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"The Importance of Engineering (an Update)"

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THE IMPORTANCE OF ENGINEERING:
AN UPDATE

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For the Centennial of Engineering in Canada in 1987, I wrote an article titled "The Importance of Engineering" which was published in the Centennial Edition (and very last issue) of the Engineering Institute of Canada's magazine, the *Engineering Journal.* During this present year - 2012 - the Institute is celebrating the 125^{th} anniversary of its founding. While the contents of the original article are still valid, the practice of engineering has changed somewhat over the past 25 years. The purpose of this present article, therefore, is to review the original briefly and to add something about the changes in practice that have taken place.

The problem remains that the general public's understanding of, and appreciation for, engineering is essentially unchanged. The whole subject area, including civil, electrical, mechanical and the other fields of engineering, is as much a mystery as it ever was to most people. Consequently, it is still taken for granted - unless, of course, there is an accident or threat of physical danger for which it can be blamed. To science, on the other hand, credit is usually given for the good, and sometimes spectacular, things that engineering has done.

Nevertheless, engineering is still important, for at least three reasons:

First, it has continued to make contributions to transportation, communications, manufacturing, construction, and resource exploitation that allow the country to maintain its status as 'developed.'

Second, it is difficult to imagine what Canada would have been like had this engineering not been done;

Third, without engineers of its own, a very great deal less would have been accomplished.

What is engineering? It is an activity that has a number of sub-activities, the most important of which is design. But there are others such as development, production, manufacturing, construction, research, maintenance and management. It applies ingenuity and imagination to the creation of machines, devices, processes, structures and so on, using the forces of nature, energy and materials. It is the key element in technological innovation, linking the ideas, the research and the inventions to the requirements - sometimes obvious, sometimes not - of the marketplace. Engineering also requires customers or clients to set it in motion and is dependent on financial support for its performance and for its creations, although these creations may have to be energetically marketed.

As a profession, engineering has three elements: the *registration and licensing* of practitioners; the *business* of engineering; and the accumulation and dissemination of information - the *learned* aspects of it. And while engineers receive their training in schools, the experience and the judgemental ability they gain in industry and elsewhere in its *practice* is even more important.

Science and technology, on the other hand, are bodies of knowledge, both of which provide information that engineers may use in their activities. Simply put, science is concerned with knowing *why*, technology with knowing *how*. One aspect of the problem for the public's perception of the profession is that engineering's relationship to science and technology can become 'cloudy.' Some scientists, at times, may function more or less as engineers and some engineers, at times, more or less as scientists; similarly, for engineers in their relations with technologists. In Canada, however, only registered engineers may put their stamps on drawings!

As a profession, engineering has a number of other problems. For example, most of those who qualify for it do not spend their whole working lives in its practice, as is the case in medicine and the law. Again, a relatively small proportion of engineers do full-time research (usually along with teaching). The majority are in practice, in one form or another. Yet recognition of engineering achievement tends to be given to the researchers rather than to those who do design or one of the other sub-activities. In the same way, the achievements of engineers in the service of governments tend to be overlooked in favour of those in the universities and industry. It is also important to recognize that the influence of Canadian engineers and engineering are not limited to markets in Canada.

The importance of engineering has three components: social, political and economic.

How many engineers are there in Canada? The figure of a quarter of a million has to be an estimate since not all of them have registered with the provincial associations and since census statistics includes some who would not qualify for registration. This figure is almost double the number in 1985. Engineering has always been a male-dominated profession and, although the number of women members has increased since World War II, it is still a relatively small proportion. The total population of the country currently stands at around 35 million.

Socially, it is unfortunate that the profession of engineering has been called 'invisible' - and especially so in comparison with medicine, law, entertainment, sport, the military and even accounting. There are no real heroes, although I don't like the term. Even those generally recognized as having demonstrated 'heroism' within the profession are from the 19th century - Fleming, Gzowski, Kennedy and the Keefer brothers. Apart from Fleming and his association with the introduction of standard time, the public does not know these names. The 20th century heroes, perhaps, include Marc Garneau and Bob Thirsk, because they were engineers before they became astronauts. Who are the others? George H. Duggan, Julian C. Smith, John B. Stirling, Robert F. Shaw, Bernard Lamarre and C.D. Howe?

The engineering function in society is to help provide the amenities required/desired by *people*, and this it does under the guidance of, and with the budgets allotted by, the various levels and departments of government, by the private sector and by individuals. This work therefore has very human dimensions and involves political, commercial and engineering judgements on what constitutes value for the money provided. Engineering must also provide employment to the best of its ability, subject to the inevitable fluctuations in market activity, both at home and abroad, and to the ability of the universities to train engineers. To an extent, the social influence of engineering will also extend to the *perceptions* of the politicians and the public with regard to large areas of public and private expenditure, such as energy, safety and the physical environment. Anti-technology movements are therefore disquieting. And as American engineer-philosopher Samuel C. Florman warned in the July 1983 issue of *The Canadian Consulting Engineer*:

> .....ironically, after several hundred years of engineering achievements, the Greek states became wealthy enough to support great academies, and then along came Plato to say that thinking is better than doing, and that pure thought is superior to thought sullied by utilitarian objectives. During the Golden Age of Athens, the handicraft arts were considered to be beneath the dignity of the citizen…..

Such thoughts should put the engineer on guard in dealing with social concerns. Basically, these will centre for him or her around the question of whether or not - as a result of peer judgement - the work done is good as *engineering*. But this may not be enough for the politicians or the public. A partial solution would be for engineers to pursue more social studies in university or afterwards.

Politically, it has not helped the engineering profession that so few of its members have been 'visible' in politics. Few, indeed, have risen to Cabinet rank in the federal government. The most visible and influential of them has been C.D. Howe, in MacKenzie King's time. Others include Robert Winters (who ran against Pierre Trudeau for the leadership of the Liberal Party in 1968), Grote Stirling (who served in the R.B. Bennett Cabinet), Robert Layton (Jack's father), Harvie Andre, Tom Siddon and William Winegard (who served in Mulroney Cabinets) and, in the current Cabinet, Steven Fletcher. Not many more have been elected as members. In the 1986 House, for example, there were 41 lawyers, 26 professors and teachers, 16 farmers…and 8 engineers. The corresponding numbers after the 2011 election in May were actually similar and included 38 lawyers, 26 professors and teachers, 13 farmers…..and 8 engineers. The largest groups in both Houses were from small and medium businesses.

The political dimension to engineering may, in practice, have more to do with the programs and operations of the individual government departments and agencies than with party politics. No party can afford to ignore it as an important vehicle for the implementation of some social and economic programs. Indeed, departments at all levels have statutory obligations to make some use of engineering. Still, engineers do have a 'sort-of' political voice. They vote in elections. They also work for governments but, as mentioned already, this work does not always appear to receive the recognition it merits. And while some politicians may remain in government for some time, they generally do not, so that the engineering profession has to renew its educational role with political people every so often. In theory, the longer serving senior public officials should provide the necessary continuity. But how many of them have qualifications or experience that will allow them to make appropriate judgements?

While the connections of engineering with society and with politics may be both direct and indirect, its connections with the economy are quite direct. Engineering contributes to the gross national and domestic products. It creates wealth and growth, and these are primary goals in most economies. It also generates jobs, incomes and profits and contributes to the improvement of productivity. It shares with economics the use of the trade-off in the solution of many of its problems. It may be a key activity in invention and it is *the* key activity in the process of technological innovation, whether this be revolutionary or evolutionary, related to products or to processes, market- or society-oriented. However, engineering cannot ensure that the benefits of any new wealth or growth will be shared appropriately among the members of the public. These are decisions best left to politicians and economists.

Unfortunately, unlike the procedure in place for the counting up of R&D expenditures, no country appears to have attempted to tabulate on an annual basis its national costs of engineering activities and, consequently, it has no means for assessing how well, or badly, its engineering has contributed year upon year to the well-being of the state. Nor are there figures that assess the *benefits* of engineering. There will almost certainly be productivity figures available, but these may reflect the needs of economists rather than those of the managers of engineering.

Countries do, however, have partial - but quite insufficient - measures for engineering, such as the output of their construction, mining and manufacturing sectors and attempts to develop better substitute measures have been made in years past by economists, such as Wassily Leontief, with his input/output models, and Edwin Mansfield. In practice, the counting of engineering costs may not be too difficult. The counting of benefits will be much more complicated since many engineered products, such as dams and bridges, have several orders of these, ranging from the benefits to those who worked on the structures to those who used the dam's generated power or the vehicles that crossed the bridge, including what has been saved by building it. And while it may be relatively easy to assess the benefits of orbiting communications satellites, how do you count up the benefits of expenditures on spacecraft exploring the moon?

During the last quarter-century, the majority of the changes that have taken place in engineering practice have been linked to the continuous development of computer hardware and software and have echoed the changes taking place in other parts of the economy and society. The slide rule, once an indispensable part of an engineer's personal equipment, has been abandoned. The design process has been significantly changed. Punched cards are no longer used. Nor is tape. Projects have become increasingly interdisciplinary. Personal computers have more or less replaced the mainframes that were used earlier for long and complex calculations. Software now allows the modelling of the possible solutions to engineering problems on a scale only vaguely imagined a quarter of a century ago. Information can be transferred quickly and efficiently from the designer to the client. Secretaries have become redundant. Engineers write and send their own letters. Engineering teams are easier to manage, although the projects they can tackle have increased in complexity.

However, Natasha McCarthy, a non-engineer, in her recent book *Engineering: A Beginner's Guide* reminds us of continuing problems for the engineer:

> Engineering practice is not like scientific research, carried out in the lab under carefully controlled conditions that can be varied by the experimenter. Engineering takes place in the real world, where numerous influences interact and where circumstances are frequently novel and variable. As a result, the engineer cannot always predict with certainty how an engineered system will behave in all of the situations it will face. This uncertainty means that engineered systems always contain an element of risk - risk that they won't function, risk that they will fail dramatically, risk that the costs of the system will escalate, and risk that they will turn out to be a huge waste of money. Therefore, key to engineering is the ability to assess and to manage the risks inherent in any engineered artifact, process or system.

One of the important problems arising from recent changes in the 'technology' of engineering practice is the fear that, having so much at their fingertips, engineers will fail to acquire the maturity of judgement that experience of the kind acquired in years past by their peers. Experience and observation will always be prime attributes of the effective engineer.

Engineers, like doctors and lawyers, deal with ethical dilemmas, with life and death situations, with health, safety and environmental considerations. They also deal with deadlines, with rising costs, with politically-motivated as well as economically motivated regulations, and socially-motivated codes and standards, with choices to be made between valid options and opinions, and with the need to maintain the reputation of the outfit they work for as well as their own. They have to use appropriate information, and this will not necessarily have been newly derived/discovered in a research laboratory but may require that a laboratory be asked to provide it. And they have to inject elements of the future into the present without knowing what that future might bring.