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The Relationship Between Engineers and Society: is it currently fulfilling its potential?

An Invited Discourse

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Abstract

The structure and operation of the complex societies of the developed world are completely dependent on countless applications of technology, as we can observe in our daily lives. But what we may be less conscious of is that the evolution of society – what it will be tomorrow – is also highly dependent on our development and application of technology; to a large extent our society is what it is today as a result of the technology we chose to apply in the past. Engineers play a major role in the development and application of technology, and so have a responsibility for the evolution of society. It is the nature of that responsibility that is the subject of this paper, and it is suggested that it is mainly in providing the information society requires in order to make its decisions.

Introduction

The mission of the Royal Society of NSW is to encourage studies and investigations in science, art, literature, and philosophy, and of these areas of intellectual activity science is currently by far the dominant topic in the Society's discourse. Science is about knowledge about Nature, and simplistically one could therefore expect that there is nothing further to be said about this knowledge as such; it is either there or it is not. But knowledge is a very human product and involves such concepts as truth, verifiability, acceptability, and many more, so that there is a significant branch of philosophy dedicated to the study of the nature of this knowledge under the umbrella of Philosophy of Science. Besides strictly philosophical issues, this umbrella also covers work that is to a large degree sociology, as it is concerned with how scientists work, how they associate, how they form opinions, etc. However, there is one important concept that does not apply to scientific knowledge, and that is *value*; not in terms of money or potential usefulness, but in an ethical sense. Knowledge itself is neither good nor bad. Knowledge has no influence on anything; it is only the application of knowledge that has an influence and can be good or bad.

The application of scientific knowledge is a central part of engineering, but while there are strong links between the three areas of intellectual activity – science, philosophy, and engineering – the philosophical aspects of engineering are on the whole quite different to those treated in the Philosophy of Science. In both, we can talk about the nature of things themselves (ontology) and the nature of our knowledge of them (epistemology). Engineering raises some special issues, arising mainly from the role of heuristics in engineering practice, but it is above all ethical issues in engineering, either explicitly or implicitly, that have seen considerable activity from both philosophers and engineers, as evidenced by some recent publications (Hector 2012, Christensen 2007, Beder 1995, Unger 1994, Vann 1997). The issues have been mainly concerned with the behaviour of individual engineers towards other individuals as well as their environments, as exemplified by numerous Codes of Ethics. These form a set of *rules* that define engineering as a practice; they form a framework that restricts *how* engineering is to be performed, but say nothing about the *value* of the engineering. The purpose of this paper is to initiate a discussion about an aspect of the responsibility of engineers that has received relatively little attention. It arises from the accepted realisation that technology has a significant and rapidly increasing influence on the evolution of society. Engineers play a major role in the development and application of technology, and with this role comes a certain responsibility for the direction in which society develops. Some of the issues related to recognising and exercising this responsibility has been the subject of recent work (Aslaksen 2014); this paper focuses on the nature of the responsibility itself. How can it be defined in operational terms, how can it be quantified, how is it influenced by other features of society? To approach these and related issues, the paper first gives an overview of previous work relevant to the relationship between technology and society, to the relationship between technology and engineers, and to the relationship between engineers and society; all three of which are crucial to any discussion of the responsibility of engineers for the evolution of society. The core of the paper is then the development of an understanding of what this responsibility consists of and what its limitations are, and as this understanding is necessarily based on a view of the process of evolution, the disclosure of that view is an important component of the paper.

Background: Technology and Society

The meaning of the word "technology" relates to the field of human activity that may be described as the modification of elements of the natural surroundings in order to meet a need; what we shall call a *purposeful* modification (Aslaksen 2012). It started when humans developed the mental ability to recognise the possibility of such a modification and the physical dexterity to realise it, and the purpose included giving visual pleasure or increasing one's self esteem (painting, ornaments, sculptures), worshipping a deity (monuments, temples), providing shelter (dwellings), increasing mobility (roads, bridges, boats), providing food (traps, weapons, agriculture), preparing, serving, and storing food (bowls, pots, plates), and so on. This is roughly what the ancient Greeks identified as *techné* (which in Greek is spelt τεχνη, and would actually be *texnh* with Latin letters). According to the dictionary (LSJ 1940), the word means "art, skill, cunning of hand", and so, in the broadest sense, applied to any creative activity and the products that arose from it. When then engineering became a recognised profession and the subject of philosophical enquiries as to its content and purpose, much of the early work was in the German language, and the word *Technik* was adopted to refer to both the activity of and artefacts produced by engineering. As a result, the word *technology* took on this same meaning in much of the work in the English language on philosophical enquiries related to engineering. But within the engineering profession itself, technology means the knowledge and resource base engineers apply to create new works; the activity of creating the works is called engineering.

The identification of the resource and knowledge bases as constituting "technology" is a deviation from the use of "technology" by philosophers and sociologists, where it is used in a much more encompassing manner, such as "the production and use of artefacts". And many publications on the philosophy of technology make no mention of engineering at all. However, while much of what philosophers say about technology can be reflected onto engineering, it is important to keep the distinction in mind. Whereas philosophers see technology as an activity (or at least including activities) and the resulting artefacts, as e.g. in Li (2010), no engineer would speak of "doing technology".

The concept of "technology" is also used extensively in sociology. The tension between the usage of "technology" in engineering and in philosophy and sociology was discussed briefly in Aslaksen (2013a), but a useful perspective on the everyday use of the concept is given by Leo Marx (Marx 1994), where he shows that the character and representation of "technology" changed in the nineteenth century from discrete, easily identifiable artefacts (e.g. a steam engine) to abstract, scientific, and seemingly neutral systems of production and control. As a result, the newly refurbished concept of "technology" became invested with a host of metaphysical properties and potencies that invited a belief in it as an autonomous agent of social change, attributing to it powers that bordered on idolatry.

The point of this is that the meaning of "technology" is unavoidably context-dependent, and that must be taken into consideration throughout this paper.

The relationship between technology and society has been a subject of study and discussion for more than a century. Heidegger (Heidegger 1977) recognised the achievements of engineering and the benefits of technology, but thought that there were already indications that this force was controlling us, that Nature in itself was losing its value and becoming simply something to be exploited, and that a run-away situation could arise. Dessauer (Dessauer 1956) saw technology (and engineering) as an expression of God's plan for mankind, which would lead us to independence from material restrictions and elevate us to a spiritual level, whereas Ellul (Ellul 1980) essentially saw the force as evil and the evolution of technology as the Devil's work. And, of course, we should not forget how we were banished from Paradise by tasting the forbidden fruit of the tree of knowledge; a parable that makes the engineer's role somewhat akin to that of the snake, tempting society to move ever further away from its "natural" state.

Much of the early work on the influence of technology regarded it as taking part between two separate spheres of existence; a genuine (or intrinsically, or unsullied) human sphere and a sphere in which technology is prevalent, see e.g. Mackenzie (1999) and Smith (1994). Technology was seen as developing under its own imperative, and so the interaction was a one-way process, with conflicts arising at the interface between the two, and with humans sometimes seen as the "victims" of technology. More recent work sees the interaction as a process that is both two-way and so dynamic that it is not possible to make a clear-cut distinction between humans and technology. Human behaviour is always a hybrid of supposedly human and technical aspects, and what is of interest are the different kinds of human-technology interactions. This two-way process is treated in an article by Dorrestijn (Dorrestijn 2012) in the context of an analysis of the relevance of Foucault's work to a philosophy of technology, and is then reflected in the relationship between technology and society, which together form a complex system. An article by Callon (Callon 1987), in which he describes and analyses the electric car project undertaken by Electicité de France in the 1970s, is an excellent example of this. He introduces the notion of an actor network to account for the interactions between the numerous elements making up the system, and emphasizes that these elements include people, organisations, and social movements, but also technological artefacts and assumptions.

Another approach to investigating the relationship between technology and society is "social experimentation", which consist of introducing an application to a segment of society and observing the effects. It was used in the 70s and early 80s, but its utility was controversial, see e.g. Hausman and Wise (1985) and Archibald and Newhouse (1980). More recently the idea of technology introduction as social experimentation has been revived, in particular with regard to ethical concerns and the public's "right to know", by such groups as the 3TU.Centre for Ethics and Technology (http://ethicsandtechnology.eu).

This two-way process, the mutual interaction between technology and society, can be viewed as a form of supply-and-demand relationship. Society makes demands, in the form of needs and desires; technology provides solutions, and society provides feedback in the form of the degree of acceptance of these solutions. The central issue is on what basis society evaluates the solutions; the quality of the information supplied by the technology providers.

Engineers and Technology

Nowhere is the context-dependence of the meaning of "technology" more apparent than in the relationship between engineers and technology. If by "technology" we understand the resource and knowledge bases, then the relationship is very close; engineers are the creators of technology. The direction and pace of development are influenced by the local market and investment conditions, as well as by advances in science, but the new construction elements, tools, and techniques added to the resource base, and the related knowledge added to the knowledge base in the form of articles, textbooks, and standards are all produced by, and the responsibility of, engineers.

But, if we take the meaning of "technology" to be that given to it by society in general, i.e. by non-engineers, then the relationship of engineering to technology becomes much less clearly defined. What society experiences as "technology" is influenced by many other groups of people besides engineers, as has been pointed out by many authors, e.g. (Hughes 1987). The reason for this is that engineers are today almost completely embedded in the framework we call *industry*, which encompasses not only private industry, but also government entities involved in applying technology and educational institutions involved in developing and disseminating technology. What society experiences as technology is the product of industry. An engineer on his or her own can accomplish very little, and so what society sees is the work of the engineer through an industrial interface in which numerous people play a part, such as workers, tradespeople, marketing and sales people, business managers, financiers, etc. This has become more pronounced with the outsourcing of the engineering of public works to private industry, but also as a result of the increased politicisation of the public service. The position of the engineer within industry, and the relationship between engineers as employees and the industrial entities in which they are employed will be a major boundary condition when it comes to considering the responsibility of engineers to society, and it is not a new issue. In his essay *The Captains of Finance and the Engineers*, Thorstein Veblen wrote; "It is perhaps unnecessary to add the axiomatic corollary that the captains have always turned the technologists and their knowledge to account in this manner (for their own gain) only so far as would serve their own commercial profit, not to the extent of their ability; or to the limit set by the material circumstances; or by the needs of the community" (Veblen 1921).

What is presented to society are applications of technology (in the engineering sense); society just call it "technology" as a sort of shorthand, but without much thought as to what this shorthand all encompasses. The process that leads from an idea in the creator's mind to a product in the user's hand is largely hidden from most of society, and, of particular relevance in the present context, the role and responsibility of engineers in this process are hidden. Most people would have a very vague (if any) idea of how the "technology" they see all around them and use every day is related to the work of engineers. It is paradoxical that as technology becomes more and more pervasive, the relationship of engineers to technology, as seen by society, is becoming less and less visible.

The relationship between engineers and industry, or what society sees as technology, is also discussed as part of a recent essay by Newberry (Newberry 2007). In particular, he makes reference to the suggestion by Noble (Noble 1977) that industry has forcefully shaped the mechanisms for engineering education and professional socialisation in order to produce a "domesticated breed of engineers".

Engineers and Society

The main point of the previous section regarding the significance of the relationship of engineering to society is that this is mainly an indirect relationship, with industry, in its various forms, as the intermediary. While society sees various occupations, from dentist to bus driver, at work and understand what they do, engineers are largely invisible. That is, the picture we need to keep in mind is that shown in Fig. 1.

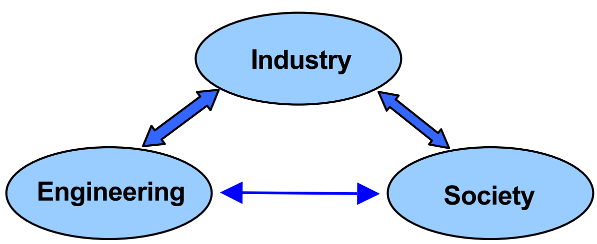

Figure 1: The relationship between engineering and society, with industry as an intermediary.

Only rarely do engineers interact directly with society, free from any considerations of their ties with industry, and the products and services society sees and sometimes associates with engineers are presented by industry. A couple of decades ago Langdon Winner wrote (Winner 1995): "One might suppose that the technical professions offer greater latitude in dealing with the moral and political dimensions of technological choice. Indeed, the codes of engineering societies mention the higher purposes of serving humanity and the public good, while universities often offer special ethics courses for students majoring in science and engineering. As a practical matter, however, the moral autonomy of engineers and other technical professionals is highly circumscribed. The historical evolution of modern engineering has placed most practitioners within business firms and government agencies where loyalty to the ends of the organisation is paramount. During the 1920s and 1930s there were serious attempts to change this pattern, to organise the various fields of engineering as truly independent professions similar to medicine and law, attempts sometimes justified as ways to achieve more responsible control of emerging technologies. These efforts, however, were undermined by the opposition of business interests that worked to establish company loyalty as the engineer's central moral concern (Edwin T. Layton, The Revolt of the Engineers: Social Responsibility and the American Engineering Profession, Cleveland: Case Western Reserve University, 1971, ch.1, 2). Calls for a higher degree of "ethical responsibility" among engineers are still heard in courses in technical universities and in obligatory after-dinner speeches at engineering societies. But pleas of this sort remain largely disingenuous, for there are few legitimate roles or organised settings in which such responsibility can be strongly expressed." This is a major difference to other professions, such as medicine, where there is a direct interface between the profession and society, as illustrated in Fig. 2.

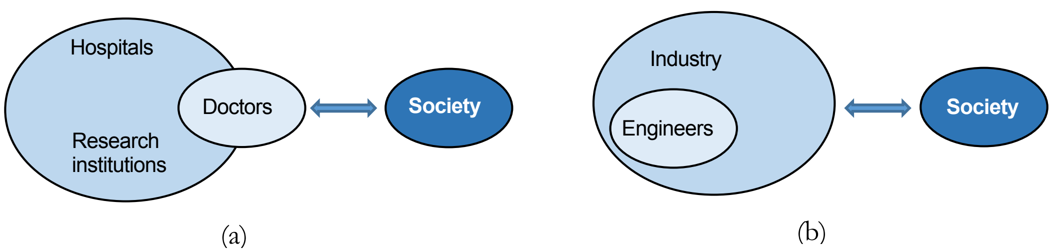

Figure 2: Illustrating the indirect interaction between engineers and society, in (b), as opposed to the direct interaction between doctors and society (their patients), in (a) (from Aslaksen, 2014).

The employment situation in engineering, which is different to that in e.g. medicine and law (although the independence of doctors and lawyers is being eroded, too), is a significant factor in the relationship between engineers and society, as discussed in (Aslaksen 2013). The peculiar situation engineers find themselves in is that they are both employers and employees; not like ordinary workers, where their organisations – the unions – are quite distinct from their employers and their organisations. Not only are the two roles of engineers, employers and employees, evident in industrial companies, but also in the organisations that are supposed to represent the interests of engineers, such as the institutions of engineering. In these organisations, the leadership is usually from the management side of either industry or academia, and there is a potential, and often a real, conflict of interest. The adage "What is good for General Motors is good for the US" is here represented by "What is good for industry is good for engineers".

The current view and utilisation of the engineering profession has become so entrenched that few even entertain the thought that it could be different, and even fewer see that it should be different. If one wants to consider the role of engineers in society, and their social and political responsibilities, one must first look at the current role of engineers in industry. Industry has its own ideology and norms, described by such concepts as profit, value, turnover, growth, return on investment, efficiency, loyalty, and so on, and as long as these norms appear as natural features of society, rather than as something imposed on society, there is little incentive for engineers to question their current role or these norms. It is not a role ordained by Nature; it is a role that has developed and received its current characteristics as part of the capitalist system, and it is a role that can be changed.

Engineers and the Evolution of Society: the processes driving evolution

The number of processes at work in society is very large, and in order to come to grips with them, we might try to introduce some form of taxonomy. As a starting point, we could characterise a society by two groups of entities. In the first group are entities characterising its physical development status, such as housing, public transport, health and education infrastructure, government institutions, and the like. Essentially, this is what Popper called World 1. In the second group are what we might call the society's intellectual content, contained within literature, visual art, music, science, technology, and the like; what Popper called World 3. (Poppers' World 2, consisting of mental states, would not be accessible for characterising a society.) Associated with each of these groups are processes that act on the entities; for example, education processes, mining processes, building processes, financial processes, etc. However, for our purpose of investigating what drives changes to society this type of taxonomy is not very useful, as the result of a change to one process will most often result in changes to other processes.

Focusing on the role of technology in changing processes in general, a starting point is to recognise that technology applications can be grouped into two large groups: those resulting in what we might call *unproblematic* changes, and the ones resulting in what we might call *problematic* changes. There is nothing particularly compelling about these names, and there is no sharp boundary between the two groups. In the first group we find those applications of technology that, at the time of their introduction, result in changes that are perceived as being obviously beneficial and not contributing to an area of significant societal concern. Applications of technology in this group include the introduction of electric lighting, the motor vehicle, and such household appliances as the washing machine. The process of acceptance is the one described above; basically the individual's perception of cost-benefit, with some regulatory involvement to ensure public safety and so on. In the second group are applications that, already at the time of introduction are related to significant societal concerns, such as global warming, biodiversity, civil liberties, and genetic modification. Both because such concerns emerge and change as part of the evolution of society and because the scale of the applications increase to a point where undesirable effects that were initially negligible become significant, applications may move from the first group into the second; a prominent example is coal-fired power generation.

The significance of the two groups to our investigation is that the relationship between technology and society is quite different in each group. In the first group, the information society requires to assess an application is very much directly related to the application; primarily concerned with the performance and cost of the application throughout its life cycle. This is information the engineers would have available as a result of developing the application. In the second group, society requires the additional information about how the application relates to the various societal concerns, and here there are a number of problems. First of all, as in the choice and evaluation of any technology application, one needs to evaluate not only the particular choice of technology in isolation, but also in relation to other possible technologies that could fulfil the same purpose. As these technologies may have different and additional societal concerns associated with them, the evaluation effort is greatly increased. Then, in addition to its intended or primary use, an application may have other uses or features, some of which would potentially change society in an unwanted direction. To what extent should engineers develop and disseminate information about these features? Another problem is that, while the direct interaction of an application with a societal concern may be a matter of straight-forward technical information, such as the amount of carbon dioxide produced, the effect of this on the concern, in this case global warming and climate change, is a different matter, and involves the interface between engineering and science, as well as the distinction between definite data and probabilistic data. This is very evident in the movement to society involvement in technology assessment (or participatory technology assessment, pTA), supported by what is known as post-normal science (Funtowicz and Ravetz 1991, Turnpenny, Jones and Lorenzoni 2011), and exemplified by such organisations as Living Knowledge: The International Science Shop Network (Living Knowledge), the Loka Institute (Loka), the Expert and Citizen Assessment of Science and Technology organisation (ECAST), and World Wide Views (World Wide Views), where there sometimes seems to be confusion between technology, engineering, and science. A further problem is that some concerns have a non-rational basis, such as religious opposition to genetic engineering, and these and other issues make it more difficult to assess what technical information is relevant and appropriate in a given case.

The Nature of Professional Responsibility

That technology and its applications have a significant, and increasing, influence on the evolution of society is generally accepted and well documented, and in Aslaksen (2014) it is argued that the direction in which technology changes society is determined by the collective judgement of the members of society. Furthermore, it was asserted that an important factor in forming that judgement is the information about the technology available to the members of society, and that the quality of this information will play a major role in determining the direction in which society evolves. This, then, places a significant responsibility on engineers, as the group within society best able to provide this information, and so we have arrived at the questions forming the core of this investigation, such as: How can we define this responsibility? What are the characteristics of the information to be provided? How can engineers discharge this responsibility? How, if at all, is this responsibility currently being addressed? How does it compare with other professional responsibilities?

But before considering this rather special example of professional responsibility, it is useful to take a look at how professional responsibility is treated in the literature. Engineers are not the only professionals faced with problems relating to their responsibilities to society; it is a characteristic of any profession, as the special knowledge of the professional represents a form of power that must be wielded with consideration of its impact on society. In particular, science has many similarities with engineering, and the responsibilities of scientists to society have taken on increasing importance since World War Two. This development, and the issues involved in it, is treated in the book *The responsible scientist*, by John Forge (Forge 2008). It gives a very readable account of the issues involved in defining and understanding the concepts of responsibility, omission, and blame in general, and then reflects this onto the work of scientists, with a number of illustrative examples. Of particular interest in the present context is the distinction between backward-looking and forward-looking responsibility, which Forge attributes to Baier (Baier 1987). Although the distinction can be thought of as arising from the temporal frame of reference, our earlier comments on the nature of the responsibility of engineers for providing information to society show that this responsibility is clearly of the forward-looking kind. Ford discusses the problems associated with assigning forward-looking responsibilities at some length, and illustrates this by the case of the French scientist Joliot.

The Particular Responsibility of Engineers for Providing Information to Society

To put this responsibility into perspective, it might be helpful to compare it with a responsibility in another profession; that of the judiciary in the legal system. In cases before the courts, judges are required to consider the information presented by the stakeholders in the cases, make judgements on the relevance and importance of the information with regard to the specific parts of the law that are applicable to each case, and provide resolutions in the form of sentences or orders. The law, which provides the framework within which cases are brought and which forms the reference for the judges' decisions, is provided by the legislative part of government and does, in principle, reflect the will of the people. The judiciary does not have to make a judgement on whether a particular piece of legislation is good or bad.

The engineers' responsibility is to provide information to society in an unbiased manner and without making any judgement, but as this information is provided prior to society making any judgement regarding the technology, there is no framework to focus or restrict the information processing. Society does define certain requirements on safety, pollution, and the like, but, firstly, these requirements usually refer to existing technology and, secondly, they are focused on preventing any physical harm rather than making any judgement on the desirability of a particular technology or its influence on society. So, whereas a judge is required to form a judgement about a case, but within the framework of the law, the engineers must not form a judgement regarding the technology application, but must form a judgement regarding the information to be presented to society, without having any prescribed framework to guide them as to what is relevant for this application. In both cases there is a requirement of impartiality, or an absence of any bias in the judgement or the processing of information. In the case of the judiciary, this requirement has been met by making the judiciary independent; in the case of engineers there is, as yet, no corresponding arrangement.

Engineers are no different to anybody else when it comes to basic human traits, such as self-interest and self-delusion, and when engineers that have spent a long time developing a technology and becoming experts in this technology get an opportunity to employ the technology on a project, they are bound to present the application in a favourable light. This is, in principle, no different to the situation in the legal world, where lawyers present their clients' cases in the most favourable light, with the two sides in each case striving for different outcomes; within the law, but without much concern for what is true or best for society. However, there is then an impartial judge who decides the outcome, and there needs to be a corresponding arrangement in engineering if society wants to be assured of receiving quality information about technology. The current approach, in which the proponent of a new application engages a firm of consultants to provide an assessment of costs (incl. risks) and benefits is clearly flawed, as experience with both Environmental Impact Statements (Beder 1995) and some recent failures of major infrastructure projects illustrate (Poljak 2014).

Let us now first consider the nature of the information and what is meant by quality in this case. Seen from a member of society, quality means how appropriate the information is to the task of forming a judgement on whatever application of technology is being put forward. That means that the language in which it is presented must be easily understandable, the depth and level of detail must be appropriate to the education and experience of the person, examples should relate to the person's environment, and it must be easily accessible to that person in a timely manner. It must also describe any relevant alternate solutions, and provide an assessment of their relative merits from a technical standpoint. While these requirements would seem to imply that the information has to be tailored to each individual member of society (and remember, society means all or a group of society, as applicable to the particular application), that would clearly not be practicable, and so there arises the issues of how to package the information, how to subdivide society into groups with relatively homogeneous membership, and how to reach each of these groups in an effective manner. It will require engineers to have a good understanding of how society operates, how groups form, and which groups are relevant to a particular application.

This packaging and targeting of the information will rely heavily on the engineers' judgement of the relevance and importance of items of information to each of the groups, and this brings us to a related issue: the completeness of the information. A problem with much of the current presentation of information about technology is that, without being directly untruthful, the presenters emphasize those parts of the complete information that are favourable to their purposes, while either suppressing the other parts or implying that they are unimportant or irrelevant. The task facing engineers is to reduce the information provided to what is required for the audience of the information to make a judgement, but in such a manner that it does not bias the judgement. The requirements this task places on the engineers seem to indicate that these engineers would form a distinct group within the profession with regard to both their education and experience, and with a broader perspective than the engineers engaged in the industrial process of developing and applying technology. The need for such a structuring of the profession was raised in a somewhat different context in a recent publication (Aslaksen 2015).

The impact of a new application of technology on society does, as mentioned earlier, depend on numerous factors in addition to those that belong to engineering and about which engineers are best able to provide information. The groups within society with the relevant information about these further factors have the same responsibility as engineers to provide factual, unbiased, and complete information, and it is the combination of all this information that then leads to society's assessment of the application. The process by which such an assessment is reached is highly complex and cannot be usefully defined in closed form. It potentially involves all the human elements of society as a system, but the importance of an element in the assessment and acceptance process varies greatly from element to element and from case to case. It is also a dynamic process which is currently changing towards broader society participation, as already noted, and as a result of the increasing presence of mass media (Petersen, Heinrichs, and Peters 2010). The important point as far as the responsibility of engineers is concerned is that as participants in that process they need to clearly differentiate between when they, as members of the profession, provide information and when they, as members of society, assess the impact of the information provided by both themselves and others.

There is then the question of the scope of the responsibility. Producing the information is one thing, but that work only has an effect if the information is also put to use by society. To what extent does the engineers' responsibility include developing and managing the process of presenting the information to society? And even actively assisting society in understanding and using the information? It would seem that at the very least it would include making society aware of the existence of the information and how to get access to it, which already points to an on-line database in which to deposit the information and from which it can be conveniently extracted, and some form of organisation to maintain it. An early example of technology assessment was provided by the Office of Technology Assessment, and office of the US Congress that operated from 1972 until 1995, and produced more than 750 reports on new technology. These reports are now stored at Princeton University, and available [1]. Today there are numerous organisations dedicated to the relationship between science, technology, and society, such as the Danish Board of Technology (DBT), the Swiss Centre for Technology Assessment (Swiss), the Rathenau Institute (Rathenau), the Institute of Technology Assessment (ITA) of the Austrian Academy of Sciences, and the Norwegian Board of Technology (NBT). However, these organisations are mostly concerned with assessing the impact of a given technology on

[1] http://www.princeton.edu/~ota/ns20/legacy_h.html.

society and only peripherally concerned with assessing the data provided by the technology developers. That is one reason why they are concentrating on the involvement of science and scientists and largely ignoring the involvement of engineers and the role of industry as a driving force within society. The organisation we are considering would be responsible for providing the technical information about technologies and their applications and about what is involved in their realisation: the changes to the industrial structure, to education and training, and, to some extent, to power structures within society.

The creation of such an organisation raises a number of issues. How would it be funded? If it is to be unbiased and impartial, it could not accept funding from any party with an interest in the information and would have to be funded as a statutory body, although it could probably start its life in a less formal guise. To what extent would it be liable for the information provided to society, and how could such a liability be covered? If the information is provided on an "all care and no responsibility" basis, which seems most likely, the credibility will rest solely on the reputation of the person(s) that provide the information. In that case, the organisation is essentially a clearing-house for the information, but it would have to ensure that only reputable engineers with no conflict of interest are accepted as providers.

There are literally hundreds of new applications of technology presented to society every day. Many of these are products and services that are scrutinised by consumer and other organisations that base their assessment on well-established standards (safety, energy efficiency, environmental impact, etc.), and for which no further technical information is required. There therefore has to be a process of selecting those applications on which the public has to (or should) make an assessment based on technical information, and the engineers' organisation would have to be free of any ideological bias in making this selection.

Could any of the existing engineering organisations take on this additional role related to discharging the engineers' responsibility for the evolution of society? There are basically two types of organisations that are relevant: Institutions or Societies of Engineering, and Academies of Engineering. Within each type there are significant variations from country to country, so in order to provide some detail within the space limitation of this paper, the following discussion is specific to Australia. In Australia, The Institution of Engineers (Australia), trading under the name Engineers Australia (EA), is the main organisation representing engineers. However, it does not represent only Professional Engineers, but also Engineering Technologists and Engineering Associates. These three groups are defined briefly as follows:

Professional Engineer: Requires at least the equivalent of the competencies in a four year full time Bachelor's Degree in engineering.

Engineering Associate: Requires at least the equivalent of the competencies in a three year full time Bachelor's Degree in engineering.

Engineering Technologist: Requires at least the equivalent of the competencies in a two year full time Associate Degree in engineering or a two year full time Advanced Diploma in engineering from a university or TAFE (Technical and Further Education) college.

Together, these three groups are called the *engineering team*, and EA considers them all to be members of the engineering profession.

According to the Census of 2011, the engineering team had 322,523 members, of which about 80% participated actively in the labour market. Of this labour force 80%, or about 206,000, were Professional Engineers. Engineers Australia has about 100,000 members, of which 41% are students, 53.5% professional engineers, and 4.5% Technologists and Associates, so that EA represents only about one quarter of the Professional Engineers in Australia.

With regard to providing information to society, EA produces two types of documents: policy statements, and submissions to Government. An example of the former is the one published in 2007, *Climate Change and Energy*, a comprehensive and clearly formulated document, setting out what EA supports and what actions EA believes need to be undertaken. But it is a "passive" document, offering advice and reflecting the fact that EA and the profession has no power to demand or initiate any action. An example of a submission to Government is the recent *Submission to the Senate Economics References Committee into Australia's Innovation System*, published in July 2014. Again, a very well argued submission, but essentially "begging" Government to recognise the role of engineers in innovation.

What these documents demonstrate is a cultural problem, and the questions EA should be asking itself, provide answers to, and find solutions to, include: Why are not a significant proportion of federal and state cabinet minister engineers? Why do engineering courses not have at least as high ATARs (Australian Tertiary Admission Ranking) as medicine and law? As it stands, and with its watering down of the profession into the engineering team, EA does not appear to be suitable to take on the role of the organisation discussed above.

The Australian Academy of Technological Sciences and Engineering (ATSE) advocates for a future in which technological sciences, engineering and innovation contribute significantly to Australia's social, economic and environmental wellbeing. The Academy is empowered in its mission by some 800 Fellows drawn from industry, academia, research institutes and government, who represent the brightest and the best in technological sciences and engineering in Australia. The Academy provides robust, independent and trusted evidence-based advice on technological issues of national importance. ATSE fosters national and international collaboration and encourages technology transfer for economic, social and environmental benefit. ATSE would, in principle, have the reputation and integrity track record required for our engineering organisation, but there is a big difference between giving high-level policy advice to organisations and providing useful technical information to the general public, and it is doubtful if ATSE would even contemplate such a role.

In the book *The responsible scientist*, introduced earlier (*op. cit.*), Forge goes on to examine how the scientific community is discharging its responsibilities. Many scientific societies, including the Royal Society of London, the Acadèmie des Sciences of Paris, and the American Physical Society, represent science as an activity that is good and worth pursuing in itself, and are dedicated to furthering pure science without any consideration of its impact on society. But there are also a number of other societies whose raison d'être is a concern with wider issues, and he mentions a sample of three. The first is the Federation of American Scientists (FAS), founded in 1945 by some of the members of the Manhattan Project who were concerned about control of the awesome new technology they had helped create. The second is the Union of Concerned Scientists (UCS), founded in 1969 at MIT, which aims to devise means for turning research applications away from the present emphasis on military technology toward the solution of pressing environmental and social problems. The third is the British-based Scientists for Global Responsibility (SGR), which has similar aims to UCS, but is more explicit in stating what research it believes scientists should and should not be involved in.

All of these organisations have a central point in common, both between themselves and with the organisation we are contemplating: they advocate something regarding what the members of their professions should and/or should not do. But there is a major difference between all those scientific organisations and our organisation: they are concerned with the members' conduct of their professional work, whether they should do certain types of work, and so on, whereas our organisation is concerned with providing society with information about its members', i.e. the engineers, work. We are, in this paper, not concerned with the type of work engineers do and the results of their work; we are solely concerned with ensuring society is in a position to make informed assessments about the resulting products and services.

What this comparison with science is starting to point out is that, while it is important to have an organisational structure to provide an interface to society, there also has to be a societal or legal framework that allows the flow of information to take place. This brings us back to the discussion, in Sec. 2, about engineers being embedded in industry, and how this limits their ability to provide information to society. For engineers to be able to provide complete and unbiased information, society will have to *demand* it, and insist, through the political process, that a corresponding legal framework be put in place. The *right to know* needs to be accepted as an inherent feature of an advanced society. Just as patients have the right to know all they want about their treatments, society should have the right to assess how technology applications will affect it, and the information provided by engineers forms an important part of that process. And from the foregoing discussion of the various existing organisations involved, it seems likely that it will require an act of political will and the involvement of government to create the type of organisation we are advocating.

The three main issues we have identified: the standing of the engineering profession in society, the visibility of the relationship of engineering with technology, and the ability of engineers to provide information to society, are all closely interrelated, and they need to be addressed in a coordinated fashion when assessing the responsibility of engineers to society.

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