian Northern's railway was built along the survey route advocated by Fleming.

Fleming retired from the CPR when the Canadian government turned over the project to a private syndicate in 1880, but he continued to do consultative railway work. He also turned his attention to other projects. He was strong advocate of a telecommunications cable from Canada to Australia, which he believed would become a vital communications link of the British Empire. The Pacific cable was successfully laid in 1902. He was also interested in the development of a satisfactory world system for keeping time.

The railway had made obsolete the old system where every major centre set its clocks according to local astronomical conditions. Fleming advocated the adoption of a standard mean time and hourly variations from that according to established time zones. He was instrumental in convening an International Prime Meridian Conference in Washington in 1884 at which the system of international standard time - still in use today - was adopted. Fleming also designed the first Canadian postage stamp.

Fleming also carried out the first survey for a railroad across Newfoundland. It was later built and operated by the Reid Company. He was part of the famous photograph - identifiable as the tall man in the middle with the square, white beard - taken in November 1885 at the 'Last Spike' ceremony for the trans-continental CPR.

Although not himself a university graduate, but as a result of his friendship with Principal Grant, Fleming was appointed Chancellor of Queen's University (the Kingston one) and served for 35 years. He also received a number of degrees from academic institutions in Canada, the United States and Britain. He was president of the Royal Society of Canada. Fleming was created a Commander of the Order of St. Michael and St. George (CMG) in 1877 and raised to the rank of Knight Commander (KCMG) in 1915. He was inducted into the Hall by NRC.

It has been noted before that, somewhat surprisingly, Fleming was not among the founding members of the Canadian Society of Civil Engineers in 1887. He had indeed been a founding member and leading light many years earlier in the first attempt to organize a national technical society, which later became the Royal Canadian Institute. He also supported the formation of the short-lived Dominion Institute of Amalgamated Engineering. He did, in fact, join CSCE - but not until 1896, and was never president. He was, however, elected to honorary membership before his death in 1915 at the age of 88.

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Gerald Robert Heffernan was honoured for his pioneering work in metallurgy by his induction into to the Hall of Fame by the National Research Council.

Alberta born in 1919, he received his engineering training in the Faculty of Applied Science and Engineering at the University of Toronto, graduating in 1943 in metallurgy and materials science. He was one of the many whose call-up to the army preceded their convocation ceremony. This was accomplished at a special ceremony in April 2007, over 60 years later, when he was 87, by which time he had received several honorary degrees - for example, from Queen's and Toronto.

Heffernan has received many other honours and awards. For example: he was elected a Fellow of the American Society for Metals, the Canadian Institute of Mining and Metallurgy, and the Canadian Academy of Engineering; he has received the UofT Engineering Alumni Medal, the Gold Medal of the Association of Professional Engineers of Ontario, and the McGill Achievement Award; he has also received the Benjamin E. Fairless Award of the American Institute for his leadership in steelmaking, and the U.K. Institute of Metals' Bessemer Gold Medal for technological innovation in the steel industry. Through his companies, Heffernan has supported postgraduate fellowships within the Faculty of Applied Science at the University of Toronto. A Chair bearing his name in materials processing was created in 2000, with his financial support.

Heffernan is renowned world-wide as a founder and developer of major steelmaking organizations and as a highly skilled engineer and scientist and is remembered in particular for pioneering the mini-mill steel manufacturing process. He has served as chairman of Co-Steel International Ltd., a company formed from two of his many highly successful ventures, Premier Steel Mills in Alberta and Lake Ontario Steel Company Ltd. at Whitby, begun by him in the 1950s and 1960s respectively, businesses that expanded into the United States and Great Britain. He founded, and was president of, G.R. Heffernan & Associates of Toronto, and has had several other company directorships.

After leaving UofT, Heffernan was commissioned in the Corps of the Royal Canadian Engineers and served in Canada, training combat engineers in combat, bridge building and mine clearing. After the war, he attended graduate school at the University of British Columbia before entering the steel industry. He founded his first company (Premier) in 1955, the year he built his first steel mill..

Heffernan, himself, has provided a 'quick view' of his career highlights in the text that accompanied his entry in the Hall of Fame website. He said:

> I guess you would say that I helped reshape the world's steel industries. I didn't start out to do that. I was just trying to create a better product at a better price, but the outcome was revolutionary.
>
> My education prepared me for a career in metallurgy. One of my first jobs was to 'soup up' the electric arc furnaces in a Vancouver steel manufacturing plant. Gaining a detailed knowledge of these furnaces, which are better than blast furnaces at melting scrap steel, stood me in good stead when I ventured out on my own. After that company went

bankrupt, I got another job building and operating an electric arc furnace plant to cast ingots - large bars of steel that are created by pouring the refined, molten steel into moulds. When management rejected my proposal to locate a plant in Edmonton, the heart of the burgeoning oil industry, I quit and decided to build the plant myself.

With several partners, I managed to raise the capital and within nine months the plant was built. But I was bothered by certain aspects of the traditional steel-making process. It seemed to me that rolling steel ingots to lengthen them was expensive and inefficient, so I began to investigate continuous casting.

We installed one of the first commercially successful continuous casting plants. Then, by combining continuous casting with the use of enhanced electric arc furnaces annd cheap scrap metal, I was able to sell my steel at well below the price being charged by large integrated mills.

This new process, referred to as mini-mill steel manufacturing, not only allowed smaller regional mills to become cost effective but, by replacing the dirty coke ovens and blast furnaces, as well as recycling scrap steel, my manufacturing process had clear environmental benefits......

Gerald Heffernan became an Officer of the Order of Canada in 1987. He has also been elected a member of the Canadian Business Hall of Fame, was appointed to the Council of Advisers of the Canadian Institute for Advanced Research, was a member of the Policy Committee of the Business Council on National Issues (as it then was), and chaired its task force on taxation policy. He was inducted into the Hall by NRC.

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Canada shares **James Hillier** with the United States, and engineering shares him with physics. Born in August 1915 at Brantford, Ontario, he graduated in physics from the University of Toronto in 1937. He received his master's and doctorate degrees from the same university in 1938 and 1941.

Both Canada and the United States can claim to be the first countries in which the electron microscope - whose principles were developed in Germany - was made practical. Hillier and his colleague, Albert Prebus, constructed the first one in Canada, with high resolution and a magnification of 7000 times, while studying at Toronto under the guidance of Professor Eli Burton. On completing his doctorate, Hillier went south to join RCA at Camden, New Jersey, where he spent many years developing production models and marketing them. Hillier also discovered the principle of the stigmator for correcting the astigmatism of electron microscope objective lenses, invented the electron microprobe microanalyser, and was the first to picture tobacco viruses and an ultra-thin section of a single bacterium.

Hillier had a long and successful career at the RCA laboratories at Princeton, New Jersey, becoming general manager of the Laboratories in 1957 and reaching the position of executive vice-president and chief scientist in 1976. Major projects with which he was associated during his career included the electron optics that led to the 90 degree deflection, 25-inch colour kinescope, the Electrofax process for copying printed matter, and the RCA *SelectaVision* videodisc system. He received over 40 patents for the devices and processes he invented while working at RCA, and published more than 150 technical papers.

Hillier retired in 1977, after which he took on the role of technology adviser, serving countries in the Third World and promoting science education.

In 1945 Hillier served as president of the Electron Microscope Society of America, the year he became an American citizen. He received numerous awards - for example, the Albert Lasker Award for basic medical research in 1960, the IEEE David Sarnoff Award in 1967, the Commonwealth Award in 1980, the same year that he was inducted into the U.S. National Inventors Hall of Fame. In 1981 he received the Founder's Medal from the Institute of Electrical and Electronic Engineers. He was awarded honorary doctorates by the University of Toronto and the New Jersey Institute of Technology, was a member of the U.S. National Academy of Engineering, and was appointed to the Order of Canada. He was inducted into the Hall of Fame in 2002.

Although holding U.S. Citizenship, he remained involved with the Brantford community throughout his life. In 1950, for example, a public school named after him was opened at Brantford. In 1993, the James Hillier Foundation was established to award annual scholarships to Brant County students pursuing education in science.

James Hillier died at Princeton in January 2007 at the age of 91.

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John Alexander Hopps is known as the 'father of biomedical engineering in Canada.' He was one of the pioneers in the development of artificial pacemakers, which improved the lives of many people around the world, and was honoured for this and other achievements in several ways.

Jack Hopps was born in Winnipeg in 1919. He graduated in electrical engineering from the University of Manitoba in 1941 and joined the staff of Radio and Electrical Engineering Division (REED) of the National Research Council in 1942. His early work was studying the pasteurization of beer using microwave re-warming. In 1949 he was seconded briefly to the Banting and Best Institute laboratory in Toronto to work with Drs. William Bigelow and John Callaghan, who were studying how extreme cold could slow the human heart rate, making open heart surgery possible. Their problem was to re-start the heart if it stopped, and they were considering using a re-warming device. Hopps took up this story in his autobiographical Hall of Fame website remarks:

> We managed to develop a 'bipolar' catheter electrode to stimulate the lining of the heart without needing to open the patient's chest. Back in Ottawa, I built an efficient portable pacemaker unit, incorporating the desired electrical features with a suitable electric circuit. Portable didn't mean that you could carry the pacemaker around with you; however, in 1950, it was still considered 'portable'!
>
> Today, pacemakers are implanted under the skin, as they have been since 1959, but transistors had to be invented before the necessary miniaturization could occur. Those transistors have enabled many, including me, to live a normal life, thanks to pacemaker technology.

The first surgical implantation of a pacemaker in a human was performed in Sweden..

Hopps was one of the first to establish biomedical engineering as a separate discipline in Canada, in which he participated for almost half a century. As head of the medical engineering section of the REED, he led - among other activities - further research in the cardiovascular field, assistance for blind people and those with muscular disabilities, and in the diagnostic uses of ultrasound, which led to the development of an impressive list of devices.

In 1965, Hopps founded, and became the first president of the Canadian Medical and Biomedical Engineering Society, and was elected a Fellow of the Society. He was also a leader in the international development of his discipline and a member of the International Federation of these Societies, of which he served as president from 1971 to 1973 and as secretary general from 1976 until 1985, becoming an Honorary Life member of it. From 1985 to 1988 he was secretary general of the International Union for Physical and Engineering Science in Medicine and received its Award of Merit.

Hopps continued his involvement with his discipline after retirement in 1979. For example, he wrote on its subject matter, worked with school children, and served as president of the Ontario Heart Foundation's Ottawa Chapter. In 1984 he himself received a pacemaker. The original one served him for 13 years. He died in November 1998.

In 1976 the University of Manitoba conferred a DSc degree on him in recognition of his pacemaker work and his leadership in biomedical engineering. He received the McNaughton Award of the Institute of Electrical and Electronic Engineers and the Distinguished Scientist Award of the North American Society for Pacing and Electrophysiology. He was also appointed an Officer of the Order of Canada in 1986, and was inducted into the Hall of Fame in 2005.

Early in 1999, the Executive Committee of the National Engineering Week - after extensive research and consultation - compiled a list of five of the most significant Canadian engineering achievements of the 20th century. An Angus Reid poll was subsequently conducted among 1500 people to determine which of the five "made them most proud to be a Canadian." The winner was the Hopps pacemaker.

***

George Klein I, originally an Alsatian, was a farmer/settler who arrived in Perth County, Ontario in 1835. He was killed in late 1852 in an accident involving a threshing machine. His son, George II, born in 1842, was originally a farmer, used to machinery, but lost an arm in another threshing machine accident at the time the Civil War was raging in the United States and just before Canada was to become a Dominion. Unable to farm, this George created a business for himself transporting milk from local farms to the cheese factory. He was successful and was able to buy a valuable piece of machinery that few farmers bothered about - a clock. In 1883, the clock needed repair. So teen-aged George III was entrusted with taking it into Stratford, to a jeweller's. As events turned out, he got the clock repaired, and was also offered a part-time job - keeping the store open during lunch-hours. This soon became a full-time one and George began his life's work among the mechanical clocks and watches handled in the watchmaking business. He went to the United States for training, returning to Canada to the city of Hamilton in the mid-1890s. With a partner, he set up in business. It thrived. In 1903, this George married. In August 1904, his wife gave birth to George IV - **George Johann Klein.** Of the four George Kleins, this one became known as 'the inventor.'

Having a father with a fascination for things mechanical helped George Johann as he was growing up. There was a workshop at home, in the basement, which encouraged his inventiveness. It was also the time of Edison, Bell, Westinghouse, Fessenden, Marconi and the Wright Brothers - and of the flights of Canadians Casey Baldwin and Douglas McCurdy. It appears that seven-year-old George shook McCurdy's hand when he later visited Hamilton. But during World War I, George's teen-age inventiveness got him into trouble with the law. He had been tinkering with radio equipment and a message he had sent was picked up hundreds of miles away. It was traced back to the Klein home. The Police suspected it was an attempt to contact the enemy. George III knew differently and told the them so. The equipment was confiscated, but George IV continued tinkering - with mechanical rather than electrical devices.

George's parents, recognizing his technical interests and apparent ability, decided he should enroll at Hamilton Technical High School, from which he graduated in June 1924, but with a rather so-so academic record. He was fortunate, however, that his jeweller father could afford to send him to the School of Practical Science at the University in Toronto, since McMaster had not then moved to Hamilton. He was a member of the Class of 1928, graduating in mechanical engineering. One of his professors was John H. Parkin, a Canadian aeronautical research pioneer, who built and operated the UofT wind tunnel - a source of attraction for good students, which then included Klein. Before his undergraduate days were over, he had co-authored research papers with Parkin.

While he did summer jobs in Hamilton as an undergraduate, Klein chose on graduation to accept a demonstration and research job at the University. It allowed him to continue the his wind tunnel work and collaboration with Parkin. However, during the summer of 1929, Parkin joined the staff of the new laboratories of the National Research Council in Ottawa as assistant director of the Division of Physics and Engineering Physics, his appointment having been helped by the fact that

Bell

Bombardier

Dawson

Fessenden

Fleming

Heffernan

Hillier

Hopps

Klein

Le Caine

MacGill

Mackenzie

McNaughton

Ouimet

Turnbull

Wilson

aeronautical research was expected to be an integral part of the new Division's purview. In September, Klein accepted a job at the Council, working under his former mentor.

The John Street Laboratory buildings, formerly a sawmill, became Klein's working home for the next decade. They were situated to the east of the new and significant laboratory building then in the process of erection for the Council on Sussex Drive. Klein's first jobs, along with a handful of colleagues, were to design, build and test a wind tunnel and a marine towing tank in these old buildings. And so began a career that would establish him as a versatile engineering designer, inventor and innovator of superior ability. The first research paper published by the NRC Physics and Engineering Division was Klein's - on the design of vanes and other innovations for the wind tunnel. The tunnel and the tank were finished in 1931 and were put to use for research.

The 1930s were tough times for Klein's family in Hamilton, but he had a secure job at NRC. The main laboratory building was finished in 1932. In 1935, an engineer, General A.G.L. McNaughton, was appointed president of the Council. In 1936, NRC split off the engineering function from physics and formed the Division of Mechanical Engineering, with Parkin as director. In 1939, C.J. Mackenzie - another engineer - took over as acting president of NRC when McNaughton returned to service duty. He became president in 1944.

Meanwhile, Klein's talents were used wherever they could be useful. For example, in the early 1930s, he participated in the project lead by his colleague, J.J. Green, that resulted in the building of the streamlined CNR and CPR locomotives that drew the Royal Visit trains in 1939 across Canada. His main challenge, however, was to improve the aerodynamic performance of aircraft skis and examine their interaction with snow, with which he included basic work on the properties of snow and ice. This work continued throughout the War, and after it, when he was involved in adapting skis to suit the Canadian-designed *Beaver* aircraft. He also developed a method for classifying the different types of snow, designed and developed a kit for testing its properties, and participated actively in Canada's first official snow survey. He became a recognized expert in these fields, acknowledged both nationally and internationally. During World War II, Klein also participated in the design and testing of an innovative, personnel-carrying tracked vehicle that acquired the name of *Weasel*, intended originally for use by the so-called U.S.-Canadian *Devil's Brigade* under snow conditions. As events unfolded, the vehicle was widely used, both before and after the War, since it was equally useful in mud as in snow.

Before the War ended, Klein became involved in the design and construction of the experimental zero-energy ZEEP reactor at the new Chalk River Laboratories, then under NRC management. It was to be used for experiments linked to the design of the NRX reactor, then also under construction. ZEEP went critical in September 1945.

In addition to his continuing work on snow and ice in the immediate post-war years, Klein took a leading role in the designing of what became the world's first practical electric wheelchair, specifically designed for quadriplegics - a project that had been inspired by a disabled veteran of the Dieppe Raid of 1942, the initiative for which came from the Department of Veterans' Affairs. In

1947 he was asked by the RCMP to suggest improvements to the heavy dog-sleds - based on Inuit designs - used by the Force in the North to make then lighter and faster. In this case, his main conclusion was that there was little that could be improved upon!

During his career, Klein participated in many other projects - for example, the design and development of proximity fuses, the microsurgical staple gun, the *Hedgehog* antisubmarine system, and a wide range of gearing systems. Latterly, he became involved in the design and development of equipment for satellites and space, such as the *STEM* antenna and the *Canadarm*. In addition to his major projects, Klein produced hundreds of useful devices, many in support of the experiments being carried out by colleagues throughout NRC. Indeed, he became the 'man to go to' for colleagues in mechanical trouble. What he did on any one day was usually dependent on the problems brought through his office door. Interestingly, and unusually, he was not interested in patenting his devices. Klein retired from NRC in 1969, at age 65 and after 40 years service to NRC - about the time two men first set foot on the moon. But he remained active, consulting in regard to the *Canadarm* and the space shuttle.

During his lifetime. Klein received a number of awards in recognition of his work. After World War II, he was made a Member of the Order of the British Empire for his wartime work. In 1969, he was appointed an Officer of the Order of Canada. He was awarded fellowships of the American Society of Mechanical Engineers and the Britain's Royal Aeronautical Society. He received honorary degrees from Wilfred Laurier and Carleton Universities. In 1996, Carleton inaugurated the George J. Klein Medal for national competition in industrial design among high school students in Canada.

George Klein died in early November 1992 at the age of 88. He was inducted into the CMST Hall by NRC.

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Hugh Norman Le Caine was born at Port Arthur in May 1914, the first child of Hubert and Susan Le Caine. At the time, his father was a stationary engineer at the Current River Power Plant. His mother had taught school before he was born. He had a younger sister, Jeanne, and an adopted sister, Alison, with whom he shared his early years. He was home-schooled by his mother until he was nine. At an early age, he developed an interest in - and talent for - music, as well as the ability to memorize it easily. He learned to play the piano and several stringed instruments. His voice had absolute pitch and he sang in choirs. Also, his father's technical abilities 'rubbed off' on him, and he developed an interest in radios and electronics which, in turn, stimulated an interest in physics. He was class valedictorian when he finished high school. He also became a 'night-hawk.'

Influenced by the Great Depression, Le Caine chose to enter the Faculty of Applied Science, intending to study electrical engineering, rather than pure physics, or music, when he went to Queen's University in the fall of 1934. But he spent part of his first summer vacation in 1935 at the

Toronto Conservatory of Music, studying piano. In his second year at Queen's, Le Caine chose engineering physics as his major. His laboratory work that year caught the attention of Dr. J.A. Gray, who became his mentor and in whose lab he found a summer job at the end of his third year. After he graduated, Gray supervised his work for a master's degree in nuclear physics. It was while in Kingston, in a church, that he first came across the Hammond organ, which he described as "a superb engineering job." He also heard a demonstration of J.D. Robb's electronic organ - the first to be invented and made in Canada. In 1937, he was working to design and build one of his own, meantime developing a vibrating reed electrometer - the subject of a paper published in 1941.

In 1939 World War II began. Armed with an MSc degree in engineering physics, Le Caine took up an NRC Studentship to work at Queen's under the supervision of Dr. Gray, at the end of which he applied for a position at NRC in Ottawa on the basis of the electrical measuring instruments he had built and tested. He joined the Council in March 1940 and was assigned to work on the development of radar systems at a field station southeast of Ottawa. The microwave sets he worked on during the war supported the armed services in the field. He also wrote a number of papers describing the devices he had designed and built during these years. When not at work, he continued his interest in music and began to develop as a serious photographer.

By the middle of 1945, with the end of the war in sight, Le Caine had decided he wanted to work on electronic music. This proved to be more difficult to achieve in practice. He was not willing to accept the commercial objectives for his work that a company would require. So, for the next three years, he remained at NRC working on measuring and other devices in the lab during the day and on electronic music independently in his spare time. As Gayle Young has written:

> Le Caine developed a reputation as an agile problem solver, and he seldom discouraged others from coming to him for advice. This often made it difficult for him to work uninterruptedly on his own projects. He was temperamentally suited to late night work and developed the habit of working after most of the others had gone home. Although this ensured his privacy, the late night schedule made his social life difficult.

In addition, he planned his work in accordance with the theory that, in any eight-hour day, a person was more efficient during the first four hours than the second four.

Between 1945 and 1947, Le Caine was involved, formally, with a project to develop a small electron accelerator (microtron), from theory to actual operation, in a group led by Dr. W.J. Henderson. He was also increasingly active, informally, in electronic music, in accommodation he rented from the Council. One of its rooms served as an electronic laboratory-cum-studio, which doubled as a bedroom, and another was a 'performance' room which housed his own piano, organ and other instruments. As Young has noted:

> In 1945 Le Caine began to build a new electronic musical instrument to demonstrate his ideas. At first the instrument was built inside drawers of a desk, with all the electronic parts hidden from view, but it was soon moved out and became a keyboard instrument

> with its own stand. Le Caine named it the *Electronic Sackbut* after the medieval wind instrument that was the precursor of the trombone. The name was probably chosen because one of the Saskbut's features was a sliding pitch device.....
>
> In essence, the sackbut was the first synthesizer......
>
> Le Caine built the sackbut himself at his home studio using methods similar to those he employed at the NRC lab......
>
> By the summer of 1946 the sackbut had progressed to the point where it was being played as a keyboard instrument, not only by Le Caine, but by many of his friends. There were regular jam sessions at Le Caine's home, and some were recorded on acetate discs.

In 1946, Le Caine took his first motorcycle ride and, in 1947, bought himself a large one. From then until the end of his life, he would be a devoted rider of motorbikes.

In 1948, based on his work on the microtron, Le Caine was awarded a doctoral scholarship in nuclear physics by NRC to work in England at the University of Birmingham, where the world's first, large proton accelerator was being built. Le Caine was to assist with the design. However, over the next three years, he became somewhat disillusioned with his part of the work, which was limited to building electronic equipment, with no opportunity to pursue his own work on electronic music. In October 1951, he returned to Canada and, with help from his sister Jeanne, finished up his thesis. Birmingham awarded him his doctorate in the summer of 1952.

At this stage in his career, he could have joined the research staff at the Chalk River Laboratories to pursue the nuclear part of his experience, but he chose to remain in Ottawa at NRC. It was during this time that the Council's research activities were being expanded under its new president, E.W.R. Steacie. For his first year back, Le Caine was more technical trouble-shooter than researcher. As Young has written:

> Le Caine's interests tended increasingly to be related to electronic music instruments. His method was not that of the pure research scientist, but more related to engineering and the practical application of electronic techniques to the process of sound production. Few people were designing (such) instruments and Le Caine possibly recognized an opportunity to make a contribution. He was also motivated by his intense curiosity.

In December 1951, he moved his studio to another house nearby, and began to spend more and more time working on electronic music, including several keyboards. However, around two years later, NRC formed a new division, for radio and electrical engineering (REED), of which he became a member. He moved again, to a house he built nearer the location of the new division that provided both home and studio. In the spring of 1954, also a result of the formation of REED, his duties within the Council were changed to allow him to pursue his electronic music interests formally in an NRC laboratory, and his home studio equipment was moved there. He was also allowed to work the hours of the day he preferred - after his colleagues had gone home.

Le Caine also began to lecture outside the Council on electronic music and to demonstrate the musical abilities of the sackbut. Formally, his objective was to develop instruments for possible manufacture by Canadian industry. His technician worked 'normal' days and met with him for briefings and discussions at the end of each day. This arrangement applied, with some variations, until Le Caine retired from NRC in December 1974.

Young has listed Le Caine's principal electronic music projects for the 20-year period he worked at NRC in this field, among which were the following: the sackbut: 1954-60 and 1969-73; the touch-sensitive electric organ: 1953-57; the multi-track tape recorder: 1955-64; the oscillator bank: 1957-59; the spectrogram: 1959-62; printed circuit keys: 1962-69; the serial sound structure generator: 1965-70; the sonde (to simplify the work of the composer): 1968-70; the polyphonic synthesizer: 1970, and the paramus: 1972-74 - an instrument that combined computer control with analog sound generation. Transistors, which became commercially available around 1957 made a significant difference to Le Caine's work. He also did some composing of electronic music, particularly in his earlier years. In Young's book, he is quoted as saying, of his best-known piece:

> By the end of 1955 I had produced *Dripsody* on my variable speed multiple tape recorder. I had been working for months on a composition using three sound objects: the breaking of a pane of glass with a hammer, the sound of a ping-pong ball hitting the bat, and the sound of the fall of a single drop of water. I had tried many approaches but none proved viable. One night, about 2:45 am, I thought: why not try the drop of water alone? The composition *Dripsody* was an experiment in the use of variable playback speed on the sound of the fall of one single drop of water recorded on a very short length of tape.

In 1970 and 1971, Le Caine and his technical people modernized the sackbut with a view to having it manufactured commercially. However, this process was lengthy and ended unsuccessfully. In 1971, he had heart surgery, followed by a successful convalescence. In the years prior to his retirement, he worked on the paramus and other instruments and was in demand as a lecturer on electronic music. His instruments were taken on a nation-wide tour by the Science and Technology Museum, but Le Caine did not participate. At the same time, his situation within NRC was becoming increasingly less secure as the objectives and personnel of REED changed. He was told that his work would not be continued once he retired. He did so in 1974.

Le Caine was also deeply involved in the establishment and programs of the electronic music studios at the University of Toronto, from 1959, and McGill, from 1964. He married later in life - but retained most of the working habits he had developed as a bachelor, although he never brought work home from the lab. In recognition of his contributions to electronic music, he was awarded honorary degrees by McGill, the University of Toronto - and Queen's, in 1974, when the new music building was also named the Harrison Le Caine Hall, after the noted musicologist and teacher, Dr. Frank Harrison, and himself.

After retiring, Le Caine continued to work at home, undisturbed, and for a time at a small office at NRC. He wrote, mostly, studied Swahili, took film courses, shot films......and rode his motorcycle. On one afternoon in July 1976 he had a very serious accident on the road to Montréal. He died of a stroke suffered almost one year to the day later.

He was inducted into the Hall by NRC.

***

Her full name was **Elizabeth Muriel Gregory MacGill**, but she was better known as Elsie Gregory MacGill or, simply, Elsie MacGill. She was born in Vancouver in 1905, and had two half-brothers from her mother's first marriage, and an older sister from her second, to lawyer James MacGill. She achieved a number of firsts - following in the footsteps of her mother, Helen Emma Gregory MacGill, who was the first woman graduate in the British Empire to receive a university degree in music (from the University of Toronto), the first woman to be appointed a judge in British Columbia (and the third in Canada), and one of the earliest Canadian feminists.

As Elsie herself wrote in the text that accompanies her entry in the Hall of Fame website:

> I was the first woman to receive an electrical engineering degree in Canada, as well as the first woman in North America to hold a degree in aeronautical engineering. Although I held many important positions in the aeronautics industry, I am perhaps best known for my work during World War II. As chief engineer for the Canadian Car and Foundry Company, I oversaw the production of the Hawker *Hurricane* in Canada, and I designed a series of modifications to equip the *Hurricane* for cold weather flying.
>
> I was also the first woman aircraft designer in the world. My *Maple Leaf* trainer may still be the only plane ever to be completely designed by a woman. Although I never learned to fly myself, I accompanied the pilots on all test flights - even the dangerous first flight - of any aircraft I worked on. It was the best way to assess the aircraft's performance.....

She did not, however, fly in a *Hurricane* since it only had a seat for the pilot!

Elsie's graduated from the University of Toronto in May 1927. Disenchanted with her first employment, at a small engineering company in Pontiac, Michigan, and attracted by the University of Michigan's activities in aeronautical engineering at Ann Arbor, she was offered a fellowship and enrolled in a master's program there the following November. She received her degree in 1929. However, just before this happened, she contracted polio and wrote her final exams in her hospital bed. For the following three years, while she recovered, she was confined to a wheelchair, after which - and almost to the end of her life, she was dependent on canes to get around.

In 1932, she resumed her career, enrolling as a doctoral student in aeronautical engineering at MIT, but dropped out late in 1934 to join the Fairchild Aircraft Ltd. at Longueuil, Québec as an assistant aeronautical engineer. Between then and May 1938, when she left Fairchild, she participated in design work related to a number of the Company's aircraft, none of which, in spite of good engineering, were commercial successes. She made contact with researchers in aeronautics at the National Research Council in Ottawa that would serve her throughout her career, as well as participating in the wind tunnel work that was carried out there. It was at Fairchild that she first met manager E.J. (Bill) Soulsby and his wife, who would figure prominently throughout her life. She was also an enthusiastic participant in the test flights of the aircraft. As Bourgeois-Doyle has written about the first of these flights:

> Elsie's legs were still too weak for her to consider piloting the plane, but on this day, she began a convention that would earn the respect of many pilots and earn recognition as a true aviation pioneer: to always accompany the pilots in any of the planes she had helped design as the 'participating observer' on all test flights....

Doyle also commented that she shared many minor achievements at Fairchild and that the special knowledge, skill and hard experience she acquired there turned her into a more capable engineer through learning what did not work as well as what did.

In 1937, the Soulsbys moved to Fort William where Bill took up a managerial appointment with the Canadian Car and Foundry Company, which was in the process of developing a place for itself in the Canadian aviation industry. When the position of chief aeronautical engineer became vacant, Bill encouraged Elsie to apply for it - which she did, successfully, moving to the Fort William in the summer of 1938. For the first while, she worked on the production of U.S.-designed Grumman *G-23* planes, most of which were sold abroad since they did not appeal to Canadian buyers. Her next project involved more design and stress analysis - for the all-metal Gregor *Fighter*, which Can-Car was developing on its own and which flew for the first time in December 1938. But the company could find no market for it.

In January 1939, Elsie received a new assignment - to prepare the complete design for the first all-Canadian biplane, which Can-Car hoped would appeal to the Canadian Armed Forces as a primary trainer, to be called the *Maple Leaf II*. (The *Maple Leaf I* trainer had been a failure, but the Company decided to continue the name.) This was quite a challenge since, among other features, the trainer had to incorporate aerobatic capabilities and be suitable for flying under Canadian conditions. The Company also expected there would soon be a war in which Canadian pilots would participate.

Maple Leaf II took its first test flight on October 31, 1939, with Elsie on board. With its safe landing, she became 'the first woman to have designed an aircraft.' As Bourgeois-Doyle commented:

> There are undoubtedly other women of achievement in the early years of aeronautical engineering. Yet the fact that Gardner, Lunn, Lotz and the other women most often cited as pioneers in aeronautical engineering acquired their qualifications at least a few years

later than Elsie MacGill reinforces the notion that Elsie might have been the world's first woman aircraft designer and aeronautical engineer. Considering her leadership and control of the unique *Maple Leaf II* trainer project, and her milestone academic work at Michigan in the 1920s, the assertion seems reasonable.

Eight months from the beginning of its design, the plane received its Certificate of Airworthiness. But, again, no market opened up for it - even in Canada, where the RCAF preferred to use British-designed training aircraft and, after World War II broke out, the British Commonwealth Air Training Plan authorities showed no interest.

By this time, however, Can-Car had begun to build a British fighter plane, the Hawker *Hurricane*, at Fort William. By the end of 1938, it had received an order for the assembly of this plane in quantity. Elsie and her 30-odd colleagues were deeply involved in the engineering needed to support this work, as well as to adapt the original design for Canadian conditions, to allow for a U.S.-made engine, and to accommodate successive versions. The first Can-Car *Hurricane* flew in early 1940, and Canadian-built aircraft took part in the Battle of Britain later that year. In all, Can-Car made over 1400 planes, in seven different versions.

As the War progressed, however, the *Hurricane's* usefulness declined, as did orders to build it. Beginning in 1942, Can-Car turned its attention to doing the same sort of thing for the Curtiss-Wright *Helldiver* for the U.S. Navy. But, as this situation evolved, the technical and production problems and design changes associated with its manufacture at Fort William became formidable, to say the least, for Elsie and her colleagues.

The *Helldiver* was only one of the problems faced by Can-Car manager Bill Soulsby, in 1942. His wife died in September. He had two children to care for. In the plant, morale was influenced by the large numbers of women employed and by attitudes towards them. His friendship with Elsie became a problem. Suffice it to say that both he and Elsie were dismissed from the Fort William plant in May 1943. A month later they were married, across the border in Illinois. The new couple moved to Toronto. Bill joined Victory Aircraft, which later became A.V. Roe Canada, again in a management capacity. In 1955 he became associated with Orenda Engines Ltd., and retired in 1967.

Elsie, who retained her maiden name, established a consulting practice with an office on Bloor Street. It appears she was the first woman consulting engineer to hang out her shingle, certainly in Canada. One of her first projects was advising Trans Canada Airlines on the feasibility of using a Canadian version of the Avro *York* as a commercial aircraft after the War. She also did work for de Havilland Aircraft Ltd. of Downsview. She was involved in NRC Committees associated with aeronautical research, and participated in discussions prior to the establishment of the International Civil Aviation Organization (ICAO). She also undertook public speaking engagements, where she discussed aircraft design issues, and which led to international recognition of her work.

In late 1953, Elsie broke a leg in an accident in her home. After surgery, during her recuperation, she researched and wrote her book on her mother - *My Mother, the Judge* - and thought a great deal about *her* thoughts on the role of women in society. And so began Elsie's second career - as an activist in policy issues with regard to women. While continuing to run her consulting business - which tended to fluctuate - she began to take active parts in organizations dealing with women's issues and women in business. For example, she submitted a paper on air transportation to the (Gordon) Royal Commission on Canada's Economic Prospects in 1956 and, in 1976, was elected to chair the Ontario Building Materials Commission. She was elected national president of the Canadian Federation of Business and Professional Women's Clubs in 1962. In 1967, she was appointed a member of the Royal Commission on the Status of Women in Canada, on which she was one of the most active and influential members, using her engineering and business training and experience to advantage. After the Commission's report was tabled in 1970, Elsie undertook many speaking engagements and was active in seeking the implementation of its recommendations. During the 1970s she became active in the National Action Committee on the Status of Women. But age and infirmity were taking their toll. Twenty-five years after her broken leg, she resorted to the use of a wheelchair again.

Elsie did, however, receive recognition - and 'firsts' - for her various activities during her lifetime. For example, in 1938 she was the first woman elected a corporate member of the Engineering Institute of Canada. In 1941, she received the EIC's Gzowski Medal for her paper, presented to the Lakehead Branch, on *Factors Affecting the Mass Production of Aeroplanes.* She also chaired the Lakehead Branch and served a term on the Institute's Council. In 1971, she became an Officer of the Order of Canada. In 1972, she was elected a Fellow of the Engineering Institute and, the following year, was awarded a Julian C. Smith Medal for her contributions to 'the development of Canada.' She was also the first female member of the Association of Consulting Engineers of Canada and the first female Fellow of what is now the Canadian Aeronautics and Space Institute. In 1979, Elsie was awarded the Gold Medal of the Association of Professional Engineers of Ontario. She was also recognized by technical societies in the United States and Britain, and was honoured with degrees by the University of Toronto and several other universities.

In October 1980, Elsie MacGill went to visit her sister in Cambridge, Massachusetts. She became very ill and died there in November. She was inducted into the Hall of Fame by NRC and, in 2007, was designated a 'person of national historic significance' by the Historic Sites and Monuments Board of Canada - her mother having been similarly designated in 1998.

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A student at Dalhousie University when the renowned C.D. Howe taught there, **Chalmers Jack Mackenzie** was born at St. Stephen, New Brunswick, of Scottish lineage, in July 1888. He worked briefly with his mason/builder father before attending university, receiving his degree in engineering in 1909, just before his twenty-first birthday.

Seeking somewhat 'greener' pastures to follow his profession, Mackenzie went west in early 1910.

With a classmate from Dalhousie, he opened a consulting practice in Saskatoon and carried out inspection and survey work. Not long thereafter, the partner left for other work and Mackenzie joined up with another St. Stephen native to continue consulting. The new partnership became involved in public works in both Alberta and Saskatchewan until October 1912 when Mackenzie received an invitation to join the staff of the University of Saskatchewan at Saskatoon to start the engineering course there - a connection that was maintained until 1939.

In 1913, having decided to stay in teaching, Mackenzie designed a full engineering degree course but, having realized that he himself needed post-graduate study, also enrolled in a master's program in civil engineering at Harvard University - a course he completed in a year. In 1916, the first of his students graduated and the School of Engineering at Saskatoon was closed for the duration. He and his teaching colleague, J.P. Oliver, joined the Canadian infantry. Commissioned and sent to France, Mackenzie served with distinction until the end of the War, winning the Military Cross.

Regular engineering classes were resumed at Saskatoon in 1919. Around two years later, it was decided that the School of Engineering should become a College within the University and Mackenzie was appointed the founding Dean. 'Dean' was the *prenom* - along with 'CJ' and 'Jack' - by which he was known affectionately by many, long after he left academia. Under his guidance, the College grew and prospered, its student body growing to 500 by 1939, and its reputation among engineering schools along with it. Mackenzie, himself, was also active in the wider community. He was, for example, a member of the Saskatchewan Drought Commission in the 1930s and a director of the Saskatoon City Hospital. He was elected to a term on the City Council, which served to emphasise his interest in future planning and development for the city. During the Depression, he was appointed chief engineer for the Broadway Bridge design and construction, which the federal government had agreed to fund as a relief project, and for which he took temporary leave from the University. The bridge opened for traffic in November 1932. He also participated actively for many years in the research work of his College and of the EIC committee examining the deterioration of concrete caused by sulphur-bearing groundwater.

In 1935, Mackenzie was appointed to a three-year term as a member of the Honorary Advisory Council on Scientific and Industrial Research, as it was then called, chaired by the president of NRC, who also headed the Council's own laboratories. He was reappointed in 1938 and selected to chair its committee reviewing the future direction of the Council's work. In September 1939, when General McNaughton, then Council president and head of the laboratories, prepared to return to military duties, Mackenzie - on McNaughton's recommendation - was appointed acting president for the period of his absence. His 'acting' status gave rise to regular correspondence between him and the General on matters pertaining to NRC. This continued for some time and led to a book being published by the University of Toronto Press in 1975 that made their correspondence public and provided a unique commentary on the wartime activities of the Council and the laboratories. In addition to his work within and on behalf of NRC, Mackenzie took part in Canadian diplomatic and scientific cooperation with the United States and Britain before, and after, the entry of the U.S. into World War II in December 1941. He also worked with his old mentor, C.D. Howe, now a federal Cabinet minister.

Mackenzie's influence on the post-war growth of scientific, research and engineering growth of Canada was significant. In 1944 he became president of NRC in his own right, and remained in this position until 1952. Deeply involved in the establishment of Canada's nuclear research and energy programs, he was named president of AECL in 1953-54 and was president of the Atomic Energy Control Board from 1948 to 1961. He was also involved in the establishment of the Defence Research Board and the Medical Research Council, in Canada's responses to Russia's atomic bomb and Sputnik, in the expansion of federal grants for university and industrial research, and in Canadian science policy generally. He served a Chancellor of Carleton University from 1954 until 1968. He also served on the Economic Council's Advisory Committee on Industrial Research and Technology in 1964 and 1965 and provided the key report to the federal government that led to the establishment of the Science Council of Canada in 1966. He maintained an office at NRC until his 90th year.

Mackenzie's membership of the Engineering Institute of Canada dated from 1911 when he joined as a junior, becoming a full member in 1920. He participated actively in its activities, chairing the Saskatchewan Branch in 1925, serving as vice-president in 1929 and as president in 1941. He was awarded the Sir John Kennedy Medal in 1943 and was elected an honorary member in 1947

Mackenzie was honoured many times. In addition to his Military Cross, he was made a Commander of the Order of St. Michael and St. George (CMG) in 1943, received the U.S. Medal of Freedom in 1947, and was made a Companion of the Order of Canada in 1967. In addition to receiving a number of honorary degrees, he was a Fellow of the Royal Societies of London and Canada and received a Royal Bank of Canada Award for 'Services to Canada.'

Dean Mackenzie was inducted into the Hall in 2007, an honour he shares with General McNaughton. His career success was due in part to his low-key manner and apparent 'unflappability' - something he apparently learned through his experience during World War I. He was also an enthusiastic golfer, playing into his 90s. At 92, he passed the Ontario seniors' automobile driving test. He died in February 1984 in his 96th year.

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It is coincidental that **Andrew George Latta McNaughton** should follow Dean Mackenzie in this present paper. They were colleagues in the 1930s and 1940s, and it was Mackenzie who followed McNaughton in the presidency of the National Research Council.

McNaughton was born in February 1887 at Moosomin, Saskatchewan, although at that time it was part of the Northwest Territories. He attended Bishop's College School at Lennoxville, Québec, before going to McGill, from which he graduated with a BSc in physics in 1910 and an MSc in engineering in 1912. He had enlisted in the Militia in 1909 and, when World War I began, was a member of the 4th Battery of Artillery in the Canadian Expeditionary Force, and went overseas. He then turned his attention to the problem of accurately pinpointing enemy targets, both stationary and moving, and used his engineering training to invent/develop a cathode ray direction finder which filled this need, and which was of particular assistance in the battle for Vimy Ridge. He later sold the rights to it to the Government of Canada. He ended the War as Lieutenant-Colonel in command of the Canadian Artillery Corps and earned the Distinguished Service Order.

In 1920 McNaughton enlisted in the regular army. He was promoted to Deputy Chief of the General Staff in 1922, and to Chief in 1929. During these years, he applied his engineering training to the mechanization of the armed forces and to the modernizing of the militia units. In the summer of 1932, while touring military establishments, he became acutely aware of the situation of the unemployed. In October he presented Prime Minister Bennett with a proposal to employ some of them in camps run by the military on work of national importance, such as building airfields and highways. Accepted with enthusiasm at first, the discipline applied to the camps' operations made them unpopular.

McNaughton returned to civilian life in 1935 and became president of the National Research Council, which he led until the outbreak of World War II and his return to the military. He was appointed to lead the First Canadian Infantry Division. As the Division grew, it was reorganized as a Corps in 1940. McNaughton continued to develop new techniques to weaponry, such as improved antitank and aircraft ranging ammunition. As mentioned above, Dean Mackenzie wrote regularly to McNaughton with regard to NRC's wartime scientific and technical activities, and their correspondence was eventually published in a book. In 1942 he was appointed Commanding Officer of the 1st Canadian Army. In spite of the positive aspects of his military and technical work, he was subject to criticism for his leadership. His views also put him in conflict with his political master, the Hon. J.L. Ralston, the Minister of National Defence. As a result of the various military, political and health pressures, McNaughton resigned his command in December 1943. Still supported by Prime Minister King, he entered politics in 1944 and was appointed to succeed Ralston as Minister in November. However, he was unable to win a seat in the House and resigned from the Cabinet in August 1945.

Post-war, McNaughton served Canada both at home and abroad in national and international appointments. Again, he brought to this work the benefits of his engineering training and experience. He served, for example, as president of the Atomic Energy Control Board in Ottawa and as Canadian representative on the United Nations' Atomic Energy Commission from 1946 to 1948. He was Canada's permanent delegate to the U.N. in 1948 and 1949, from 1950 to 1959 he served as chairman of the Permanent Joint Board of Defence and, from 1950 to 1962, was president of the Canadian Section of the International Joint Commission, which dealt with water resources along the Canada-U.S. border. In this latter position, his independence of mind surfaced again when he declared his opposition to the Columbia River Treaty.

McNaughton joined the Canadian Society of Civil Engineers in 1914 as an associate member and became a full member of EIC in 1927. In 1940 he was given the Institute's senior award, the Sir John Kennedy Medal which, because he was then on service in England, was presented to him at a meeting of the Institution of Electrical Engineers in London. He received many other awards during his lifetime for 'eminent services in scientific research and military leadership' - including British decorations, honorary doctorates and membership in the Royal Society of Canada. IEEE Canada's senior award is named the McNaughton Medal. As he said in his entry in the Hall of Fame website:

> Rarely is a soldier renowned as a scientist, or a scientist renowned as a soldier. My fame is derived from both of these pursuits, and my greatest impact comes by bringing science to the military, and the military to science.

McNaughton was a member of the military in the days before the Defence Research Board became formally responsible for bringing science to the military. Before and during World War II, however, the National Research Council fulfilled this function.

Andrew McNaughton died at Montebello, Québec, in July 1966. He was inducted into the Hall by NRC.

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Joseph-Alphonse Ouimet was a pioneer or 'father' of television in Canada. Born at Montréal in June 1908, he was educated at l'Université de Montréal and McGill, graduating from the former with a BA degree in 1928 and from the latter in 1932 at the head of his class in electrical engineering. His first jobs, for about one year each, were in research for Canadian Television Ltd. and the Canadian Electronics Company in Montréal, where he helped carry out the first Canadian experiments on television. In 1935, he joined the Canadian Radio Broadcasting Commission in Ottawa, again to do research, but was soon back in Montréal as an operations engineer. In 1939, he was appointed a general supervising engineer. One of his special achievements during this particular year was providing radio coverage for the Royal Tour. From 1941 until 1951, Ouimet served as assistant and later chief engineer of CBC. As chief, he was credited with the excellent technical quality achieved by Canadian television, as a result of which he was invited to advise the TV authorities in Australia.

Ouimet wrote in his Hall of Fame website entry:

> As early as 1932, I helped design, build and demonstrate the first Canadian TV set. It was at least 15 years ahead of its time, and my work helped me find a job with the Canadian Radio Broadcasting Commission, which soon became the Canadian Broadcasting Corporation. In 1936, I was responsible for setting up and running CBC's national radio service.

Ouimet went on to say that, when TV started to make its mark in the United States in 1947, he urged CBC's management to undertake this huge task for Canada, which they did - and they put him in charge of it. This meant establishing operating and engineering services using the two official languages, plus the problems of serving such a huge country - as well as overcoming the attitudes of those who believed TV was just an expensive toy!

In 1951, Ouimet was appointed assistant general manager of CBC, becoming its youngest general manager in 1952 and supervising the construction of television stations in Toronto and Montréal. In 1958, he was appointed to the additional post of president, one that he held until his resignation in 1967. By this time, broadcasting and its legislation in Canada had become politically contentious and was a contributory factor in his resignation from the CBC. But by this time, also, Canada had public and private networks providing one of the best services in the world and Ouimet was recognized internationally as a leading technical and organizational authority in the provision and operation of TV services. In 1969, he was appointed chairman of Telesat Canada, which built and launched many of Canada's communications satellites, and served until 1980.

Ouimet received many honours during his career - for example, the Archambault Medal of La Société Canadienne-française pour l'avancement des sciences, the Smith and Kennedy Medals of the Engineering Institute of Canada and the McNaughton Medal for public service, as well as honorary degrees from several Canadian universities. He was a member of EIC, the Institution of Radio Engineers and the (then) Corporation of Engineers of Québec. He was appointed a Companion of the Order of Canada in 1969.

Alphonse Ouimet died in December 1988. He was inducted into the Hall by NRC.

Wallace Rupert Turnbull was another of the present group to be designated a 'person of national historic significance' by the HSMBC, as well as being elected to the CMST Hall of Fame. He was also a member of the Engineering Institute of Canada, joining in 1944, although he gave a paper before the Saint John Branch on the Fundy tides many years before that. He was elected to honorary membership in 1951.

Turnbull was born at Rothesay, New Brunswick, in October 1870, a member of a wealthy family. He studied electrical engineering at Cornell, followed by two years' post-graduate work there and further study in Germany. His first job, for six years, was with the General Electric Company at Harrison, New Jersey. During this period his interest in aeronautics was stimulated by correspondence with Samuel Langley, glider experimentalist Otto Lilienthal, and Gustav Eiffel, who built the first wind tunnel.

In 1902, as his interest in heavier-than-air flight was developing, he established a private laboratory at Rothesay. His work there, over the next dozen years, included the building of a wind tunnel - his first, and the first in Canada - which he used for tests on aerofoils. Turnbull also collaborated with aviation pioneers such as Alexander Graham Bell and J.H. Parkin of the University of Toronto. He worked on hydroplanes driven by propellers and built an experimental track for testing the efficiency of airscrews - the first in aviation history. The results of this latter work led to Turnbull's receiving a bronze medal and a fellowship from the Royal Aeronautical Society in Britain At that time he was one of a very few Fellows of the RAeS in Canada and the only medallist.

Turnbull's 1955 obituary in the *Engineering Journal* goes on to say:

> In 1914 he closed his laboratory and went to Britain where he engaged in the design of various wartime devices, such as air propellers, bomb sights and torpedo screens. Returning to Canada in 1918, he continued his work on the development of a controllable pitch propeller, begun in 1916 when he was overseas. Because his first idea of mechanical brake control, attempted in 1923, turned out to be impracticable, he sought a solution for changing the pitch of the blades by electrical control. A second model working on this principle was developed (further) and built by Canadian Vickers Limited and was successfully tested at Camp Borden in 1927. Patents on the Turnbull controllable pitch propeller were taken out in Britain by the Bristol Aeroplane Company and in America by the Curtiss-Wright Corporation. Today, every propeller type aircraft aloft uses this control device - a small metal cylinder at the hub of the blades - for changing the pitch of the blades.

This device provided for safety and efficiency at all engine speeds. Since it was perfected independently in several countries, such as Britain and the United States, and because he licenced its manufacture, Turnbull's work on it tended to be overlooked by historians of aviation.

Turnbull, himself, had moved on. He did research on wing surfaces, patenting the double curvature wing surface. Earlier, in Britain, he had become interested in tidal power. On his return to Canada, he began work on harnessing the power of the Bay of Fundy tides. His paper on these before the EIC in 1919 attracted wide attention. He became a consulting engineer to, and a director of, the Peticodiac Tidal Power Company.

In 1942 the University of New Brunswick awarded him an honorary doctorate. The HSMBC designated him in 1960 in recognition of his contributions to aeronautical engineering in Canada, and especially his first wind tunnel.

Rupert Turnbull died at Saint John in 1954. He was elected to the Hall by NRC.

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Known affectionately as 'Jock' or 'Tuzo,' **John Tuzo Wilson** was a registered mining engineer in the Province of Ontario as well as an internationally known geoscientist and pioneer in the study of plate tectonics. He spent much of his professional life as a member of the Department of Physics at the University of Toronto.

Wilson was born in Ottawa in October 1908 to Scottish immigrant parents. He was the first

Canadian to take a course in geophysics, at Trinity College of the University of Toronto, graduating with a BA degree in 1930. He went from there to England on a Massey Fellowship, to St. John's College at Cambridge, where he graduated with a second bachelor's degree in 1932. Then it was back to the United States and to Princeton for his doctorate in geology, which he received in 1936. At both Cambridge and Princeton he met a number of outstanding teachers and students who would remain friends and distinguished colleagues throughout his life.

Wilson joined the Geological Survey of Canada as an assistant geologist on leaving Princeton. His first assignment was in Nova Scotia, where his work was mostly conventional mapping but it began his interest in the overall geology of the Maritime Provinces, which served him well later on, when he studied the oceans. He was then moved to Québec and to the Northwest Territories, where he was again mapping, but with help from the new technique of aerial photography - something that Wilson pursued when back in Ottawa. Nevertheless, he found the publishing of novel ideas difficult within the Survey and decided to become part of a more research-oriented organization. But World War II intervened to disrupt his plans. He obtained a commission in the Royal Canadian Engineers and was eventually sent overseas with a tunnelling company. However, his broader talents and experience were appreciated by his superiors and he was put to other work, which included appointment as director of Army Operational Research and promotion to the rank of colonel. He returned to Canada in 1944 where, for the next two years, his directorate tested army vehicles under severe Arctic and sub-Arctic conditions, as part of Exercise Musk Ox. As mentioned above, the civilian consultant on vehicle design for Musk Ox was Armand Bombardier.

Wilson left the Army in June 1946 to return to the University of Toronto to accept appointment as a full professor of geophysics in the Department of Physics - and the only one in Canada at the time - on the basis of his doctorate and his wartime record and without having spent time in the junior professorial ranks. He had also a cross appointment as a professor of geology. His task was to re-build the geophysics group and seek funds and students for research that applied physics to the broad problems of the earth. His own initial work was centred on the Canadian Shield and on the age zoning of continents - the beginning of scientific geochronology in Canada . He preferred to work with associates and colleagues and, after 1955, limited his supervision of students. His work for the Department of Geology was also limited.

One of his close associates at this time was the applied mathematician, A.E. Scheidegger. A paper of their's, published in 1950, first made Wilson's name internationally known to earth scientists around the world. One result was an invitation to visit Australia, which he turned into a world tour. Within Canada, his unique appointment led to his being asked to serve on national and international scientific policymaking committees, one such being the Canadian Committee for the International Union of Geodesy and Geophysics (IUGG), of which he became a vice-president (and later president) in the years leading up to the International Geophysical Year (IGY) in 1957-58. He was also the first western geoscientist in many years to visit colleagues in the U.S.S.R. On this same trip, he visited China and South Africa, again, where he formed connections and friendships that lasted his lifetime.

Wilson's international activities became less onerous after 1960. He was able to devote more time to research, and especially with regard to continental drift. As the University of Toronto website noted (University of Toronto II):

> At some point in the late 1950s he abandoned his former belief that the continents were fixed on earth and began to examine the consequences of large-scale displacements of continents and oceans. It is fascinating in retrospect to trace this conversion. According to his own statement......it would be nine years after his visit, in 1950, to South Africa before he would accept continental drift. It is known that he remained unconvinced at the time of the General Assembly of the IUGG in Toronto (in 1957), where there was an important discussion of the paleomagnetic evidence for drift.

From the study of the tectonics of the Canadian Shield, he turned his attention to the Atlantic Ocean and to the ocean floor and the ages of oceanic islands. By 1963, it appeared that the main concepts of ocean-floor dynamics had been accepted by most earth scientists world-wide. By 1967, plate tectonics had become generally accepted and Wilson was recognized as a leader in the study of the earth. He also became active in the study of the life histories of oceans, beginning again with the North Atlantic. This work led later, in 1983, to the categorization of the oceans in terms of their life cycles, which became known as 'Wilson's cycle of oceans.'

1967 was also the year Wilson - an untried university administrator - was invited by the president of the University of Toronto to become principal during the difficult first years of the new suburban Erindale College. Over the next seven years, using various means and a great deal of energy, and apparently with success, he built the new College and its campus. The fields of study and research differed in emphasis from those of the main downtown campus and included the establishment, at Wilson's instigation, of a Department of Earth and Planetary Science, which combined geology and geophysics. His own research began to take on a more philosophical appearance. He also engaged in an international debate on plate tectonics. And following his long-time interest in China and its culture, he commissioned the building of a junk in Hong Kong, which he sailed from his summer cottage on Lake Huron.

In 1974, at the age of 65, Wilson was invited - as an scientist, known internationally, who could express his views to lay people with ease - by the Premier of Ontario to become the director general of the Ontario Science Centre in suburban Toronto. His policy, while preserving the museum-artifact-model nature of the Centre, was to stress the 'hands-on' approach to its exhibits since it was through doing experiments that one learned about science. He also featured temporary exhibits, one of which was on the technologies used by the Indians and Inuit and another on the development of science and technology in China. And he sent travelling exhibitions to various parts of the world.

At this late stage in his career, Wilson was one of Canada's recognized spokesman on matters of policy for the earth and other sciences and technologies and he devoted generously of his time to this work, serving for example on both the National Research and Science Councils of Canada. With his support, for example, Science North was built at Sudbury. He also chaired several investigative commissions. And he hosted a television series.

Wilson retired from the Science Centre in 1985. He then returned to the University of Toronto, principally to write and to continue his interest in tectonics. He was also, from 1983 to 1986, the Chancellor of York University.

During his lifetime, Wilson received recognition in the form of degrees, medals and awards from many sources. He became, for example, an Officer and later a Companion of the Order of Canada. He was a Fellow of the Royal Societies of Canada, Edinburgh and London, and president of the RSC. He held the U.S. Legion of Merit and was an Officer of Britain's Order of the British Empire. He was awarded the Wollaston Medal of the Geological Society of London and the Bucher Medal of the American Geophysical Union. A medal bearing his name is awarded by the Canadian Geophysical Union and recognizes achievements in geophysics.

John Tuzo Wilson died in April 1993, in his 85th year. During his lifetime, he constantly acknowledged the significant help from his wife, Isobel, in his many endeavours. He was inducted into the Hall in 2003.

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Some Comments

The 16 were very different people and had very different backgrounds, careers and lifetime achievements - some better known by the public than others - but all culminating in induction into the Museum's Science and Engineering Hall of Fame.

Of the 16, nine had formal training in a discipline of engineering at the university level. Of the others, in Fleming's case a university degree in engineering was not an option when he was young, but he did study engineering before embarking on his career in Canada. Bombardier had an abundance of 'mechanical' talent, served an apprenticeship and took some night-school courses. Fessenden and Bell were hugely talented and largely self-taught. Hillier trained as a physicist, but much of his later work was related to engineered products for the marketplace. Wilson was a geophysicist but was also a registered professional engineer in the mining branch in Ontario. The kind of research work he did was indeed valuable when applied by others to engineering projects. Dawson trained as a geologist, but has been included for his leadership and contributions to the beginnings of engineering education in this country.

When the criteria for induction into the Hall are considered - contributions to the advancement of science and engineering, leadership, and bringing benefits to society - all 16 qualify, as one would expect in the light of the rigour applied to their selection.

Research, usually with development, was the main concern of a half-dozen of them: Bell, Hillier, Hopps, Klein; Le Caine and Turnbull. In Heffernan's case, he combined R&D with innovation, engineering practice and the management of companies exploiting the technology he developed. Dawson and Wilson were basically researchers, but both added administration and management as their careers developed. In varying degrees, Bombardier, Fessenden, Fleming, MacGill and Ouimet combined development and innovation with engineering practice, administration and management. Mackenzie began as a consultant, moved into education - with time out for research, practice and local politics - and ended his formal career in administration and management in the public service. He then became an 'elder statesman' for engineering. In spite of spending much of his life in a service uniform, McNaughton engineered devices for army use, as well as performing as a military man. He was also an administrator/manager - and a politician - and in his final years combined engineering with elder statesmanship.

Interestingly, if one notes the instances of major R&D contributions among the 16 engineers and assumes that the contributions of the 26 scientists inducted into the Hall came wholly or principally from research, it could be concluded that 'the way into the Hall' - so to speak - is through research. Incidentally, this in no way denigrates the contributions of the scientists concerned, but it could, in theory at least, eliminate from consideration the 80-90 per cent of engineers whose careers and achievements are associated with design, practice, consulting and management. On the other hand, among the 16, there are some examples of the latter activities having been recognized by the induction selection committees.

One other cautionary note. When the National Research Council was responsible for inductions, prior to 1996, 11 of the 20 inductees were among the 16 mentioned in this paper, although only three - Klein, Le Caine and McNaughton - were the Council's own 'people.' Since the Museum became responsible for induction selections, only five of the 22 were among those considered in this paper, and three of the five - Dawson, Hillier and Wilson - were not engineers by training. One might conclude that, for the Museum's committees, science provides a surer way 'into the Hall' than does engineering. On the other hand, it may well be that not enough engineers are being nominated in the first place.

It has been estimated that the 'populations' of scientists and engineers in Canada has, for at least five decades, been about equal. So, on balance, 16 out of a possible 42 places in the Hall is not too bad a showing.

Lastly, individual 'bios' in this paper have been of varying lengths, depending on the secondary material available. Those for whom book-length biographies were used were obviously at an advantage!

Now, for the selection of more notables......

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