Engineering – a social activity

Erik W. Aslaksen
Gumbooya Pty Ltd
3 Gumbooya Street, Allambie Heights NSW 2100
www.gumbooya.com

Contents

1 Introduction

For most people, engineering is a hidden activity. Not like other professions, such as medicine, law, or science, with which they are frequently confronted, either through direct personal contact or through the media. Of course, in reality they are confronted by the results of engineering more frequently than by anything else, as almost every object they look at has required an engineering input at one or more stages in its existence, but this input is hardly ever made explicit. The word "engineering" might be used quite frequently, but in different contexts and without any one defined meaning. It is actually the lack of any sharply defined meaning that makes the word useful in daily language; when we need to indicate any activity with a technical component, "engineering" will do. For most it simply conjures up the image of some obscure background activity, something that they know must take place for our society to function, but that takes place automatically and that the ordinary member of society does not need to worry about.

In a time when the influence of engineering on the development of society is actually greater than ever, and rapidly increasing, this image of engineering is at best unhelpful and at worst dangerous in a democratic society where public opinion and understanding play a major role. Not only does engineering influence the direction in which society evolves, but it is a significant factor in the stability of the global society. As a complex, dynamic system, the state of the global society is a stochastic variable, and the frequency and magnitude of the fluctuations of this state are critically dependent on the technology developed by engineering. The purpose of this monograph is to show that engineering is fundamentally a social activity, and that its present isolation from society is an anomaly resulting from the capitalist production structure currently dominant in western societies, although it is most pronounced in the Anglo-Saxon societies, and so the discussion is directed mainly at these and, in particular, at the Australian society. The material presented here is, to a significant extent, taken from previous publications by the author, although often modified and augmented in order to provide a coherent focus on the subject of the monograph.

By a social activity we understand an activity that involves the interaction of the members of society and relates to their collective existence. The interaction between engineering and society takes place in both directions and, as with all interactions involving humans, the effectiveness depends on the two sides having a common language with a vocabulary whose words have well-defined meanings accepted by both sides. It is suggested that the lack of such a language is one of the main reasons for the "invisibility" of engineering as a component of society. That is, by using concepts with a very general meaning, e.g. the current use of "technology" in daily language, the dialogue is necessarily at such a high level that the identity of specific entities, such as engineers and their activities, is no longer visible. Consequently, the next chapter is devoted to exploring this issue from a historical perspective, to assessing its current state and problems, and to providing a way forward based on defining some of the central concepts of a common language.

With the applications of technology all around us, indispensable and forming an intrinsic component of our existence as human beings, it is not surprising that the relationship between society and technology has attracted the attention of both philosophers and sociologists. There is a substantial body of work addressing such issues as how technology is forming our attitudes and view of the world and of ourselves, how the structure of society is being transformed by technology, and how the needs and desires of society, or groups within society, influence the development of technology. While the philosophical and sociological aspects of the interaction between society and technology are not directly the subject matter of this book, and much of the material does not even mention engineering, the work presents viewpoints and insights that need to be taken into account in any serious consideration of the nature of engineering and its relationship to society, given that engineers are the main creators of the applications of technology. Consequently, a limited overview of that body of work is included in Chapter 3.

Engineering does not interact directly with society, as does law or medicine; engineering is completely embedded in industry and exists only as an integral part of industry. Understanding the complex and many-faceted relationship between engineering and industry is essential for understanding the social aspects of engineering, so in Chapter 4 we look at this relationship from a number of points of view. Engineers appear as both employees and employers, there is an ethical point of view, a professional point of view, a business point of view, and so on, and as they all interact in the execution of engineering projects, they form a complex system from which engineering emerges as a coherent activity.

When we assert that engineering is a social activity, that statement has two aspects. One is seeing engineering as a component of society, just as we do medicine, law, and politics, and to understand the role of engineering in society viewed as a system of these components. That is the subject of Chapter 5, with a focus on the situation in Australia. The other aspect arises from the activities taking place within engineering; that is, the activities required to execute engineering projects, such as building a freeway or a new computer, involve a temporary "society" of all the persons involved. The nature of the social, or non-technical, interactions between them has a determining effect of the outcome of the project, and it is also where issues of social responsibility an moral obligations become most visible. This is the subject of Chapter 6. In both cases, the relationship between engineering and society can be viewed from two perspectives: the view "outward", from engineering to society, and the view "inward", of engineering from society. And in both cases there is often an "us and them" format to the perspectives, with the people involved acting more as observers rather than as participants in a relationship. This lack of mutual engagement is the most significant symptom of the social isolation of engineering, and it is due to a number of factors that are explored in this chapter

The monograph is intended to provide the source material for a one-semester seminar to graduate engineering students. The seminar would progress through three periods: The first would consist of a number, say, four, two-hour sessions, with lecture and associated question and discussion. The second period would be used by the students to prepare a paper on a topic directly related to the subject matter of the seminar and defined by the lecturer. This period would allow three to four weeks for the students to prepare their submissions, and a couple of weeks for the lecturer to assess them. The third period would then consist of a couple of two-hour sessions of critical analysis of the papers and developing further the ideas expressed in them.

2 A Common Language

2.1 Historical Perspective

If we, for the moment, define engineering as the application of knowledge about Nature to meet needs expressed by society (or groups within society), and engineers as the persons performing this work, then engineering has a very long history, going back to the early tool-makers and builders [1]. Here we shall consider only the history of the language used by engineers in their work and in communicating with other members of society; the history of the relationships between engineers and other groups of society will be explored in Chapter 4.

Starting with the development of agriculture and the establishment of settled communities, around 8,000 BC, engineering was performed by what we would characterise as craftsmen, resulting in such items as dwellings, rafts and boats, irrigation channels, simple bridges, and artefacts out of wood, clay, and metal for daily use. The knowledge employed in this work was gained by observation and by verbal transmission, and the language used to express this knowledge was the everyday language. The process of construction or manufacture, as well as the items themselves were visible to everyone, as were their relationships to Nature, as expressed by e.g. a water-wheel or an arch. Engineering was completely embedded in the community, just like any other occupation, such as farmer, hunter, or fisherman.

The first major change to this simple state of affairs came as the communities grew in size, wealth, and organisational complexity, resulting in the need and desire for larger and more complex constructions, and in the associated need for *documentation*. Firstly, for obtaining approval for the works (e.g. from a ruler) prior to construction. Secondly, for conveying to the workforce what was to be constructed and as a means of checking during construction, and thirdly, to preserve the knowledge base, which had become too large to be accurately transmitted verbally. This documentation employed a combination of common language with elements of specialised languages, such as drawings, symbols, and diagrams. But, while this now separated the engineers from the rest of the workforce, they remained basically craftsmen by training and would be directly involved in the construction work, much as a site manager today, and the work and its relation to Nature was still visible and understandable to the rest of the society. Engineering had made a step on the path to becoming a profession, but there were no language problems in communications between engineers and society.

The next major change came in the eighteenth century in the form of the rise of science. Heuristic knowledge was augmented by, and often replaced by, scientific knowledge, and engineering started to acquire a solid theoretical foundation. Not only did this lead to a need for formal engineering education, as exemplified by the founding of the first technical university, L'ecole Polytechnique in Paris in 1794 (although this was preceded by L'ecole Des Ponts Et Chaussées in 1747), but it created a whole body of knowledge, with its own language and world view, that was not available to the general public. That is, while people could still both use and admire the products of engineering, they could no longer understand the process of creating them or certain details of their functioning. The nature and details of the work performed by engineers became hidden, but this did not in itself affect the dialog between engineers and the rest of society. Engineers were public figures, involved in the public discussions about, and promotion of, their ideas and products, and of their influence on society, and so had no problems with "translating" between the language of engineering and the daily language.

The third major change, and the one with the most impact on the language issue, came as a result of industrialisation and mass production; starting perhaps around 1850 and persisting today. The process of creating a product became structured into a sequence of sub-processes – depending on the product e.g. market research, engineering, production, marketing, distribution, and sales – and so engineers became almost completely isolated from society as the users. What society experienced was the result of this process, with engineering becoming almost invisible. Like the transformation of craftsmen to workers in the industrial revolution, engineers have become invisible intellectual labourers, "seen as having lost their traditional aura of heroism and individuality, to have become anonymous team members, soldiers in the corporate army" [2]. As a result of this isolation there developed an increasing difference between the precise language of engineering and that used by society to describe its experience with the industrial process. Without engineers to provide the "translation" and maintain the relationship between the two, the language used by non-engineers – other professions, including philosophers and sociologists, as well as the general population – became imprecise and ambiguous, and words such as "technology", "technics", and "engineering" are now used with all sorts of different expressed or implied meanings, as we shall see in later sections. In order for us to be able to present our profession to society in a more detailed and sharply delineated manner we need to develop adequate definitions, and we approach this from three directions. Firstly, we propose a set of definitions covering the meaning of top-level concepts in a vocabulary of engineering, much as one would find in a dictionary Secondly, we place these concepts into an ontological framework that provides a formal definition of their properties and relationships. And, thirdly, we elaborate on their use and significance, as well as on their implications for the development of the profession.

The last major change, which has been taking place in parallel with the industrialisation, is a shift in the centre of gravity of the population of engineers from industry to academia. Instead of universities being the place where the knowledge and experience gained in industry is transmitted to students, many engineering professors and lecturers now have never worked in industry [3]. As far as the "naked" content of much of the curriculum is concerned, which is of a theoretical nature anyway, this is not such a great concern. The problem is related to what is a core issue of this chapter: a language must be appropriate to its purpose, to the subject matter involved in working to achieve that purpose. The purpose of engineering is very different to the purpose of science, and so the language of engineering, and the world view reflected in that language, needs to be different from that of science. The format of the material presented to engineering students should reflect that it is to be used to achieve that purpose, and this requires corresponding experience. With the shift to academia, the language of engineering has become more like the language of science, creating its own problems in the relationship between engineers and society. - A related issue is that the visibility of engineering and the involvement of engineers in society, limited as it is, is now provided mainly by academics [4], resulting in a skewed vision of the profession.

1. A brief history of engineering, and numerous references, are contained in Aslaksen, E.W. (2013), *The Engineering Paradigm*, Int. J. of Engineering Studies, ISSN 0975-6469, vol. 5, no. 2, pp. 129-154.
2. Quoted from *Engineering in Society*, Panel on Engineering Interactions With Society, input to the Commission on the Education and Utilization of the Engineer, National Research Council, National Academy Press, 1985
3. As an example, the academic staff listing for the Faculty of Engineering and Information Technology at the University of Technology, Sydney (UTS), http://www.uts.edu.au/about/faculty-engineering-and-information-technology/feit-academic-staff shows a total of 168 permanent teaching staff (lecturers, senior lecturers, associate professors, and professors), although this number is only approximate, as the identification of teaching staff, as opposed to research staff, is not always clear. Of this number, at least 74, or 44 %, appear to have had no significant industrial experience. – Limiting the analysis to the School of Electrical, Mechanical, and Mechatronic Systems, the numbers are 39 and 18, or about 38 % without industry experience.
4. A symptom of this is that Australia does not have an Academy of Engineering, but one of Technological Sciences and Engineering (it is not clear what is included in Technological Sciences that is not included in Engineering).

2.2 Concepts and Their Definitions

Throughout this chapter we shall introduce and analyse a number of *concepts*. Concepts are the building blocks of our thoughts, created through abstraction from experience, and the solidity of the mental edifices we construct depends on the quality of the concepts we use. Quality is, in this case, the measure of how well a concept fulfils its purpose, which is to convey a precise meaning to the persons involved in a discourse, and this is accomplished by having a *definition* that is known to and accepted by these persons.

To understand exactly what it entails for something to be a concept, as well as the nature of the associated definition, it is useful to make a brief detour into linguistics [1]. A language is characterised by its *grammar*, which is the pairing of the phonetic representation of a signal (which we may take to a sentence) with its semantic representation (i.e. meaning). A grammar is described in terms of a *lexicon* and a system of *rules*. The system of rules may be subdivided into three components: a *syntactic component*, a *semantic component*, and a *phonological component*.

The lexicon is a listing of words, together with knowledge about these words, which allows the owner of the lexicon to use them. This knowledge can again be subdivided into three parts: phonological, syntactic, and semantic. The phonological part is concerned with the correct pronunciation of the word, not only on its own, but also in its possible different applications. The syntactic part contains information about the type to which the word belongs, i.e. whether it is a noun, a verb, an adjective, and so on, thereby specifying in what position in a sentence the word may appear. Finally, the semantic part explains the meaning of the word, as one would find it in a dictionary. However, the problems involved in the semantic part of the lexicon are central to the definition of concepts, and we need to develop our understanding of linguistics a bit further before we return to this point.

We note that on the level of the lexicon, i.e. on the level of words, there are no relations between the three parts of the knowledge about a word. Aside from a few onomatopoetica, there is no way one can correlate the pronunciation and meaning of a word. Sound and syntax are largely unrelated, and the same is true of syntax and meaning. Grammar, as we defined it, is concerned with the phonological, syntactic, and semantic properties of sentences rather than words.

Syntactic rules formalise the fact that sentences are not random sequences of a given set of words, but exhibit very definite structures. These structures are to a large extent immediately recognisable to someone competent in English, and so we need not pursue them any further here. The phonological rules provide a phonetic representation for each word on the basis of its phonological representation in the lexicon and its position in the syntactic structure (i.e. sentence), but as we are only interested in written definitions, we need not pursue these rules any further, either. That leaves the third interpretive component: the semantic component. Given a lexicon, the semantic interpretation of a sentence has two aspects: the *literal meaning*, an inherent property of the sentence, independent of the context in which it finds itself, and the *pragmatic implications*, additional information conveyed by the sentence when it is combined with all the other knowledge available to the reader at the time of reading. It is the literal meaning that is the subject of the semantic component, and that constitutes the purely linguistic meaning.

The meaning of a sentence may be described as a set of *propositions*. Propositions are related sentences expressing elements of the sematic structure without regard for syntactic of phonological form. In the example below, the sentences (b) – (g) may all be considered to be propositions belonging to (a); however, whereas (b) - (e) are necessarily true as a result of (a), (f) and (g) are not.

(a) The system failed due to excessive input voltage.
(b) The system has failed.
(c) The system has an input.
(d) The input voltage was excessive.
(e) The cause of the failure is known.
(f) Excessive input voltage makes the system fail.
(g) The system has one input.

Propositions whose truth follows necessarily from a sentence are called *entailments* of that sentence. They are logically definable elements, and one can therefore use the rules of logic to define some of the main semantic concepts, such as synonymous, contradiction, and ambiguous. It turns out that sematic descriptions in terms of logic entailments alone is inadequate to explain several types of subtler distinctions [2], but we shall see shortly that the idea of entailments is mirrored in the definition of a concept.

A *semantic element* is a word from the lexicon together with its semantic part. If someone is asked to define a semantic element, say, X, the answer is usually a sentence of the form “X is a Y that ( )”. Y is the *class* to which X belongs; it is a more general element. To it are related a large number of qualifying or specialising elements, and ( ) is the appropriate subset of these. Thus, the definition process consists of three sub-processes: First, the *generalisation* that places the element into its class, then the *analysis* that determines all the characteristics of this class, and then the *specialisation* that chooses the appropriate characteristics for the present case. That is, the specialisation depends on the context in which the semantic element is to be used.

The definition of a concept reflects these three sub-processes. The two main parts of a definition are:

- the *classification*, which describes the class to which the element is to be defined belongs, and
- the *relations* that relate the element to other, already defined elements.

Each of these parts may vary in length and complexity, but the classification is usually the shorter one, limited to a sentence of the type "X is Y (---), where (---) is qualification or reference such as "as defined in …" or "of the type found in …", and so on. The relations are expressed in one or more sentences, relating the element to others by expressing such characteristics as what it consists of and what it does. This recursive form of the definition of a concept implies that concepts are hierarchically ordered in some way, and this leads us to a further subject; that of an *ontology* [3]. The use of the word here is somewhat different to its traditional use in philosophy, where it is concerned with the question of existence and what exists; the current interest is about explicit specification of conceptualisation, about the vocabulary we can use to speak about a particular domain of interest. Or, conversely, a given ontology defines the objects that can be represented by its concepts, the universe of discourse defined by that ontology. In our case, that universe is engineering.

The hierarchical ordering implies that there must be a set of top-level concepts, and a common top-level categorisation of the things that exist in reality is shown in Fig. 2.1; this ontological sextet is from [4], but with the formal-ontological relations amended by adding the relations between properties and processes, making properties symmetrical with regard to substances and processes.

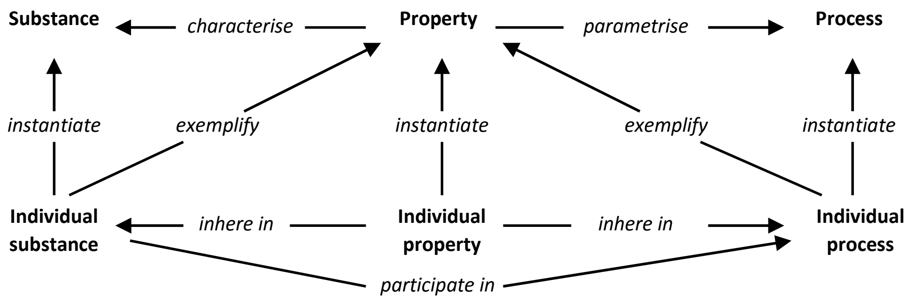

Figure 2.1 The ontological sextet and the formal-ontological relations.

However, as it stands, this categorisation is not entirely suited as a basis of an engineering ontology; the problem being that the concept of "substance" must go beyond the narrow meaning of something that has mass. To understand what this wider meaning is, we need to take a step back and consider an ontological structure that, at its highest level, has only two categories, "continuants" and "occurrents". A continuant is anything that exists *as a whole* at any point in time when it exists, as opposed to an "occurrent", which only exists as a whole over a period of time. The category of "occurrents" is what is identified as Processes in Fig. 2.1. The category of "continuants" can be divided into the subcategories of "independent continuants", and "dependent continuants", and the latter category includes what is identified as Properties in Fig. 2.1 plus what we shall call "descriptions".

The issue that now arises is that engineering deals with "independent continuants" that take on different forms in different parts of the engineering process (see later). For example, we can talk about a crankshaft *in general* (as part of an interface between linear and circular motions), we can write a specification for a *specific* crankshaft, and we can design a crankshaft that meets the requirements of that specification, all without there being any physical entity that is a crankshaft. And then there is the physical realisation of the design; a real crankshaft. Somehow, the *concept* of a crankshaft must encompass all of these forms. - Another example is the concept of stakeholders; we can talk about stakeholders in general, we can specify the stakeholders (set requirements on what type of persons should be included), we can design (choose) a set of stakeholders that meet the specification, and finally, the actual stakeholders, as a group of persons, may appear at a meeting.To handle this, we shall use the word “objects” as the top level category of “independent continuants”, and assign to objects the property “form”, which can take on the four values “inherent”, “specified”, “designed”, and “realised”. As a result, our top-level categorisation is as shown in Fig. 2.2.

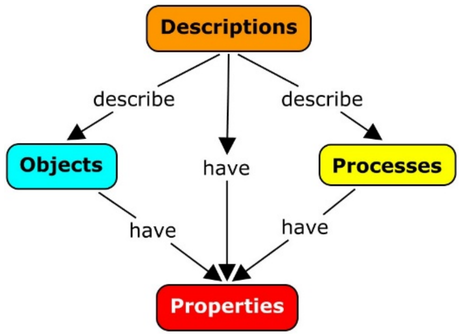

Figure 2.2 The four top-level categories of the engineering ontology.

In addition to this ontological ordering, which is effectively an ordering of the classes used in the definition of concepts, a different ordering appears if we consider the relations in a definition, which involves other concepts. It would be natural to say that a concept defined in terms of a number of other concepts is in some way more complex or more specialised that the latter, or, as we shall say, that it is more context dependent. In this manner, concepts become ordered by the number of definition processes they are removed from some initial set of words or concepts, each step increasing the level of detail with which the context is defined. At the lowest level is a *primitive set* of words or concepts; it is made up of all those words well known to and assigned the same meaning by all persons regarded as having some defined minimum degree of competence in English.

This ordering makes the set of all concepts appear as an unbounded sphere, with the primitive set as a central core and then layer upon layer of words of increasing complexity. The direction in which one progresses outward represents the particular profession or area of application, and the further detailing of the context within each profession forms a cone. Thus, as one progresses outward in any direction, the meanings of the concepts become more and more context-dependent; the sphere is decomposed into finer and finer cones or fibres between which there are significant differences of meaning given to the same word, as illustrated in Fig. 2.3 This is on the one hand a result of increasing specialisation and lack of communication between professions, but on the other hand, and more importantly, it is an inherent function of the increasing complexity, of the increasing richness of the concepts.

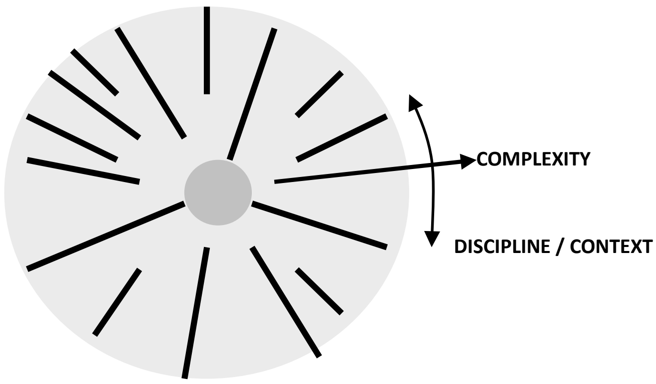

Figure 2.3 A two-dimensional representation of a lexicon, parameterised by the degree of complexity (distance from center) and discipline (or context, angular coordinate). The radial lines separate different disciplines, and the darker grey area in the middle represents the primitive set [4].

Introducing an arbitrary measure of context dependency, κ, normalised to $0 \leq \kappa \leq 1$, then κ will be a function of the distance, *r*, from the centre of the sphere, as shown in Fig. 2.3. Up to a certain radius, r_0, there is no context dependency; this is the primitive set. (The value of r_0 should be steadily increasing with time due to the increase in the level of general education.) From here on the value of κ rises slowly until, at $r = r_k$, it rises rapidly towards 1. As the value of *r* increases in the range $r_0 \leq r \leq r_k$, persons with increasingly specialised knowledge will automatically infer the correct context; thus allowing virtually context-free definitions. In this range it therefore becomes a question of correctly identifying the degree of specialisation of the persons who are to use the concept in their discourse. Above $r = r_k$, even the specialist will need to know the context in order to give precise meaning to the concepts; using abstract concepts alone will lead to ambiguity.

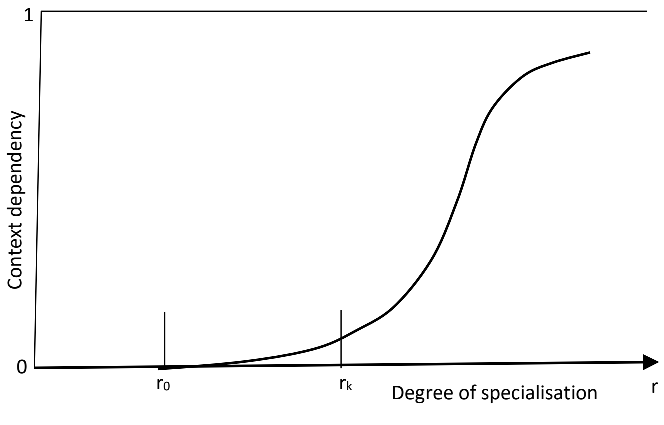

Figure 2.3 Context dependency as a function of the degree of specialisation of the reader [4].

The set of concepts within a cone of the sphere $r \leq r_k$ defined by a particular specialisation or profession may be regarded as a *kernel* for that specialisation. They form a subset of the lexicon of the English language, and each word in the kernel is either and element of the primitive set, for which the meaning is context-independent, or defined in terms of such elements by one or more definition processes, which determine the meaning within that context. The definition process introduces certain relations between semantic elements and, in addition to the "distance" from the primitive set, imposes a further structure on the set of elements. There is an obvious analogy with binary operators imposing an algebraic structure on a set, but the definition process, viewed as an operator, is much more complex than a binary one.

With the above understanding of concepts and their definitions, and that concepts carry the meaning of words in particular contexts, we can now turn to defining some of the concepts that apply in the context of engineering, among which three stand out for two reasons. One, they are used frequently by most people, and two, they are used by most people either in a general sense, without being conscious of any definition, or in a particular, well-defined, but highly context-dependent sense. These three concepts are engineering, technology, and system, and as the first one occurs in the title of this monograph, we shall start with it.

1. The main sources for this section were the two books by Noam Chomsky, *Syntactic Structures*, Houton & Co (1957, second printing 1962), and *Language and Mind*, enlarged edition, Harcourt Brace Jovanovic, Inc ((1972), and the Book by Neil Smith and Deidre Wilson, *Modern Linguistics*, Penguin Books Ltd (1979).
2. This issue is treated in *Modern Linguistics*, pp. 148-189.
3. The main sources for this outline of ontology are Munn, K. and B. Smith, *Applied Ontology – An Introduction*, vol. 9 in the series Metaphysical Research, Reicher/Seibt/Smith/von Wachter (eds.), ontos verlag, 2008, available online at http://nemo.nic.uoregon.edu/wiki/images/8/88/978-3-938793-98-5_Munn_Ontology.pdf, and N.F. Noy and D.L. McGuinness, *Ontology Development 101: A Guide to Creating Your First Ontology*, available online at http://protege.stanford.edu/publications/ontology_development/ontology101-noy-mcguinness.html. Much of the material was also contained in *Elements of a Systems Engineering Ontology*, paper presented at SETE 2011, Canberra, 2-4 May, and available online at www.sesa.org.au/component/docman, and again in *The System Concept and Its Application to Engineering*, Springer, 2013, both by the author.
4. Aslaksen, E.W, *Requirements Definition – A Plea For a Return to English*, Proc. Thirteenth Int'l Symposium of INCOSE, Arlington, VA, 1-3 July 2003.

2.3 Engineering

Engineering is a major component of the activities taking place in society. This is obvious from just taking a look at the objects surrounding us; almost all owe their existence to engineering to some degree. Consequently, one could expect that engineering would have a significant impact on the direction in which society is developing, but do engineers have a significant impact, or are they just the ones turning the crank? It is astonishing how little attention this question has received, and the reason can be summarised by saying that engineers are practically invisible, as far as society is concerned. This is evidenced by the observation that there has been quite some interest in what is characterised as Science, Technology, and Society (STS), or Science and Technology studies, but that the overwhelming part of the literature on this subject makes no mention of engineers at all. This despite the fact that technology is created largely by engineers, whereas scientist provide mainly the theoretical foundation. Science is fairly well established in the public mind, whereas most people have no idea what engineering entails, and its achievements are rarely reported. This was exemplified recently with the tabling of two statements on "Science and Innovation" in the House of Representatives [1], where engineering was almost ignored, and which missed the fact that technology is created mainly by engineers. It is also illustrated by the Government's *Report on the National Science and Innovation Agenda*, [2], which manages to avoid any mention of engineers and engineering at all.

The reason for this situation is, at least to a certain degree, due to the engineering profession failing to provide a clear, detailed, and well-founded definition of engineers, engineering, and technology, as well as the interface to science. This is evident from searching the Engineers Australia website [3], which does not provide a definition of engineering, but instead attempts to place engineering within a framework of competencies. There are numerous definitions of engineering; for example:

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

"The application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems" [5].

"The work of designing and creating large structures (such as roads and bridges) or new products or systems by using scientific methods" [6].

"The branch of science and technology concerned with the design, building, and use of engines, machines, and structures; the action of working artfully to bring something about" [7].

"The discipline, art and profession of acquiring and applying technical, scientific, and mathematical knowledge to design and implement materials, structures, machines, devices, systems, and processes that safely realize a desired objective or invention" [8].

These definitions are neither entirely correct nor specific enough to provide a point of departure for developing a deeper understanding of what engineering is. In particular, by combining activities like "designing", "constructing", and "use of" on an equal footing, they seem to imply that these are equal components of engineering and, by implication, of what engineers do. This has the effect of, on the one hand, obscuring and submerging the essence of engineering in its industrial environment and, on the other hand, presenting it as a form of applied science, thereby making it very difficult to assign any precise meaning to "engineering" and to any related concept, such as "the value of engineering".

Referring back to the introduction to ontology in the previous section, engineering belongs to the upper level category of processes. Within this category we can distinguish a sub-category of *purposeful processes*; these are processes that have a purpose formulated by humans, as opposed to other processes, such as the change of seasons, erosion, and the processes taking place within stars, as well as the numerous processes carried out by all other organisms. A purposeful process satisfies the following criteria:

a. It is created and/or performed by people (the *practitioners*)
b. It has a *purpose* defined by a group of people (the *stakeholders*)
c. It is performed within a *timeframe,* starting with the definition of the purpose and ending when either the purpose is deemed to have been achieved or the attempt to achieve it is abandoned.
d. It has a *resource base*, from which the resources required to achieve the purpose are extracted.
e. It has a *knowledge base*, from which the knowledge of how to apply the resources is extracted.

The requirement for a purposeful process to take place within a timeframe, as stated in criterion c, may at first seem an unnecessary restriction, as there are many purposeful processes that appear to be progressing with no time limit. An example would be the process of education. However, on closer examination, that process is really defined in terms of the change in the state of individual persons within a definite timeframe, and it is the multitude of these individual instances of the process that goes under the general name of "education".

The category of purposeful processes contains two sub-categories. One is what we shall call *realisation processes*; these are processes that convert the results of intellectual work into *services* useful to society or to groups of society. The other sub-category is what we shall call *professional processes*. These are distinguished by the extent of their resource and knowledge bases and the intellectual effort required by the practitioners to acquire and apply this knowledge; in effect, by the investment in education and experience. This sub-category includes the engineering process, but also a wide range of processes outside of engineering, such as medicine, dentistry, architecture, and economics. Professional processes are further distinguished by the fact that each one is related to and, to some extent, embedded in, a corresponding realisation process. Law is related to law enforcement processes (without which law would be without value), medicine is related to health care processes, and so forth. Engineering is related to the *industrial processes*, which are processes that involve a conversion of natural resources in order to fulfil their purposes, but the distinguishing feature of engineering is that *every instance of the engineering process is embedded in an instance of the industrial process* (this is also true of architecture, which is embedded in a subset of the industrial processes: the building industry). This means that we cannot consider the value of engineering, or any other effect of engineering on society, without considering the associated industrial process. Engineering without industry is just like dreaming. The foregoing framework is illustrated in Fig. 2.4.

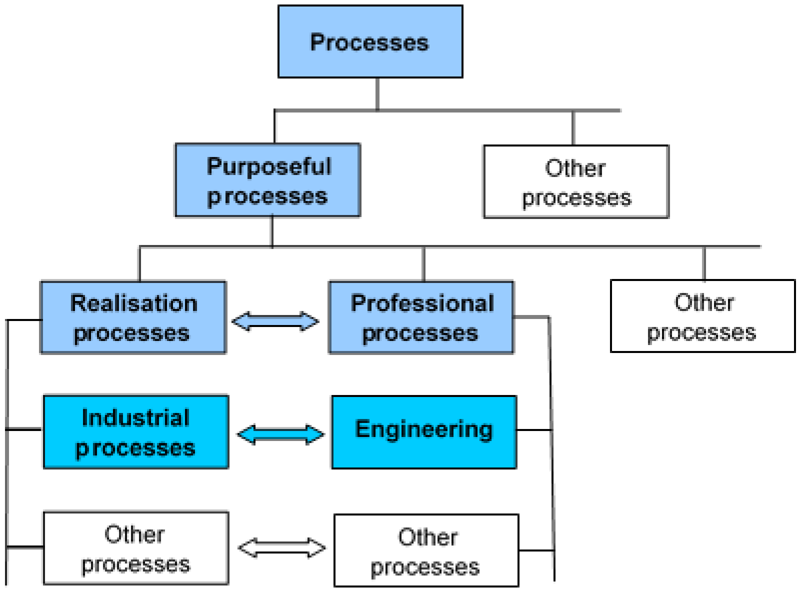

Figure 2.4 The framework of processes within which engineering is defined.

A feature peculiar to professional processes is that the definition of a process is provided by the practitioners of the process, and the definition of who is a practitioner is defined by the body of practitioners. In the case of engineering, this situation is illustrated in Fig. 2.5, and it shows a self-referential, dynamic definition process, with the current status documented in the form of requirements on the education and experience to be satisfied by an engineer. That documentation often consists of two sets of requirements, one on the education, in the form of requirements to be satisfied by education providers through accreditation process performed by a statutory body (in the US this is ABET, in Australia it is Engineers Australia), and the second in the form of competencies to be demonstrated by an engineer, and it is this second part that effectively defines engineering.

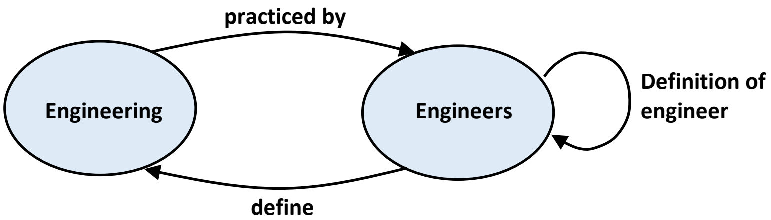

Figure 2.5 The self-referential nature of the definition of engineering via the definition of an engineer.

We see, then, that the current definitions of engineers and engineering are the result of a historical evolution, related very much to the evolution of the environment in which engineering operated, or the *engineering paradigm*, as we shall discuss in the next section. In Sec. 5.2 we will look at some of the confusion that has arisen in Australia with the definitions of engineer and engineering.

1. Macfarlane, I, *Science and Innovation: Building Australia's Industries for the Future*, and B. Shorten, *Response*, Hansard, OzParltHR-17Aug15.docx.

2. http://innovation.gov.au/page/national-innovation-and-science-agenda-report
3. Engineers Australia, https://www.engineersaustralia.org.au/membership/assessment-qualifications-and-competencies
4. ABET, quoted in http://en.wikipedia.org/wiki/Engineering
5. www.thefreedictionary.com/engineering
6. www.merriam-webster.com/dictionary/engineering
7. www.oxforddictionaries.com/definition/english/engineering
8. http://en.wikipedia.org/wiki/Engineering

2.4 Technology

In order to define technology, we first need to define one of the concepts used in the definition; that of a construction element: A *construction element* is a reusable artefact embodying experience from previous applications of the engineering process. A construction element is defined by a specification that is available to all or groups of society, often in the form of a standard. Examples are fasteners, reinforcing steel bars, bearings, capacitors, and semiconductors, and an example of a standard for a construction element is DIN 653, *Knurled thumb screws, low type.*

Technology shall be defined as consisting of the knowledge base comprising both science-based knowledge and heuristic knowledge arising from experience, and a resource base consisting of construction elements that engineers and the technical workforce can draw on in executing projects, as well as the facilities within industry for fabrication and construction.
The knowledge base is comprised of textbooks, standards, published papers, operating manuals for tools and instruments, company internal documentation (intellectual property, IP), etc, and spans a continuum from advanced research to Tables for everyday use. Technology can be subdivided, with the major subdivisions defining engineering disciplines, such as civil/structural, mechanical, electrical, and chemical.

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; in particular, the above definition of technology does not include any activity. Whereas philosophers see technology as an activity (or at least including activities), no engineer would speak of "doing technology". The concept of "technology" is also used extensively in sociology, as we shall consider in some detail in Chapter 3. - What we have here is a prime example of how a concept is a word plus its context-dependent meaning, and as the word "technology" penetrates into all areas of our discourse, its context-dependence must simply be accepted, and taken into account in each instance [1].

With this definition of technology, the results of the engineering process can be considered to be applications of technology, and so, instead of focusing on the class of processes called "engineering", another approach is to focus on instances of this class, called *projects*. In terms of engineering projects, it is possible to distinguish two broad types:

– Projects that utilize technology to meet a need expressed by all or a part of society; and
– projects that increase technology.

Projects in the first group *apply* technology, in order to meet requirements imposed by entities or people who are generally not engineers, and it is these stakeholders that are the judges of project success. Projects in the second group *develop* technology, using that part of the knowledge base that is provided by science, and their success is judged generally by other engineers. Let us call these two groups of engineering projects *application projects* and *development projects*, respectively. There is not a sharp boundary between them, and there will be many projects that contain sub-projects of both types.

The importance of this distinction becomes apparent when we consider some of the characteristics of the work undertaken by engineers in the two project groups:

- The projects in the two groups differ in the *distance* of the work from the engineer to its effect on society, and thereby in the level of responsibility and accountability and, more generally, the ethical issues involved. In the case of a development project, such as the development of a new type of semiconductor device or a new type of fastener, the engineer has no control over what the work will eventually be used in; it could be a weapon of mass destruction or a life-saving piece of medical equipment. In the case of an application project, the engineer normally has a good idea of what the work will be used for and its intended effect on society.
- While engineers in both types of projects will receive reward in the form of personal satisfaction, the more tangible aspects of the reward structure are considerably different. In a technology development environment, the reward is mainly peer recognition based on published results and in an elevation to more senior status in the development organization. In an application environment, the reward is more likely to be a gradual transition out of design (see below) and into project management, business development, and corporate management roles, with commensurate privileges and remuneration increases.
- The scope of the work that engineers undertake (or the roles that engineers play) within the two types of projects differs. In development projects, the work is mainly comprised of core engineering activities such as studies, experiments, design, and fabrication. In application projects, engineers may additionally be involved in project management, procurement, construction, commissioning, community consultation, and engagement with various stakeholders, such as debt providers.

However, despite these differences, projects within both groups have a purpose that is external to the engineer; without such a purpose it would not be engineering, but rather art (as self-fulfillment), science (the search for truth), or simply playing or dreaming. Different projects have different purposes, but if we reduce the level of detail in the description of the projects, they start to form groups with the same purpose. For example, both a motorway project and a rail project can be thought of as having the purpose of providing public transportation. If we continue to decrease the level of detail in the description, we come to the point of asking “Is there a purpose common to all projects?”, and that question will occupy us in Chapter 3.

So much for the definition of the concept technology; that is, for the meaning of the word “technology” in the context of engineering, as it is used in this book. However, in the next chapter, where we look at the history of the relationship between engineering and society, we will meet the German word “Technik”, as much of the early (say, the period from 1880 to 1940) work on the philosophical and sociological aspects of engineering was carried out in Germany or published in German. This might be a suitable place to examine the meaning of “Technik” and its relationship to engineering and technology, and in doing so, we shall repeatedly be referring to the book *Streit um die Technik* by Friedrich Dessauer [2], as we shall do again in Chapter 3. Besides Dessauer’s penetrating analysis of the nature of engineering, the book contains a wealth of references and quotes, albeit almost exclusively focused on German publications.

Starting with the classical Greek concept of *techné*, in particular as it was explored in the philosophy of Socrates, Dessauer points to its meaning as ability based on knowledge, applicable to any activity, such as painter, stonemason, musician, farmer, bricklayer, and so on. True knowledge leads to good and beneficial activity, and so knowledge becomes synonymous with virtue. Through its usefulness, *techné* becomes a realisation of the metaphysical concept of good, establishing a connection between ethics and Technik [3]. However, he then points out that *techné*, as well as Socrates’ identification of ability with knowledge, are not adequate to express the meaning of Technik. First of all, as Plato already realised, virtue, or the concept of the good life, cannot be identified with ability and knowledge alone, as this would make the thief as virtuous as the keeper, so there must be a higher form of knowledge, not tied to practical ability, that defines the good. Secondly, Technik is much more than just knowledge, more than applied science; a central characteristic of Technik is creativeness. It is not about routine activities that are learnt through repeated practice; it is about the uniquely human possibility of adaptive transformation of the natural environment, and as such it is a significant component of our culture. Technik encompasses both the activity of transformation (engineering) and the knowledge on which it is based (technology), but also the products of the transformation and their interaction with society (usefulness). These products include both artefacts, from tooth brushes to space stations, and processes, from welding to design methodology. A well-known engineer, Akos Paulinyi, defined Technik as "the totality of all artefacts, as well as all processes and actions with which the human being plans, designs, produces, and uses these artefacts in order to fulfil a purpose". That is, Technik is quite close to what philosophers and sociologists understand by "technology", and is probably where that understanding comes from. However, this definition is so general as to be almost vacuous, as it includes every man-made object and the great majority of actions, from sweeping the floor in a factory to striking a match. In particular, the concept so defined does not lead to any insight into the relationship between engineers or engineering and technology. We may also note that this concept is not an ontologically "pure" concept, in the sense that it can be assigned to one of the categories in the upper ontology; it is a combination of processes and substances that is not amenable to a simple definition.

1. The tension between the usage of "technology" in engineering and in philosophy and sociology was discussed briefly in Aslaksen, E.W. 2013, *The Engineering Paradigm*, Int'l J. of Engineering Studies, vol. 5, No. 2, pp. 129-154., but a useful perspective on the everyday use of the concept is given in Marx, L. 1994, *The Idea of "Technology" and Postmodern Pessimism*, in *Does Technology Drive History?*, M.R. Smith and L. Marx (eds.), The MIT Press., 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 inclusion of activity in the meaning of technology is quite common, see e.g. Li, Bo-cong, 2010, *The Rise of Philosophy of Engineering in the East and the West*, in *Philosophy and Engineering*, I. van de Poel and D.E. Goldberg (eds), Springer.
2. Dessauer, F, *Streit um die Technik*, Verlag Josef Knecht, 1956. This includes much of the material in the earlier work, *Philosophie der Technik*, Cohnen, 1926.
3. An in-depth examination of the relevance of Greek philosophy to the ethical aspects of engineering can be found in Hector, D.C.A, *Towards a Modern Engineering Ethical Framework: The Foundations of Western Engineering Ethics*, doctoral dissertation, University of Sydney, and presented at fPET-2012, the Forum on Philosophy, Engineering and Technology conference, hosted by the University of the Chinese Academy of Sciences in Beijing, November 2-4, 2012. The full paper to be published as a chapter in the Springer Series on Philosophy of Engineering and Technology.

2.5 System

Why do we need to consider the concept of a system, when our objective is to show that engineering is a social activity? The reason is that the social aspect of engineering is a very *complex* subject matter, and we shall show that the basic feature of the system concept is that it is a means of handling complexity. Consequently, this concept will appear numerous times throughout this monograph, and an understanding of it will be essential to appreciating our discussions of the relationships between engineering and society.

The word "system" is used in all areas of human activity and at all levels; some examples are education system, transport system, solar system, telephone system, Dewey decimal system, weapons system, ecological system, space system, and so on; there is almost no end to the uses of the word "system" that come to mind. But what do people *mean* when they use the word "system"? To what extent is that meaning context-dependent? Is there some part of the meaning that is common to all applications? These and similar questions, all relating to the use of the word "system" in everyday language, need to be given careful consideration if we are to achieve a clear understanding of the underlying system concept itself before specialising to the engineering context.

To understand what something is, it is often useful to consider its history; how it got to be what it is [1]. The word "system" would appear to have originated in ancient Greece, where it related to music and meant a compound interval or a scale or series of notes extending through such an interval, but, for reasons which will be discussed in the next Section, it is likely that the system concept, i.e. something being both whole and consisting of parts, was also present in other cultures, e.g. in China.

In Latin, it retained the meaning of a music interval, but was also used to signify "allness" or "wholeness", as in "the universe".

In the English language, the word came into use during the seventeenth century, when we find it used with a number of somewhat different, but closely related, meanings. In the early part of the century there is still the meaning of the universe, as e.g. in "In this Round Systeme All", but soon we find it used to signify an ordered collection, as e.g. in "Mans life is a systeme of different ages" or "The yeare is a systeme of four seasons", or "Aristotle is more noted for his order, in bringing Morality into Systeme, ... and distinguishing vertues into their several kinds, which had not been handled Systematically before, ..." And in astronomy one now speaks of "The systems of the world, i.e. Ptolemaick, Tychonick, and Copernican". Another couple of examples of a similar meaning (i.e. ordered or systematic) are "System is a treatise or body of any Art or Science" and "That there might no vice be wanting to make his Life a systeme of Iniquity".

A use that stands on its own is "System and Hypothesis have the same Signification, unless, perhaps, Hypothesis be a more particular System, and System a more general Hypothesis".

One of the first instances of where the interaction of the parts is a specific feature of the system concept is in Hobbes (1651), "By Systemes, I understand any numbers of men joyned in one Interest or one Business".

In the last century there was a great upsurge in the interest in systems, which has continued with increasing intensity into the present day. On the one hand, this was driven by the realisation that "everything is interconnected" and that the compartmentalisation into (non-interacting) specialist areas of knowledge has some serious limitations; this is the basis of what is known as General Systems Theory [2]. On the other hand, the size and complexity of man-made objects required a new approach to their design and development, and this became what is now Systems Engineering [3]. As a result of these developments, coupled with the popularisation of technology and science, the word "system" has become a very common word in everyday language, and so we might ask if is it possible to find something in the meaning of the word "system" that is true in all uses of the word? There does not seem to be, and this points to a core problem in conducting a wider discourse - that the word "system" is used so frequently and so loosely that it has lost much of its value. The value can be brought back in by defining the meaning in a particular context, such as engineering, which we shall do shortly. But before doing so, we should note two things. Firstly, as the above examples show, the uses and meanings of "system" fall into two distinct groups. Both groups consider a system to consist of a set of elements, but in the one group - the one that we shall be interested in and consider the "real" meaning of "system" - the elements are interacting and form a whole that has properties that are not found in any of the elements (the emergent properties), whereas in the other group, the elements are not interacting, and the whole is just the sum of the elements. In this latter group, "system" is more or less synonymous with "ordering", and may be considered a degenerate version of the first group, in the sense that the interactions in the first group are identically zero. Getting these two groups confused is one of the most common problems in discussions within INCOSE about the meaning and properties of systems.

Secondly, as always when restricting a concept to a particular context, we have lost its general applicability and convenience. In order to operate with this concept, we have to have been instructed in its meaning and use. This situation is somewhat analogous to the use of the word "God"; it is very useful when we want to signify something like "whatever one believes in" without going into specifics. Once we narrow the context to a specific religion or sect, we need to have been taught what the meaning is and its proper application.

We get closer to answering our initial question if we recognise that when we say "A car is a system", this is an abbreviated mode of expression; what we really mean is "For our present purposes, we shall describe a car in the form of a system". There are many purposes for which it is not necessary to describe a car in the form of a system; e.g. for the purpose of describing a car as an investment object, a traffic hazard, a greenhouse gas emitter, etc., in which case one or a few global parameters are adequate. But if we want to describe its functionality and performance in more detail, the number of variables and their relationships increase rapidly, and as the *complexity* of the description increases, we find it easier to process mentally if we structure the description in the form of a system. So we might suspect that the system concept is, in some way, a reflection of the way our mind works, and I would venture to make the following statement:

> *The system concept is a practical manifestation of Kant's view of how the mind processes information and forms concepts (i.e. general descriptions). In particular, the core of the system concept - viewing the whole as the result of interacting parts - is nothing but an application of Kant's fifth category, the ability to see the whole as made up of parts.*

So, if we accept this statement, we can say that a system is what Frege would call a *second-level concept* [4], or what we shall call a *mode of description*; a concept for formulating the concepts the mind uses to process its sensory inputs.

That the mind tends to handle complexity in this manner has been a matter of observation for some time, and has led to the realisation that complexity is relative - for example, what is complex to the human mind may be simple for a computer, and vice versa. The mind can manipulate objects that are characterised by more than one parameter as entities; that is, it is able to consider the parameters simultaneously rather than sequentially, as a computer normally does. But there is a limitation to this ability; as the complexity of an object increases and the number of parameters exceeds a certain number, the mind finds it rapidly more difficult to consider the object as an entity, and automatically starts to group the parameters into smaller groups and to process them as separate objects [5]. The most immediate evidence of this is language; in order to express something complex, such as a story, we use a limited set of vowels which can be combined to form words, the words are subdivided into groups (nouns, verbs, predicates, etc.) and combined to form sentences, and the whole story is a string of sentences. However, the elements need to *interact*, and in the case of language the interaction takes place in the mind of the listener and is determined by the sequence of the vowels, words, and sentences.

Another example of using the system approach is provided by structured programming. The partitioning of a program into modules is so that it is easier for the human to understand and thereby be able to verify, test, and maintain. To the computer it would make no difference (except perhaps with regard to memory requirements) if the program was just one long unstructured file.

To see what the proper use and meaning of the system concept is in engineering, we need to recall our understanding of it as a mode of description of an object. A description of a physical object can be considered from two points of view - *what* we want to describe, and *how* we want to describe it. We never describe everything about an object (this would require an almost infinite number of variables), we describe those features that are relevant to our current purpose, such as functionality, cost-effectiveness, reliability, etc. (or any combination of such features). And we can present the description in different ways, e.g. unstructured - just listing all the parameters and their values in random order - or structured, and one of the ways of structuring the description is as a system, as per our definition of the system concept. This is illustrated in Fig. 2.6, where the shaded matrix element represents one system. All the elements in the "as system" column represent systems, so there are many systems associated with any one object.

Thus, we now understand that the meaning of the phrase "the x system" is "the description of certain properties of the object x in the system mode", and the proper use of this phrase in systems engineering presupposes a definition or common understanding of what constitutes the object x, and what properties we are considering.

With this understanding, we also see that the truth value of the sentence "x is a system" is TRUE if x refers to a description in the system mode of an object, and FALSE otherwise. So the truth value of the sentence "A car is a system" is FALSE within the context of engineering, and this confronts us with a central issues in engineering today - a situation somewhat analogous to that of a Christian Scientist with appendicitis. On the one hand, most engineers recognize that the daily language use and meaning of the word "system" is too general for it to be useful as a key concept in technology, and so many of the discussions within engineering for a are really just misunderstandings about or different opinions about the meaning of "system". These discussions often end with a frustrated "it all depends on what you mean by a system", and there has even been suggestions that we should abandon the word "system" and coin a new word with a precisely defined meaning. On the other hand, the daily language, imprecisely defined meaning of "system" is so prevalent and useful, and the use of a sentence like "A car is a system" so ingrained in us, that it would be neither beneficial nor practically possible to abandon it.

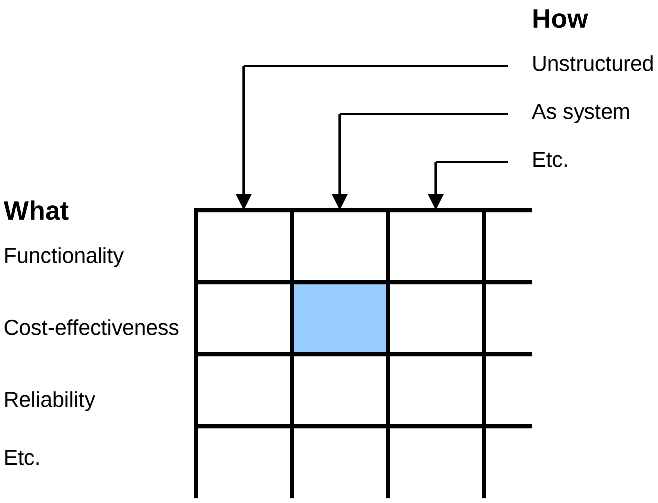

Figure 2.6 The set of all descriptions of an object.

The way out of this dilemma is neither to abandon the general language use nor to coin a new word; it is to accept the fact that many words have a context-dependent meaning. It does require us to be more disciplined in our use of language and, above all, it requires a conscious effort to think in terms of functionality, i.e. what a physical object does, rather than usually in terms of what it is. The word "car" immediately conjures up the image, in our minds eye, of the physical object, with four wheels etc.; what it should conjure up is the description of its functionality, i.e. the capability of transporting a small number of people and meeting certain performance criteria. This immediate connection between a word and the physical object it refers to is the greatest barrier to lateral thinking in design, and it is, of course, also at the root of our problems with the word "system". Instead of associating "system" with a description, we associate it directly with the physical object to which the description refers.

There are numerous definitions of the system concept, both in different contexts and within a single context, such as General Systems Theory or Systems Engineering [6]. We shall use the following, very broad, definition:

*A **system** is a mode of description consisting of three related sets:*

- *a set of **elements***
- *a set of **internal interactions** between elements*
- *a set of **external interactions** between one or more elements and the external world; i.e. interactions that can be observed from outside the system.*

The internal interactions take place between elements, the external interactions take place between the elements and the external world. In both cases, the *possibility* of supporting the interaction must be a characteristic of the element; the set of interactions is merely a formal or logical set denoting which of these possibilities are actually used in a particular system. That is, the interactions do not express any additional functionality not already inherent in the elements. - This above definition does not conflict with any of the other definitions; it was chosen to allow the widest possible applicability, while at the same time be precise enough to be useful in an operational sense.

There is one point that needs to be made about our definition of a system, and that is the use of the term *set*, and in particular, as it is used in the set of elements. One possible definition of a set would be any collection of elements, such as {Paris, 4, grey}, where the elements have nothing in common except that they are elements of this (arbitrarily) defined collection. Our definition will be more precise (and more commonly accepted in mathematics), in which the elements all belong to a *universe* of elements, such as the natural numbers {1, 2, 3, …}, and the set is defined by one or more *properties* which selects its elements from the universe, such as e.g. the set of even numbers.

1. The early history of the word "system" is taken from The Oxford English Dictionary, Second Edition, Clarendon Press, Oxford 1989. Much of the material in this section was first presented in E.W. Aslaksen, *A Critical Examination of the Foundations of Systems Engineering*, half-day tutorial, Proc. Fourteenth Int'l Symposium of INCOSE, Toulouse, France, 20-24 June 2004. The text is available at www.gumbooya.com. An expanded form of the material is contained in E.W. Aslaksen, *The System Concept and Its Application to Engineering*, Springer, 2013.
2. General Systems Theory can be said to have its beginning with the work of Von Bertalanffy from 1932 onwards, and the publication of his book "General Systems Theory", by George Brazillier in 1941. This lead to the creation of the International Society for Systems Science (ISSS). - Some well-known references are:
   i. Laszlo, E., ed., *The relevance of General Systems Theory*, George Brazillier, 1972
   ii. Bowler, D.T., *General systems thinking: its scope and applicability"*, Elsevier, Amsterdam, 1981.
   iii. Boulding, K.E., *The World as a Total System*, Sage Publications, Beverly Hills, 1985.
   iv. A more recent book, which gives a good overview of the current state of GST, is the one by Lars Skyttner, *General Systems Theory - An Introduction*, Macmillan Press, Basingstoke, 1996.
3. A good overview of the early years of systems engineering is given in the report by Hans Bode, 'The Systems Approach', in *Applied Science - Technological Progress*, report to Committee on Science and Astronautics, US House of Representatives, 1967. - Four other standard references are:
   i. Blanchard, B.S. and W.J. Fabrycky, *Systems Engineering and Analysis*, Prentice-Hall, 1981/2010 (5^{th} ed.).
   ii. Chestnut, H., *Systems Engineering Methods*, Wiley, 1969.
   iii. Johnson, R.A., F.W. Kast, and J.E. Rosenzweig, *The Theory and Management of Systems*,McGraw-Hill, 1963.
   iv. Sage, A.R., *Methodology for Large-Scale Systems*, McGraw Hill, 1977.
4. The distinction between objects and concepts, and the subdivision of concepts into first- and second-level concepts is discussed by Frege in *Ueber Begriff und Gegenstand*, Vierteljahrsschrift für wissenschaftliche Philosophie, 16 (1892), pp. 192-205, in English in P. Geach and M. Black, *Translations from the Philosophical writings of Gottlob Frege*, Oxford, 1952, pp. 42-55. We would perhaps call a second-level concept a *class* of concepts.
5. The seminal work in this area is a paper by G.A. Miller, *The Magical Number Seven, Plus or Minus Two: Some limits on Our Capacity for Processing Information*, The Psychological Review, vol. 63, pp. 81-97, 1956, available online at www.well.com/user/smalin/miller.html. References to subsequent papers can be found at http://citeseer.nj.nec.com/context.
6. In General Systems Theory some of the (very broad) definitions are:
   "A system is anything unitary enough to deserve a name", Paul Weiss (biologist);
   "A system is anything that is not chaos", Kenneth Boulding;
   "A system is a structure that has organized components", West Churchman.
   The INCOSE Systems Engineering Handbook gives the following definition:
   "An interacting combination of elements to accomplish a defined objective. These include hardware, software, firmware, people, information, techniques, facilities, services, and other support elements."

3 Society and Applications of Technology

3.1 The Impact of Technology Applications

The context-dependency of the meaning of "technology" demonstrated in subsection 2.4 has led to the situation that there is a significant body of work that treats the relationship between technology and society without, or only in passing, relating this to engineering and the role of engineers in this relationship. This chapter provides a limited overview of that body of work and, for those readers that would like to examine this further, a number of useful additional references as background material to the development of an understanding of engineering as a social activity in Sections 5 and 6.

The impact of technology on our society is both undisputed and very obvious. Just take a look around you, and almost everything you see owes its existence to applications of technology. If you are reading this book in a printed version, the paper on which it is printed was produced by a highly sophisticated process that converts woodchips into a fibrous "soup", which is spread out as a thin layer on a moving cloth that drains off most of the moisture and delivers a continuous sheet of felt-like material to a highly sophisticated machine, where it is pressed and dried by passing through numerous hot pairs of rollers at high speed. The steel used in this machine was produced in a complex process using iron ore and coal as its raw materials, and by many individual pieces of equipment, each one itself the product of a long development and improvement process. These raw materials were excavated, crushed, washed, and transported by numerous, high performance machines, and so on; a chain that goes on almost without limit. Or take an ordinary drinking glass; the numerous applications of technology involved in converting quartz sand into a finished product at a cost of a dollar or less per glass are each based on a huge body of knowledge. Or the incredible precision required in the manufacturing and operation of the weaving machines that produce the cloth we wear. The involvement of technology in our daily existence has become so ubiquitous that it is no longer given much thought, in the same way that we take our natural environment for granted; as something that is simply there.

And it is exactly this ubiquitousness that is the core of the problem when it comes to considering both technology and the environment. But while there is a great deal of discussion about the extent to which we are responsible for changes to the environment, there is no doubt about that we are solely responsible for every development and application of technology. Technology does not harbour any inherent force that determines its development and that makes its increasing influence in our lives inevitable. We control that development, the problem is that our view of the effects of technology have been superficial, in the sense of concentrating on the immediately visible effects, such as the economic effects, or the effects on power projection, or the effects on physical health, and so on. What has had much less scrutiny is the effect on the structure and fabric of society itself. As an example, we have now seen a number of cases where military superiority is used as a means of suppressing a problem, starting perhaps with Palestine/Israel, followed by Vietnam, Iraq, Afghanistan, and now the whole Middle East. (And the use of technology as a means of suppression is now creeping into our own societies in the form of surveillance, enforcement, and an associated legal framework.) Technology is increasingly allowing one side to inflict grievous losses on the other side with minor own losses, and so this is seen as a relatively easy and, unfortunately, also popular approach to suppressing a problem without having to address the much more difficult task of reducing or eliminating the cause of the problem.

The lack of understanding of, and concern with, the influence of the application of technology on the evolution of society displayed by the general population does not mean that there has not been a significant amount of thought and effort expended on this issue. As we mentioned briefly in the previous chapter, the concern with what might be broadly subsumed under the concept of technology goes back to the Greek philosophers, and from about 1800 onwards, there was a slowly increasing awareness of the applications of technology as significant factors in society. A good review of this developing awareness and of the major issues under discussion is given in the book *Streit um die Technik*, by Friedrich Dessauer (already referenced in Section 2), most of which was first published in 1926 under the title *Philosophie der Technik*, and in its final form in 1956. It is, unfortunately, only available in German, as is much of the literature on this subject in the years before World War Two, but reviews can also be found in many of the works listed in References at the end of this monograph. The main point, as far as our story is concerned, is that most of this work was concerned with the effect of mechanisation on the role of workers, transforming artisans and craftsmen into operators of machinery, without addressing the impact of technology on the development of the fundamental nature of society. There were, certainly, exceptions, such as Karl Marx [1] and Thorstein Veblen [2,3], but it was only after the appearance and explosive growth of information technology (IT) in the years following World War Two that the influence of technology on the evolution of society became an object of study in its own right, with contributions from philosophy and various branches of social science.

1. Marx, K, *Capital : a critical analysis of capitalist production*, translated from the third German edition by Samuel Moore & Edward Aveling and edited by Frederick Engels,Allen & Unwin, 1971.
2. Veblen, T, *The Theory of Business Enterprise*, Transaction Books, 1904, available from Internet Archive.
3. -, *The Captains of Finance and the Engineers*, p.61, in *The Engineers and the Price System*, B.W. Huebsch, Inc. New York, 1921.

3.2 The Interaction Between Technology and Society

The interaction between technology and society is a complex subject, with numerous components and aspects, and one on which the view has changed significantly over time. 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 and Wajcman [1] and Smith [2]. 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 [3] 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 [4], 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 [5] and Archibald and Newhouse [6]. 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.

This can be seen, for example, in the importance of a collective readiness to accept and try out new ideas when they become available. This sensitivity to invention is a compound of many social, political and cultural factors, sustained by tradition and passed on by education and training. A well-known example is the stagnation of technological development in Chinese civilization under the control of the mandarins. Up until, say, 1400, Chinese technology and its applications were on a par with, if not superior to, technology in Europe, but in the following centuries European technology developed rapidly, whereas in China a veneration of tradition and ritual by a centralised government stifled development. Some measure of political liberty, a degree of freedom from the constraints of class and conformity, a tolerance towards unfamiliar and even apparently bizarre points of view are all parts of the "social package" required for technology to develop. This was again demonstrated in the relative rates of industrial development in France and England during the period 1600-1800, when an entrepreneurial middle class in England had considerable freedom to develop new industries, whereas in France such development was mainly the prerogative of the nobility, under the control of a powerful monarch. A distinct body of research is what is identified as the social shaping of technology (SST), and a seminal work here is the book *The social shaping of technology* [1]. The point of departure of SST is to acknowledge the much greater complexity of the socio-technical interface than is recognised by either technological determinism, which saw technology developing according to an inner logic, or social determinism, which saw technology development as reflecting a single influence, such as an economic imperative. Central to SST is the concept that there are choices (although not necessarily conscious choices) inherent in both the design of individual artefacts and systems, and in the direction or trajectory of innovation programmes. Different routes are available, potentially leading to different technological outcomes, and they could have differing implications for society and for particular social groups. Rather than merely assessing the social impacts of a given technology, SST examines what shapes the technology which is having these impacts – its artefacts and practices – and draws together views from different areas of sociology and economics to form a deeper understanding of the innovation process and the social factors influencing it.

An important critical strand within SST has highlighted the politics of technology. Technologies can be viewed as "politics pursued by other means" or as the outcome of social conflict; in either case, technologies are not neutral, but are fostered by groups to preserve or alter social relations. Of particular interest to our investigation is the promotion of the Weberian class conflict perspective by proposing that the ability of a society to favour technical change is enhanced by conflicts taking place in a large number of arenas. The nature of the conflicts may be economic competition or social conflicts, and the arena might be industry, a profession, or a neighbourhood, but in any case, in a totally homogeneous society new technology will not be easily introduced, and technical change is more likely to occur in a society or an arena in which power and influence are unequally distributed among a relatively large number of agents.

Closely related to SST is what is known as Social Construction of Technology (SCOT). It is based on an approach called the Sociology of Scientific Knowledge (SSK), which considered scientific knowledge as arising from the socially influenced interpretation of scientific discoveries. SCOT studies technological artefacts and explains how social factors entered into the particular choices among a number of possible ones. One aspect of this social constructivist program, and which is relevant to our story, is that a problem is closed when the relevant social groups see it as being solved. But this is certainly not true in general; in many cases closure simply means that the differences between social groups have been reduced to the point where power relations of a political or economic nature make any further development futile. Thus, closure does not mean the elimination of conflict, and it is the suppression of latent conflicts through power relations that reduce the stability of a society, as we mentioned above.

1. MacKenzie, D and J. Wajcman, *The Social Shaping of Technology: How the Refrigerator got Its Hum*, Milton Keynes, Open University Press, 1985.
2. Smith, M.R. and L. Marx (eds), *Does Technology Drive History?*, The MIT PRess, 1994.
3. Dorrestijn, S, *Technical Mediation and Subjectivation: Tracing and Extending Foucault's Philosophy of Technology*, Philos. Technol. 25, 2012, pp, 221–241.
4. Callon, M, *Society in the Making: The Study of Technology as a Tool for Sociological Analysis*, in *The social construction of technological systems: New directions in the sociology and history of technology*, W.E. Bijker, T.P. Hughes, and T.J. Pinch (eds.), MIT Press, 1987.
5. Hausman, J.A. and D.A. Wise, 1980, *Introduction to "Social Experimentation"*, ch. 1 in *Social Experimentation*, Hauseman and Wise (eds.), Uni. of Chicago Press.
6. Archibald, R.W. and J.P. Newhouse, 1980, *Social Experimentation: Some Whys and Hows*, Rand Report R-2479-HEW, available at www.rand.org/content/dam/rand/pubs/reports/2007/R2479.pdf

3.3 The Public Discourse

Central to all considerations of the influence of society on technology, whether explicitly or implicitly, are the processes by which this complex system we call society forms its opinions about technology, and how these opinions are expressed through various components of the system, such as individuals, special interest groups, and professional associations. The most general and basic process is that of the *public discourse*, a very complex and ill-defined process utilising person-to-person interaction and one-to-many interactions through social media and public media (newspapers, radio, and TV), as well as various public discussion fora. How exactly opinions and assessments are formed and grow using these communications channels is difficult to describe, but various aspects of this public discourse, including its effectiveness in influencing the development and acceptance of applications of technology, have received considerable attention.

In the article *Technology's Challenge to Democracy: What of the Human?*, Nikolas Kompridis discusses a number of aspects of the public discourse that are highly relevant to our purpose [1]. It is centred around the question "What does it mean to be a human being?", posed in response to the risks presented by genetic intervention into the basis of human life. After pointing out how this essential question is being sidelined by the current naturalistic and anti-essential stance of European and Anglo-American philosophy, it sets out a program for challenging technology through the democratic process of public discourse. He recognises that "scientific experts, market imperatives, and the culture of liberal democracy all contribute to a conceptual framework from within which it is extremely difficult to think about technological development except as the welcome expansion in the range of choice available to formally free and equal individuals". The issue here is not the expansion in the range of choice, but what our criterion is for making the choice, and the process used for establishing that criterion. The current focus is on risk reduction, but the definition of risk is "consequence of not achieving the desired outcome", so that without an agreed definition of what constitutes "the desired outcome", such efforts are at best *ad hoc*. That is why "the debate about these new technologies should not be restricted to a debate over appropriate normative regulation. That would be to lose the battle even before it began. … Surely we must be given an opportunity to consent to, or dissent from, so spectacular and irreversible change as the alteration of our biochemical nature. But more importantly, we must be given an opportunity to pose the question ourselves, prior to having it settled by "experts", scientific or otherwise". He quotes Habermas [2] in support of this view, and generalised to the introduction of any new application of technology, this resonates strongly with the concept of the importance of being able to exercise our intelligence, which was discussed in Aslaksen [3].

Kompridis then goes on to propose a counter science of the human based on the concept of the person as a being for whom things matter, and matter in a peculiarly human way. And, in particular, what matters, and which constitutes and sustains personal identity are our relations with others. This does, to a large extent, reflect our view of the individual as an element of a system – society – and that the importance of the individual arises from its contribution to the behaviour of society as an emerging property through interaction with other individuals.

The last part of this thought-provoking article describes and advocates the process of public discourse, setting out two main conditions for such discourse to be meaningful: "First, we need to ensure that democratically organized processes of public reflection can take place in both official and unofficial public spheres, maximising the opportunity for citizens to speak and be heard, to listen and learn. Second – and this is far more challenging – we need to develop, and to comfortably speak, evaluative languages not already structured by the presuppositions of the language of progress, which does not allow us to be critical of progress without appearing to be politically and morally conservative, and so, without appearing to be against science and against reason." The importance of effective use of language in conveying the information required for assessing applications of technology has been highlighted by various authors, and was one reason for addressing this issue in Section 2.

Similar thoughts are expressed by Marx Wartofsky [4] when he poses the central question: Given that technology so decisively affects the lives and futures of people, nationally and globally, and since policy decisions are now on such a general political scale as to become largely national and international governmental decisions, can the democratic imperative of self-government by the people be effectively carried into the arena of such technological decision making? For this, which he calls the fourth revolution, to happen, two major changes will have to take place: the democratization of power in society, and the education of the scientific and technical understanding of the public, both to the extent that some form of democratic participation in scientific-technical policy-making becomes feasible and useful, and not simply an empty populist piety.

The importance of democratising the assessment of technology has been emphasized by a number of authors. For example, Andrew Feenberg [5] states: “Technologies form the framework of our lives, but they are designed with little or no democratic input. This is a serious failure of our institutions. It must be addressed by reforms in education, the media, the corporations, law, and the technical professions.” And Ian C. Jarvie [6] says: “The most important philosophical problems of technology are, then, social and political ones. Neither in civilian use, nor in military and clandestine use, is there remotely adequate input from the general public about technology, its costs and its benefits.”

The last couple of decades have seen a growing interest and activity in what is known as participatory technology assessment (pTA), particularly in Europe, where it has been supported by such government bodies as the Danish Board of Technology [7] and the Rathenau Insititute [8]. It has given rise to various networks, such as Living Knowledge: The International Science Shop Network. Closely related to this is the rise of mass-mediated expertise, which allow citizens to become involved in expert deliberations on science and technology issues. A German study by Petersen *et al* [9] supports the hypothesis that mass-mediated expertise has a significant impact on policy processes, whereas a survey on *The Impact of New Technology on the International Media and Foreign Policy* by Hopkinson [10] found that the influence of public opinion (and of the media) was less that often thought, as public opinion is often incoherent. It is dependent on the particular case, but in general most important when the government is weak. A cautionary note is also sounded by Gabriele Abels [11] when she asks: “Can strategic actors become interest-free deliberators? Why should they restrict themselves to contributing expertise, if they can mobilise other channels of influence to lobby for their interests? What about the danger of stakeholder capture?”.

A recent article by Hennen [12] makes a strong case for pTA, stating “pTA should fundamentally be considered an element of what Sheila Jasanoff [13] has termed “civic epistemology”. The emphasis should be on “an element”, namely as an element of the manner in which societies adapt and value scientific knowledge. In this regard, it is one element among several that are decisive, some of the others being the forms of political representation, the role of experts in the political system, the culture of public deliberation, and the degree of transparency in public institutions. It is a deliberative element of the organization of the way in which society treats knowledge, not an Aristotelian point to turn the system upside down”.

1. Kompridis, N, *Technology’s Challenge to Democracy: What of the Human?*, Parrhesia, no. 8, 2009, pp. 20-33.
2. Habermas, J, *The Future of Human Nature*, H. Beister and W. Rehg (transl.), Polity Press, 2003.
3. Aslaksen, E.W, *A Story About Us: Evolution and the Individual*, Gumbooya Pty Ltd, , 2015, available online at www.gumbooya.com.
4. Wartofsky, M.W, *Technology, Power, and Truth: Political and Epistemological Reflections on the Fourth Revolution*, in Democracy in a Technological Society, L. Winner (ed.), Kluwer Academic Publishers, 1992.
5. Feenberg, A, *Toward a Democratic Philosophy of Technology*, ch. 6 in *Philosophy of Technology*, J-K.b. Olsen and E. Selinger (eds.), Automatic Press/VIP, 2007.
6. Jarvie, I.C, ch. 13 in *Philosophy of Technology*, J-K.B. Olsen and E. Selinger (eds.), Automatic Press/VIP, 2007.
7. Danish Board of Technology, www.tekno.dk.
8. Rathenau Institute, www.rathenau.nl, accessed 06.10.2014.
9. Petersen, I, H. Heinrichs, and H.P. Peters, *Mass-Mediated Expertise and Informal Policy Advice*, Science, Technology, & Human Values, vo.. 35, No. 6, 2010, pp. 865-887.
10. Hopkins, N. (ed.), *The Impact of New Technology on the International Media and Foreign Policy*, Wilton Park Paper, 1995.

11. Abels, G, 2006, *Forms and functions of participatory technology assessment - Or: Why should we be more skeptical about public participation?* Proceedings of the PATH Conference, 4-7 June 2006, Edinburgh, available from http://www.uni-tuebingen.de/index.php?eID=tx_nawsecuredl&u=0&g=0&t=1421191058&hash=9a984be3b7b1e9ddd7e2da78edb33412080eae7e&file=fileadmin/Uni_Tuebingen/Fakultaeten/SozialVerhalten/Institut_fuer_Politikwissenschaft/Dokumente/abels/Abels_Participation_PATH_conference_2006.pdf, last accessed on 13.01.2015.
12. Hennen, L, *Why do we still need participatory technology assessment?*, Poiesis Prax. no. 9 (1-2), 2012, pp. 27-41.
13. Jasanoff, S, *Designs on nature: science and democracy in Europe and the United States*, Princeton University Press, 2005.

3.4 The Information Society

Due to the strong and ubiquitous interaction between ICT and society, as already mentioned, the presence of ICT in the structure and functioning of society can be considered a defining characteristic of society, and one speaks of *the information society*. Here we should distinguish between two types of theories about the impact of ICT on society: those that focus on the direct impact of developments in ICT on politics and culture, and those that focus on the impact on the economy or mode of production. With regard to the former, there is an almost euphoric view that problems of social and cultural inequality can be solved and barriers to full political participation removed by technologies for the production and distribution of information. Put the processes of democratic politics on-line and full political freedom will be achieved. Put University and school courses on-line and the age of universal education will finally arrive. And with regard to the latter, people like Daniel Bell have argued, based quite explicitly on both Marx and Weber, that post-industrial society is developing in stages. Capitalism is moving from a stage of industrial capital based on the exploitation of matter and human energy to a post-industrial stage based upon the exploitation of what Bell called "organised knowledge". The core resource has shifted from monetary capital to knowledge.

Several authors have pointed out that what we are witnessing is a second "industrial revolution", in which an increasing number of human activities in all fields are being taken over by IT. Kevin Robins [1] states that the past history of multinational corporations gives little promise that they will have democratic interests at heart in the future. For them, IT represents just another series of exchange values which by no means correspond to real social needs, and they have shaped it - without democratic participation and consultation – to express specific corporate values and priorities. There is no reason to believe that IT will not reinforce, and aggravate, existing inequalities at both national and international levels. He quotes Schiller as saying "contrary to the notion that capitalism has been transcended, long-prevailing imperatives of a market economy remain as determining as ever in the transformation occurring in the technological and informational spheres", a view that is further detailed by Schiller [2,3], who argued forcefully that the current role of the media in modern society, and in the US in particular, is to support the capitalist economy and suppress any meaningful debate on alternatives.

A similarly sobering view with regard to the impact of ICT on society, and one that we should keep in mind, is that put forward by Nicholas Garnham in a number of publications [4,5,6]. He makes the observation that much of the talk of an Information Society is just the Service Economy relabelled, and that arguments about ICT having caused an epochal shift in either economy or society are largely specious. He challenges the view that the information technology will usher in a new era of cultural freedom, diversity and abundance and shows that we are here in the presence of ideology in its pure, classical form; that is to say, a social analysis that not only misrepresents its object of analysis by focusing on its surface rather than its underlying structure and by denying its real history, but also misrepresents it in such a way as to favour the interests of the dominant class. In this case, the trick is played by concentrating upon the technical potentialities, rather than upon the social relations that will determine the form in which those potentialities are realised and by denying history by exaggerating the novelty of the process in question. We are witnessing merely the latest phase in a process integral to the capitalist mode of production; an "industrialisation of culture" or "colonisation of leisure" by which massive market interests have come to dominate an area of life which, until recently, was dominated by individuals themselves.

Garnham then discusses the growing information gap in western societies, between the information-rich and the information-poor, and how this is related to the widening gap between rich and poor. Also, the information technology is structured to reinforce this, splitting the culture into two classes. Choice, being increasingly expensive, is offered to upper-income groups, while an increasingly impoverished, homogenised service is offered to the rest. Eventually, we will have to choose between two social forms. On the one hand, we can choose a society which primarily fosters social relations, based upon the Aristotelian notion of men and women as essentially social animals, based therefore upon notions of social reciprocity and interchange, upon the public as opposed to the private as the essence of humanity. Without such a notion, politics in any true sense is unthinkable. On the other hand, we can choose (or more likely have forced upon us) a society which is merely a social structure within which atomised, privatised individuals interrelate, primarily through commodity exchange, and by so doing necessarily reproduce the dominance of the capitalist mode of production and of those who control it, namely the owners of the means of production. Such a society will necessarily subordinate the public to the private sphere and destroy politics in favour of a manipulative form of elite control if we are lucky – what Bertram Gross has dubbed 'Friendly Fascism". These latter tendencies will be powerfully reinforced in the cultural sphere by the introduction of information technology under market conditions. Such introduction should therefore, as far as possible, be opposed.

An interesting view, although somewhat peripheral to our purpose, is represented by a very significant body of work within sociology that treats the relationship between technology and society. This work is clearly related to the subject matter of this monograph, but there are some significant differences, and the first of these is the meaning and treatment of "technology". Most of the items of this body of work do not contain any definition of "technology", and where there is an implied definition, such as in the Introduction to the already referenced book edited by MacKenzie and Wajcman, the relationship of society to technology is seen as a relationship to things. And while engineers are mentioned, there is relatively little interest in how engineers relate to technology. Nor is there much discussion of the relationship between industry and technology. It appears that sociologists view technology mainly as a "black box", relying on our intuitive and everyday understanding of the concept, and focus on its external interactions.
This is in marked contrast to their treatment of society, which is considered to be a complex system and subjected to a variety of views, such as gender, social status, education, power, etc. And so, this deeper understanding of the nature of society on the part of sociologists and the better understanding of engineering, industry, and the internal workings of "technology" on the part of engineers could be an area of fruitful collaboration between the two disciplines.

Sociologists also appear to take a more pragmatic approach than do philosophers; they do not worry so much about if something is "good" or "bad"; they are mainly interested in understanding how it works. How does technology influence society, and *vice versa*? And so they view the world as a giant laboratory in which experiments are going on all the time, and they observe, record, and analyse. The result is numerous and varied valuable insights into the interaction between society and technology and, in particular, the understanding that this is a two-way interaction; something that resonates strongly with the view developed in this monograph. Quoting again from MacKenzie and Wajcman, the view that technology just changes, either following science or of its own accord, promotes a passive attitude to technological change. It focuses our minds on how to adapt to technological change, not on how to shape it. It removes a vital aspect of how we live from the sphere of public discussion, choice, and politics.

Finally, when considering the influence of technology on public discourse, it is important to distinguish discourse, which implies an active involvement of the participants, from the (often one-sided) provision of content. Technology has, on the one hand, provided unprecedented possibilities for engaging in public discourse; on the other hand, it has led to both an information overload and to a mixture of products, facts, opinion, and advertising being presented in a manner that makes it difficult to differentiate between them. One result is that we have become media-rich and information poor, another is that culture has become a commodity. As far as public discourse is concerned, the result is a sidelining in favour of the commercial interests of the media owners.

A detailed, if perhaps not entirely unbiased account of the relationship between technology and society is given by Naomi Klein [7] in her recent book, *This Changes Everything*. It is focused on the environmental impact of the carbon-extracting applications of technology, such as fracking and tar-sand processing, and on the crisis of global warming, but – without in any way downplaying the magnitude of this crisis – the major significance of this work in the context of the present investigation is Klein's clear understanding that it is not technology itself that is the problem. The problem is the application of technology through an industry that is locked into the capitalist "free" market economic system and an associated system of values expressed through an addiction to things and consumption, to the neglect of social and moral values and the importance of interpersonal relations. She also illustrates, through numerous examples, the illusion of the "free" market, and promotes the understanding that the socially beneficial operation of a market can only take place with a significant amount of regulation and intervention by government (to the extent that it represents all of society).

1. Robins, K, *New Technology - The Political Economy of General Ludd*, Ch. 4 in Bannon, Barry, and Holst 1982, 1982.
2. Schiller, H.I, *Who Knows: Information in the Age of Fortune 500*, Ablex, 1981.
3. Schiller, H.I, *The Packaged Consciousness*, Cyrano's Journal Online, 1982, available at http://www.cjournal.info/packaged.html (last accessed on 04.01.2015).
4. Garnham, N, *The Information Society is also a Class Society*, Ch. 24 in Information Technology: Impact on the way of life, Bannon, Barry, and Holst (eds.), Tycooly Publishing Ltd, 1982.
5. Garnham, N, *Concepts of Culture: Public Policy and the Cultural Industries*, in Studies in Culture: An Introductory Reader, A Gray and J. McGuigan (eds.), Arnold, pp. 54-61, 1987.
6. Garnham, N, *The Information Society: Myth or Reality?*, Bugs, Globalism and Pluralism Conference, Montreal September 19-22, 2001.
7. Klein, N, *This Changes Everything: Capitalism vs. the Climate*, Penguin Books, 2014.

Additional references that the author found relevant to this subject matter, some of which were also referred to in the references in this section, include:

a. Arata, L.O, *Literary Models of Technological Mediation: Jean-Paul Sartre's Nausea and Julio Cortazar's The Treasure of Youth*, 2013, in *Critical Insights*, Colatrella, below.
b. Arthur, W.B, *Competing technologies and economic prediction*, Chapter 6 in *The social shaping of technology*, D. MacKenzie and J. Wajcman (eds.), Open University Press, 2nd ed, 1999.
c. Bannon, L, U. Barry, and O. Holst (eds.), *Information technology: Impact on the way of life*, Tycooly Int'l Publishing Ltd, 1982.
d. Buchanan, R.A, *The Power of the Machine*, Penguin Books. Chapter 11, *Technology and People*, 1992.
e. Byrne, K.B, *Introduction*, in *Responsible Science – The Impact of Technology on Science*, Nobel Conference XXI, K.B. Byrne (ed.), Harper & Row, 1985.
f. Colatrella, C, *On Technology and Humanity*, Introduction, in C. Colatrella (ed.), *Critical Insights: Technology and Humanity*, Salem Press, 2013.
g. Collins, H and R. Evans, *Rethinking Expertise*, University of Chicago Press, 2007.
h. Haard, M, *Beyond Harmony and Consensus: A Social Conflict Approach to Technology*, Science, Technology and Human Values, vol.18, no. 4, 1993, pp. 408-432.
i. Hughes, T.P, *Technological Momentum*, in *Does Technology Drive History?*, M.R. Smith and L. Marx (eds.), The MIT Press (1994).
j. IMF, *Global Economic Model*, 2004, https://www.imf.org/external/np/res/gem/2004/eng/
k. Latour, B, *How to Write "The Prince" for Machines as well as Machinations*, in *Technology and Social Process*, B. Elliott (ed.), 1988, pp. 20-43.
l. Lenski, G, *Ecological-Evolutionary Theory: Principles and Applications*, Paradigm Press, 2006.
m. Luria, W.E, *The Single Artificer*, chapter 3 in *Responsible Science – The Impact of Technology on Science*, Nobel Conference XXI, K.B. Byrne (ed.), Harper & Row, 1985.
n. Mitcham, C, *A Philosophical Inadequacy of Engineering*, The Monist, vol. 92, no. 3, 2009, pp. 339–356.
o. -, *Engineering Policy: Its Scope and Limits*, Forum on Philosophy, Engineering and Technology 2012 (fPET-2012), University of the Chinese Academy of Science, Beijing, 2-4 November 2012.
p. Pinch, T.J. and W.E. Bijker, *The social construction of facts and artifacts: Or how the sociology of science and the sociology of technology might benefit each other*, in *The social construction of technological systems: New directions in the sociology and history of technology*, W.E. Bijker, T.P. Hughes, and T.J. Pinch (eds.), MIT Press, 1987.
q. Williams, R. and D. Edge, 1996, *The Social Shaping of Technology*, Research Policy, vol. 25, pp. 865-899.

4 Engineering and Industry

4.1 The Engineering Paradigm [1]

The concept of a *paradigm* was elaborated by Thomas Kuhn in his seminal work, *The Structure of Scientific Revolutions* [2], and the title of the present paper reflects the inspiration provided by that work. Kuhn showed that, for long periods of time, science works within a set of accepted truths and norms, which he called the scientific paradigm, and that it is the existence of this stable framework that, to a great extent, underpins the efficiency of scientific work. However, these periods of stability are interspersed by relatively abrupt changes to the paradigm, brought about by two factors: the number of experimental results that cannot be explained within the existing paradigm reaches a critical value, and a new theory is put forward that explains all or most of these results.

Engineering has some similar characteristics. This has also been argued by E.W. Constant [3], who called it a "culture of technology", expressed both in large-scale organisations and institutions and in the career commitment of individual practitioners, that creates technological momentum, the propensity of technology to develop along previously defined trajectories unless and until deflected by some powerful external force or hobbled by some internal inconsistency. But adapting this picture of evolution to engineering requires us to take account of the significant differences between engineering and science. Basically, whereas science is about discovering the truth of our understanding of Nature, engineering is about using that understanding for beneficial purposes. And whereas the paradigm within a domain of science can change relatively rapidly, caused by a single revolutionary new theory, such as the heliocentric view of the solar system, Newton's laws, Darwin's theory of evolution, relativity, and quantum mechanics, changes within engineering are more gradual. In particular, is not that existing engineering knowledge and works are found to be incorrect and need to be discarded; it is that new knowledge and works are added and then, over time, replace the old for reasons of greater cost-effectiveness. Consequently, the concept of an engineering paradigm cannot be that of an accepted state of the knowledge and resources that engineering applies, which is what we have defined as technology, but rather the place and nature of engineering itself within a wider field of human activity.

Thus, the engineering paradigm consists of a number of components:

- the relationships to the other participants in the technical workforce, such as technicians and technologists, drafters, machine operators and trades personnel;
- the relationships to non-technical participants in engineering projects, such as business, finance, and marketing personnel; and
- the relationships to society.

All of these components underwent rapid change in the eighteenth and nineteenth centuries, and while this change had a different character and extent in different parts of the world, it resulted in creating, particularly in continental Europe, a profession on a par with science, medicine, and law. The salient feature of the development was the successive structuring of the technical workforce in response to the increasing volume and complexity of technology; it was no longer possible for a single individual to master all the contents of technology, from practical, manual skills to analytical, science- and mathematics-based design processes. This structuring is illustrated in Fig. 4.1; it is what we might call a *vertical* structuring, to distinguish it from the *horizontal* structuring into disciplines that took place in each of the workforce groups, resulting in plumbers, electricians, fitters and turners, etc. in the trades, and civil, mechanical, electrical, and chemical in engineering.

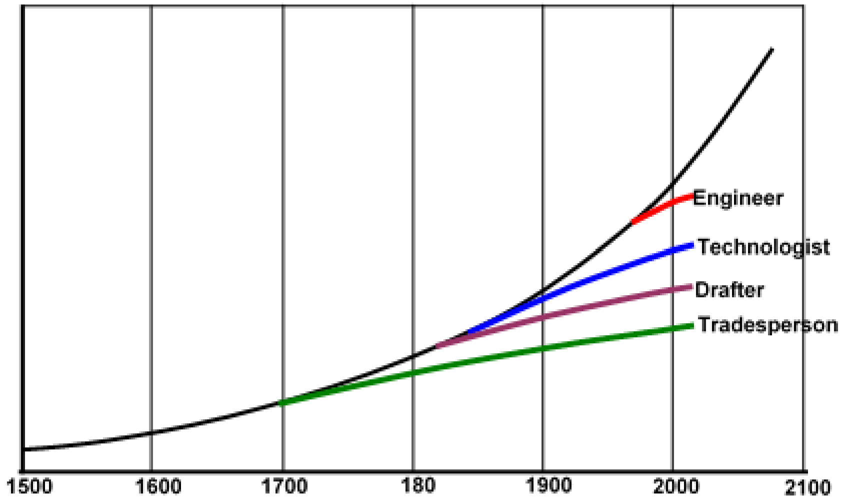

Figure 4.1 The development over the last six hundred years of one aspect of the engineering paradigm: the structuring of the technical activities within engineering projects by intellectual content (the vertical axis is intended as a qualitative indication only) [1].

However, in the last century, in which technology underwent an explosive expansion, the development of the paradigm was hijacked by industry in response to an insatiable demand for more technology-based products of all kinds, driven by a free-market capitalist business model. One significant change has been that, despite the increase in specialisation in both the education and employment of engineers, the increase in the volume of technology has led to a neglect of subjects not directly relevant to the industrial process. And so, while this horizontal structuring brought with it its own problems, in the form of inter-disciplinary communications barriers and a narrow, stove-piped approach to projects, more significantly, it has not been complemented by a further vertical structuring; the *role* of engineers within the technical workforce is essentially the same as it was a century ago. In a sense, engineering became a victim of one of the underpinnings of its own success: standardisation. Technical universities became facilities for the mass production of engineers of a single vertical level, reflecting the idea of "one size fits all" or Henry Ford's "you can have any colour you like, as long as it is black". Another significant change has been the trend in engineering education towards emphasizing the scientific aspects of engineering, rather than the heuristic and creative aspects, something we shall come back to in Section 5.1.

The relevance of the concept of an engineering paradigm to the subject matter of this book is that it makes it clear to us that the social aspects of engineering – both within engineering and in its relationship to society – are, to a large extent, determined by the relationship between engineering and industry, That relationship makes up the first two of the three components of the paradigm, which is what the next two subsections are about. The third component, the direct relationship between engineering and society, is taken up in subsection 6.2.

1. Aslaksen, E.W, 2013, *The Engineering Paradigm*, Int. J. of Engineering Studies, Vol. 5, No. 2, pp. 129-154.
2. Kuhn, T.S. (1996), *The Structure of Scientific Revolutions*, Univ. of Chicago Press, 3rd ed.
3. Constant, E.W. (1987), *The Social Locus of Technological Practice: Community, System, or Organisation?*, in The Social Construction of Technological Systems, Bijker, Hughes, and Pinch (eds.), The MIT Press, 1987.

4.2 Structure of the Relationship

In trying to understand the relationship between engineering and society, a major issue is what might be described as the symbiosis of engineers and industry. Engineering is embedded in the *industrial process*, which is a process that involves a conversion of natural resources in order to fulfil its purposes, as was indicated in subsection 2.3. Any attempt to understand the relationship between engineering and society must be based on an understanding of the relationship between engineering and industry, as the relationship of engineering to society 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. 4.2.

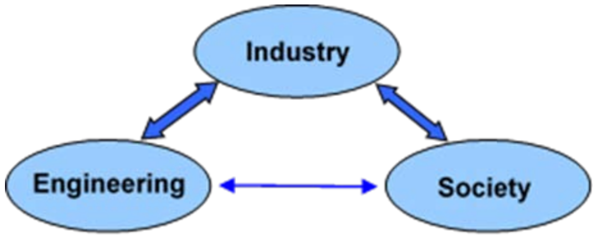

Figure 4.2 The relationship between engineering and society, with industry as an intermediary.

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. This is illustrated in Fig. 4.3, where engineers perform the process of engineering, which is part of the technology process, which is embedded in industry. All three groups have an interface to society, but it is dominated by that of industry. What society experiences as "technology" is largely determined by industry.

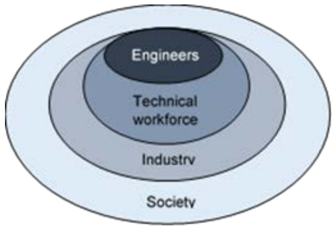

Figure 4.3 The relationships between engineers, the technical workforce, industry, and society. It also illustrates that the direct interface between engineers and society is very limited.

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. 4.4.

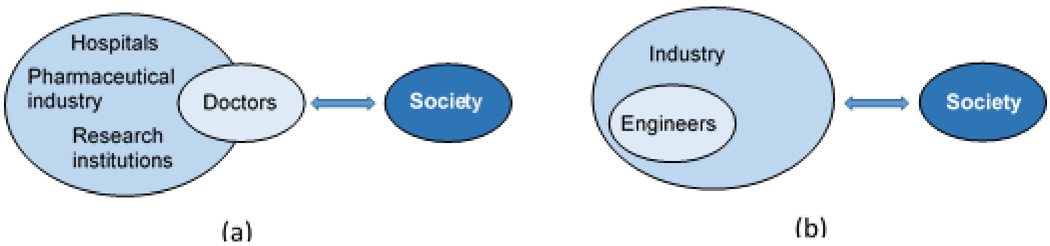

Figure 4.4 Illustrating the indirect interaction between engineers and society (b), as opposed to the direct interaction between doctors and society (their patients) (a) [1].

The purpose of industry is to make profits, grow the business and build value for the owners, and as long as the activity stays within the limits imposed by society, that is appropriate in a free, competitive market. Society determines which projects will be successful and which not, and in most cases that process works well. However, most engineers would be confronted at least once in their careers with a situation in which the progress of a project is not in accordance with best practice as they know it, or in the best interests of the client, but they are restricted from doing anything about it by requirements on company loyalty, confidentiality agreements, and being "team players", in addition to their own careers and livelihoods being tied to the commercial success of the projects. And in many projects the opportunity does not even arise, as the interface between industry and society is provided by business people and marketing professionals; engineers have let themselves be relegated to "backroom boys" (and now, also girls).

The realisation that the role and outlook of engineers is conditioned by industry is not new; in the 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" [2]. It is also discussed as part of a recent essay by Newberry [3]. In particular, he makes reference to the suggestion by Noble [4] that industry has forcefully shaped the mechanisms for engineering education and professional socialisation in order to produce a "domesticated breed of engineers". However, it is important to realise that this "domestication" is not a malicious behaviour, nor is it a lack of regard for engineering, nor an attempt to subjugate engineering, on the part of industry. On the contrary, industry supports engineering through grants and prizes. It is simply that 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 engineering in industry. 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.

A well-known example of how the interaction between engineers and society is modified by industry as an intermediary, is the issue of standardisation. Engineers see standardisation as a means of rationalising the industrial design and production processes and lower the cost of products to society; it is also something desired by society for a number of reasons, including ease of replacement, reduced need to learn new operating instructions, and greater ability to maintain and repair products. However, industry often sees standardisation as detrimental to branding, differentiation, market position and, in the end, to their profits. Here is a conflict of interest only too familiar to all of us in the form of the variety of chargers for mobile electronic devices. This conflict was also recognised and detailed by Veblen in his two publications, *The Theory of Business Enterprise* [5] and *The Engineers and the Price System* [2], and has been analysed in an article by Knoedler and Mayhew [6].

Central to understanding the industrial process and the role of engineering in it is the realization that its function is to meet a set of *stakeholder requirements* on a project. The engineer attempts to meet that need by creating an object that meets the relevant part of the stakeholder requirements and, when put into operation, provides a *service* that meets the need. The judgement of the stakeholders as to the extent to which the service meets the need is the measure of the project's success. This industrial process is illustrated in the diagram in Fig. 4.5. The colouring of the entities is intended to indicate that, while engineering plays an important part in the industrial process, this is a process controlled and executed by industry. The degree to which engineers are involved in the entities varies greatly from project to project, and only the two objects coloured blue, design and specification, can be unequivocally ascribed to engineering. That is to say, engineering is a sub-process of the industrial process, and engineers work within the industry structure required to realise a project; a framework that involves many other people besides engineers, including politicians, business men, lawyers, financiers, marketing and sales personnel, technicians, tradesmen, and labourers, so that what society experiences is often influenced only to a limited extent and in an indirect manner by engineers. And, what is equally important: society has little insight into and understanding of exactly what this extent and manner are.

The tensions within industrial projects can be illuminated by viewing the stakeholder requirements as belonging to one of two groups. In the first group are the requirements of the users; i.e. of the people constituting the part of society that expressed the need, and these requirements, plus any requirements imposed by law, should be considered the primary requirements. In the second group are the requirements of the people involved in realizing the project, such as project managers, contractors and investors. These requirements are generally concerned with profit and return on investment, so we might call them financial requirements, and they should be considered as secondary requirements, in the sense that they are only addressed contingent upon the primary requirements having been fulfilled. a point of view put forward by other authors, such as van de Poel and Kroes in their work on value-sensitive design [7].

However, in some cases it is the other way around; projects are seen primarily as business opportunities, with the user requirements as of lesser importance. This may not be visible to the users, but it is to engineers.

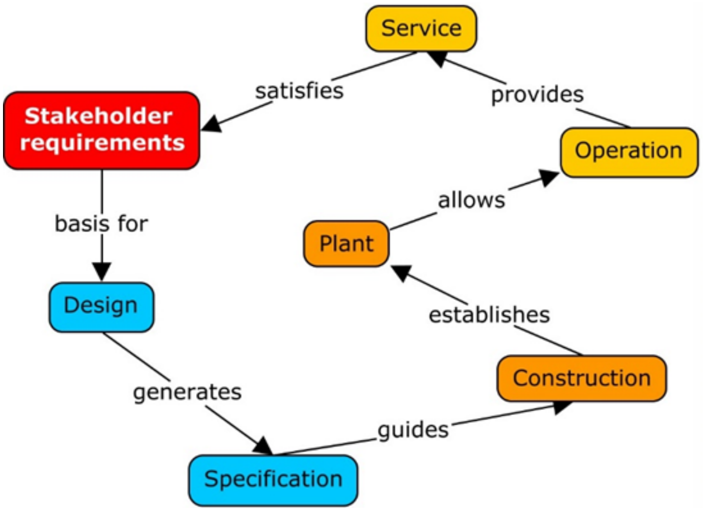

Figure 4.5 The involvement of engineering, indicated by the two blue entities, in the industrial process.

It is important to recognize that the issue we are addressing there is not the same as the cost-benefit optimization that is part of every engineering project – a process that is wholly dependent of the user requirements. There is always a trade-off between two types of user requirements, performance and cost, and the optimum solution is determined by the users' perception of the relative importance of the two. From an engineering perspective there is nothing controversial about this optimization process, even though as a citizen one might question the users' perceptions. In particular, as to the extent to which fashion and prestige dominate the performance requirements, as can be observed, for example, in the choice of car.

At a first glance, one might think that there is no conflict between the two processes – the optimization process based on the users' requirements and the process of overall optimization, taking into account both groups of requirements. Surely, what is perceived as the best product by the users will also be best for the owners of the financial requirements? This is not always so and, in fact, it is never so; it is only that the difference in outcomes of the two optimization processes is often negligible or very subtle. And the reason why this is not so is that, while in the case of the users' requirements any conflicts and disagreements that may exist within the users are, at least in principle, not the concern of engineering, a conflict between the users' requirements and the financial requirements involves the engineers through their integration into one of the parties.

Again, we need to emphasize that the conflict we identify here is not the obvious one between supplier and consumer, which is an issue of market forces and regulatory arrangements; it is the possibility of modifying the design of the product to include features that provide financial benefits in ways that are hidden from the users. Prominent examples are search engines, where the user has no insight into the features of the search algorithm, but where these features are important parts of the business model, and news channels, where the user has no insight into the algorithms determining the selection and presentation of the news, and their financial implications, such as favouring major advertisers.

The main point to take away from this discussion of the role of engineering within industry is the realization that while technology may be developed by engineers, the applications of technology are determined largely by the commercial processes taking place between industry and society. While scientists can create great scientific work on their own, engineers can create virtually nothing on their own; creating a bridge or a new microprocessor requires a large industrial organization. The significance of this difference, and the effect it has on the ability of engineers to act freely, is sometimes overlooked by authors that attempt to project the more developed philosophy of science into a philosophy of technology.

1. Aslaksen, E.W, 2014, *Engineers and the Evolution of Society*, Abstracts of fPET-2014, the forum on Philosophy, Engineering and Technology, hosted by the Virginia University of Technology, Blacksburg, VA, May 27-29, 2014.
2. Veblen, T, 1921, *The Captains of Industry and the Engineers*, p.61, in *The Engineers and the Price System*, B.W. Huebsch, Inc. New York.
3. Newberry, B, 2007, *Are engineers instrumentalists?* Technology in Society 29.
4. Noble, D.F, 1977, *America by design: science, technology, and the rise of corporate capitalism*, Alfred Knopf.
5. Veblen, T, *The Theory of Business Enterprise*, Transaction Books, 1904, available from Internet Archive.
6. Knoedler, J. and A. Mayhew, 1994, *The Engineers and Standardization*, Business and Economic History, vol. 23, no. 1.
7. Van de Poel, Ibo, and Peter Kroes. 2014. *Can technology embody values?*, in *The moral status of technical artefacts*, eds. Peter Kroes and Peter-Paul Verbeek, Springer, 2014, pp. 103-124.

4.3 Dynamics of the relationship

An interesting view of the relationship between engineering and society, not least because it demonstrates the central position of industry in that relationship, is provided by the report *Engineering in Society* [1]. It was produced by a panel consisting roughly 50/50 of leaders in academia and industry, and focuses much of its attention on the historical development of the engineering profession, believing that some understanding of the evolution of American engineering in the social context is essential for understanding its current structure and status (see Section 5.1). However, the "social context" is strongly coloured by the narrow business interests of academia and industry, and so sees the major interaction between engineering and society as being one of supply and demand. Society has a need, industry endeavours to meet it, for which it needs engineers, which leads to a demand on academia to supply them. It also leads to increased salaries and opportunities for engineers, which helps to attract students. Conversely, when society's needs are reduced, industry scales back, there is a surplus of engineers, students are no longer attracted to engineering, and engineering schools have to scale back. The two main drivers of this cycle are general economic conditions and government spending on technology, mostly in the form of defence projects (the report was written in 1985); the dynamics of the interaction is determined by the time lags associated with changes in the capacities of industry and education, including the four years it takes to educate an engineer, but also by the evolution of the attitudes of students to technology.

The picture presented by the report is slightly depressing, in that engineering is seen largely as a commodity; an issue was lamented in the book by Patricia Galloway [2]. It makes the evolution of engineering simply a response to demands of industry, and while that is not a view supported in this book, there is a kernel of truth in it, and so we can ask: How will industry itself develop, in both its internal structure and in its relationships to society? Considering its development from individual craftsmen to its present role as a cornerstone of the capitalist economic system, it seems unlikely that it will suddenly come to a halt. In particular, as the present industrial edifice is showing a number of cracks that have become increasingly visible as society is starting to draw a long breath in its headlong pursuit of consumption and the accumulation of wealth.

In the simplest (simplistic?) terms, our economic system is based on growth; initially driven by the desire for a secure lifestyle, but once this and the capital associated with the security has been achieved, growth is driven by the pressure to provide opportunities for investing this capital and receiving a return on it, as the earning value of capital (in addition to the earning value of labour) is the basic tenet of capitalism. And that is what industry provides; each project can be viewed as basically an investment opportunity. This is illustrated in Fig. 4.6.

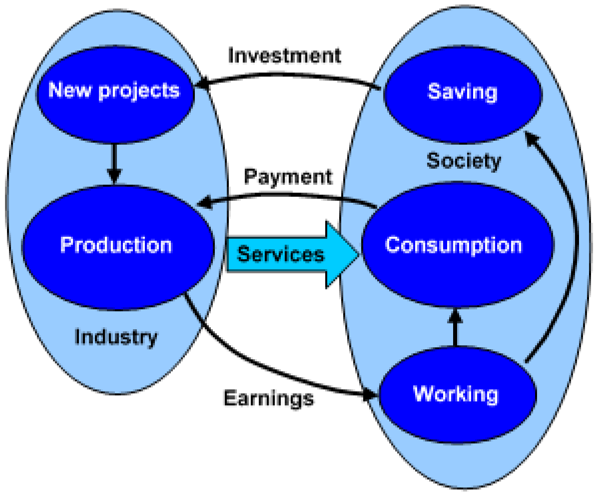

Figure 4.6 The flow of money and services between industry and society, illustrating how industry grows through investment. In this figure, "Earnings" includes earnings from both labour and capital, and "Working" must be interpreted accordingly.

The process illustrated in Fig. 4.6 displays an exponential increase in the size of the economy, as measured e.g. by GDP, and this can, of course, not continue indefinitely. A good discussion and model of long-term economic growth is given in [3]. However, in the medium term, say, the next few decades, we should expect continued and increasing economic growth and an increasing technical content of the new services, so that engineering will play a major role in a rapidly increasing fraction of the GDP. One question is then: What will this role be? Will it be simply as a commodity, "turning the crank" as directed by industry in its endeavour to provide opportunities for investing the accumulating capital, with the only criterion being return on investment? Or will it be as a determining force in the application of existing technology and a proactive force in the development of new technology? The latter means a change in the current dynamics, as it would typically involve an assessment of the existing situation and the problems associated with it, development of proposals to address the situation, and then an evaluation process involving society. In this whole process, to which we shall return in Section 6.2, the structure of the relationship between engineering and industry would remain basically unchanged, but it would be one between equal partners, not servant and master, and with each partner respecting the capabilities and responsibilities of the other. The interaction would take the form of a dialogue, and so constitute a significant change in the dynamics of the relationship.

Some of the changes on the part of industry that would promote this relationship include:

- a more detailed and formal structuring of both the work and the workforce so as to get a better match between capabilities and requirements, and thereby improve the cost-effectiveness of projects;
- a more effective use of computers. In particular, improved human-machine interfaces and the increased use of skilled operators, freeing up engineers to concentrate on the innovative and creative aspects of engineering as well as on the interaction with society; and
- a change of the interface with society to reflect the increasing level of education and the resultant understanding of technology and concern with how technology is mediating changes in society. This would mean a shift in emphasis from marketing and "the hard sell" to an informative dialog based on relevant engineering knowledge.

On the part of engineering, beneficial changes include
- a better understanding and acceptance of the environment in which industry operates, with its complex dependence on political, economic, and social (or market) forces;
- a proactive attitude to the problems encountered by industry, bringing the engineering problem-solving skills to bear on them; and
- development of the level of trust required between partners by accepting a consistent level of responsibility.

A second question is: Given this now very rapid evolution of society under the influence of technology, how do the relationships between engineering, industry, and society influence the *stability* of this evolution? Society is a highly complex and dynamic system, and any measure of its evolution is a stochastic variable, displaying largely random fluctuations. Two world wars, and now the situation in the Middle East, are recent examples of such fluctuations, and there are obvious reason for believing that the development of technology is a main factor in determining both the probability of occurrence and severity of future fluctuations. An examination of this difficult question, which requires a dynamic model of society (even if highly simplified), will be the subject of a forthcoming monograph; here we just note that, as part of the social aspect of engineering, engineers should see it as a part of their responsibility to apply both their knowledge and their insight into the operation of industry to the minimisation of such fluctuations, and some further consideration regarding social responsibility are provided in Sec. 6.3.

An important aspect of the dynamics of the relationship between engineering and industry arises through the dynamics of the project team, as a result of the dynamic nature of technology. However, in order to investigate that, we need to look inside the project team and at the interaction between the technical workforce and technology, and we postpone that until subsection 6.1, so that we can formulate our investigation in terms of and understanding of engineers as a social group, which is the subject of the next section.

1. Engineering in Society, Panel on Engineering Interactions With Society, input to the Commission on the Education and Utilization of the Engineer, National Research Council, National Academy Press, 1985
2. Galloway, P
3. Danielmeyer, H.G. and T. Martinetz, 2009, *An exact theory of the industrial evolution and national recovery*, www.inb.uni-luebeck.de/index.php?id=128#2009.

5 Engineers as a Social Group

5.1 Historical Background

We started Section 2, on the issue of a common language, by considering the history of the language used by engineers in their work and in communicating with other members of society. In now addressing the subject of engineering as a social group, it is again useful to briefly consider this aspect from a historical perspective. That is, how society saw engineering, and how engineers related to society, leading up to the present day. Activities that can be identified as engineering by their basic characteristics have been performed since way before historical times, but engineering as a profession and as a distinguishable component of society can reasonably be said to have their origins around the middle of the eighteenth century. And the two most easily identified measures of the development of the social aspects of engineering from that time onward are the education of engineers and its influence on their position in society, and the organisation of engineers into professional societies and institutions, and the influence of those organisations on the position of engineers in society. These two measures have developed at different rates and with somewhat different characteristics in different countries, and as much of the work into engineering and society in the last hundred years or so has been undertaken in four countries – France, Germany, England, and the US – we shall concentrate our brief historical overview on these, and use this as the background for discussing the situation in Australia. We start with education.

France may be considered to be the early leader in providing professional, specialised engineering education through the establishment of a number of state-sponsored institutions, often with a military focus, such as *l'École royale de l'artillerie* in Douai in 1679,; what is currently *ENSTA Paris Tech* as a school for educating naval architects in 1741, *l'École royale de génie de Mézières* in 1748 and the current École des Mines Paris Tech founded in 1783 to educate inspectors to oversee the French mines (which were government owned). Following the reorganisation of the education system after the revolution of 1789, the National Convention created the first of the *grandes écoles* in the form of the *École Normale Supérieure* (there are currently four of these) and *l'École Polytechnique*. Throughout the nineteenth century numerous additional *grandes écoles* were established, often in the form of *écoles centrale*, such as *l'École centrale Paris*, and while graduates from many of these were simply identified by the name of the institution, by 1894 there were six institutions, with a total of 1350 students, that issued a diploma in engineering [1]. Today there are more than 200 institutions that provide education for engineers; in 2008 there was a total of 115 000 engineering students, with about 55,000 in *grandes écoles*, 26,00 in universities, and the rest in private institutions.

Engineering education in France is of a high standard, and generally of five years duration following a *baccalaureat* graduation, resulting in a Master's degree. In particular, the most prestigious of the *grandes écoles* have very stringent entrance requirements after two years of preparatory studies, and in this manner there is a *de facto* structuring of the engineering profession. Engineers from these universities progress into leading administrative positions in government and government-sponsored organisations, and so, in addition to being near the top of the professional/social ladder, they provide visibility of the profession. Also, as these institutions educate most of the leading business people and politicians, and as their alumni organisations form strong relationships, engineers are well integrated into the social structure. The social status of engineers in France is probably the highest of that in the four countries we are considering, even though the title "*ingenieur*" is not protected by law. Anyone may call him- or herself an engineer, but claiming untruthfully to have graduated from one of the *grandes écoles* is punishable by a hefty fine.

Germany may have had a slightly later start to its engineering education, but it also had quite a different start. Where the early French institutions were motivated by the needs of the military and those of the central state power for technical administration, the German ones, with one exception, the *Ingenieurakademie zu Dresden* (1743), which was run by the Preussian army, were motivated by the practical needs of local industry – mining. The first institution was the Bergakademie Freiberg in 1765, followed by similar institutions in Berlin (1770) and in Clausthal (1775) [2]. More general technical education developed in the nineteenth century [3], with a series of Polytechnische Schulen patterned on the École Polytechnique in Paris, starting with Nürnberg (1823), Karlsruhe (1825), München (1827), and Dresden (1828). Today Germany has thirteen Technical Universities (TU) [4], some of which are renamed *Polytechnische Schulen,* but engineering subjects are also taught in some of the other sixty universities. However, in addition to universities, there are 239 *Fachhochschulen* (FH) [5]; higher education institutions with a more practice-oriented curriculum for various professions, including engineering, and where TU courses generally require five years full-time study, the FH courses require four, but often with a requirement for some practical experience prior to, or during, the course. Also, while the FH award bachelors and master's degrees on an equal basis as universities, only universities can award doctoral degrees. Prior to the Bologna-Accord in 2000, German engineers graduated with a diploma, and, to quote a Daimler CEO, "a Dipl.-Ing. in front of the name was like the star on the bonnet", but the transition to bachelor and master seems to have gone well, not least because many of the leading firms have adopted the policy of encouraging new employees with a bachelor degree to engage in company-sponsored master's degree programs. The title "Ingenieur" is legally protected by laws promulgated by the governments in each of the sixteen states of the Federal Republic of Germany, and in general the definition is anyone who has completed a full-time, six-semester course at a FH or technical university.

The status of engineers in Germany is, on the average, reasonably high, even if not as high as it was before 1914, but this status is due mainly to the importance and success of German industry, rather than to the structure of the education system, as in France, and it is through their presence in industry that German engineers have maintained their position in society. Consequently, the social prestige and influence depends more on the position in industry and the renown of the industrial firm (or the relation to industry, in the case of academia) than on the institution from which the engineer graduated, although there is a certain ranking, with technical universities like München, Aachen, and Karlsruhe near the top.

In **England** engineering education followed a different path [6], resulting in part from the social stratification and an associated intellectual snobbishness that venerated the classics above science and engineering, as exemplified by the two universities at Oxford and Cambridge, and in part from the fact that industry was mainly in private rather than in government hands, so that the government had little incentive to promote a general and technically oriented education. This refusal to recognise the importance of educating the working population can be highlighted by a quotation from the Lord Bishop of London in 1803 – "*It is safest for both the government and religion of the country to let the lower classes remain in that state of ignorance, in which nature has originally placed them*", and religious dogma and beliefs impeded the development of an effective national system of education. Despite being in many ways leading in developing new technology, as is illustrated by such names as Thomas Telford, George Stephenson, James Watt, and Matthew Boulton, engineering and engineering education in the UK remained on the level of apprenticeship and on-the-job training and self-education until the middle of the nineteenth century. However, many people interested in science and technology who were religious non-conformists and therefore barred from the two universities created the *dissenting academies*. Despite being given a hard time by the Church of England, they provided a substantial amount of technical and commercial education in the period 1750-1820. The cause of technical education was then taken up by the *Mechanics' Institutions*, founded by George Birkbeck, professor of Natural History at the Anderson's Institution in Glasgow. By 1850 there were over 700 Institutions in Britain, but by that time the technical education they provided declined rapidly, due to such factors as the low level of public elementary education and lack of suitable teachers, and only relatively few of them made the transition into technical colleges, polytechnics, and some even into universities.

However, this somewhat dismal state of both general and technical education was about to change. Already in 1833 a third university was created, the University of Durham, and it opened the firs engineering course in engineering in 1839. A privately financed institution, London University, which had started without official sanction in 1826, became the University College London in 1836, an official rival, King's College London was created in 1828, and a new examining board was called the University of London. A number of new university colleges were founded in the period 1850 to 1890, and Cambridge and Oxford also updated their curricula; all not least in response to the increasing competition from the Continent, as was made obvious in the Great Exhibition in Paris in 1878, where British industry did not fare well. The result is that today Britain has about 130 universities (or university colleges), of which about 28 offer engineering courses, and Cambridge, Oxford, and Imperial College are all in the top 10 engineering universities world-wide.

The social position of engineers in Britain started out from a very low level, simply as a result of the class structure, the emphasis on a classical education, and the disdain for manual work. This, despite the fact that industry was doing very well, and exploiting its position of supplying the Empire with manufactured goods to the full. So, the position enjoyed today, while slightly lower than that enjoyed by German engineers, is mainly due to the greatly improved extent of education. In particular, through the acceptance of technical education at university level, and the rise of famous and influential professors in the engineering faculties and in associated research facilities, the profession gained in visibility and social acceptance. The title of “engineer” is not legally protected.

The development of engineering in the **United States** followed a somewhat distinctive course, as one might expect from a relatively young and rapidly developing country, and the position of engineers in society was also quite different to that in England and Europe. Firstly, there was much less of a class distinction based on inherited social position and wealth. Secondly, there was no disdain for work involving manual labour. Thirdly, there was, at least for a considerable time, little government regulation and interference. And, fourthly, together with abundant natural resources there for the taking, there was a rapidly expanding local market. The result was that the people involved in technical work and realising the need for technical education were also the people reaping the financial awards and therefore in a position to do something about it. In the crucial first half of the nineteenth century, engineering in the US transformed itself from largely craft-based to a profession with an intellectual level and technical sophistication outstripping that in its erstwhile colonial master [7]. For example, by the middle of the century, a standardised system for the production of parts, called the “American System” of manufacturing, had developed, which became much admired and copied on the several international exhibition in the second half of the century. As a result, by 1900 corporate engineering became dominant; professional standing was now closely aligned with corporate standing, and consumer goods manufacturing started it inexorable rise. However, as far as engineering was concerned, the years immediately following the end of WW2 saw a significant change, firstly, through massive government spending, particularly on defence, so that public/defence needs surpassed those of the private/commercial market as the primary driver of new development in engineering, and, secondly, through a closer dependence on science and new scientific discoveries. This led to greater emphasis on science in the curriculum and to an increase in research within the engineering schools.

The rise of higher technical education in the United States can be briefly chronicled as follows [8,9]:

The US Army created the Corps of Engineers in 1802, which then established the US Military Academy at West Point in 1817. Norwich University in Vermont established the first school dedicated to (civil) engineering in 1819, followed by Rensselaer Polytechnic Institute in 1825. From the middle of the nineteenth century universities introduced applied science and engineering subjects/courses: Union College (1845), Yale (1846), Brown (1847), Harvard (1847), Dartmouth (1851), Michigan (1852), and Cornell (1868). There were also dedicated institute schools, such as MIT (1862), Worcester Polytechnic Institute (1865), and Stevens IT (1867), and between 1862 and 1872, the number of engineering schools rose from 6 to 70.

With the expansion of engineering education and the increasing demands from industry, the was a corresponding rise in demand for graduate level engineering education [10]. The first graduate programs that followed a four-year undergraduate education began in the 1890s, The Lawrence Scientific School at Harvard offered a graduate program in electrical engineering in 1893, while MIT offered a master’s degree in civil engineering in 1893, and graduate programs in chemical, mechanical, and sanitary engineering within the next ten years. In 1904, 114 engineering colleges reported a combined enrolment of 15,004 undergraduates and 249 graduate students, and in 1922 there were only 368 graduate students enrolled and 18 advanced degrees granted. In 1920, 11 engineering schools awarded the PhD, increasing to 30 in 1933. By 1934 there were 2,756 graduate students enrolled and 1197 graduate degrees awarded.

Turning now to the second of the measures of the development of the social aspects of engineering - the organisation of engineers into professional societies and institutions – we again start out with **France** [11]. The first engineering association, the *Société centrale des ingénieurs* civils, was formed in 1848. The term "civil" was used here to distinguish these engineers from those who were government functionaries, such as the graduates of l'École Polytechnique. After joining with *l'Union des associations et sociétées industrielles francaises*, which was created in 1948, this became the *Société des ingénieurs et scientifiques de France* (ISF) in 1978.

The individual schools soon created their own alumni associations, e.g. Arts et Métiers in 1849, Ponts et Chaussées in 1860, l'École des Mines in 1864, l'École Polytechnique in 1865, and so on. These alumni associations formed an umbrella organisation, the *Fédération des associations et sociétés francaises d'ingénieurs diplomés* (FASFID) in 1929. Finally, ISF and FASFID, together with the *Conseil national des ingénieurs francais*, formed a single organisation, the *Conseil national des ingénieurs et scientifiques de France* in 1992, renamed *ingéniurs et scientifiques de France* (IESF) in 2012; this is now a federation of more than 160 alumni associations and about 30 individual societies.

What runs through this whole long history is the strength and social importance of the alumni associations and the reputation of their schools. The prestige and social standing of engineers in France appears to be more due to these "old boy" networks than to any professional organisation, such as IESF.

In addition to civil engineering (roads, bridges, canals, furnaces and kilns, etc.), the engineering activity and educations in **Germany** was initially focused on the mining and metallurgical industry, although there was also significant craft-based activity, e.g. in clock-making. It must also be kept in mind that Germany, as a nation, did not come into existence until 1871; until then the German Empire (in its various incarnations) was a loose confederation of largely independent kingdoms and dukedoms. Nevertheless, an organisation dedicated to the advancement of technology and the professional interests of German-speaking engineers – *Verein Deutscher Ingenieure* (VDI) – was founded already in 1856, and this organisation worked to define engineering as a profession and to raise the social status of the profession to that of other professions (science, law, and medicine) [12]. In this endeavour the VDI was assisted by the rise of German industry, which became renowned for its innovation and high quality, thereby making engineers key players in the national economy [13].

While the VDI is the largest of the technical organisations, with about 150,000 members, it is by no means the only one. Of the 1.6 million persons who can be considered to have a technical profession, i.e. engineers, architects, chemists, physicists, mathematicians, and technicians, many have their professional interests represented by about 30 special-focus organisations, all of which belong to an umbrella organisation, *Deutscher Verband Technisch-Wissenschaftlicher Vereine* (DVT). Many of these organisations assist FHs and universities in the assessment of individual courses and subjects, but the final decision regarding subject design rests with the individual institutions; there is no external accreditation, although the EUR-ACE framework is becoming increasingly influential.

In addition to these organisations, there is a type of organisation called a *Kammer* (chamber) for some of the professions (e.g. engineering and architecture) in each state. These have a more commercial purpose, in that they maintain lists of members, such as consulting engineers, that meet certain requirements for individual practice, including continuing education, insurance, and contract conditions.

England was the first nation in which engineering started to organise itself, with the Society of Civil Engineers being formed in London in 1771 [14]. Here "civil" meant as opposed to military; the founding members included two surveyors, an architect, a lawyer, and four millwrights. Of these eight, three were members of the Royal Society. By 1792, the membership had increased to about 20, with some being instrument-makers, and only six of the 24 members elected in this period appear to have had any engineering training. The main purpose of this Society seems to have been as an interface between industry and government; for the development of technology the concentrations of engineers in the various significant enterprises, such as Boulton and Watt's Soho workshops were more important. Due in part to its development into a select industrial-political "dining club", the Society was replaced by the Institution of Civil Engineering in 1818 to cater for the increasing number of engineers (many involved in canal-building), and by 1856 it had about 800 members, including many mechanical engineers. A number of the members were associated with the by then very important railway industry, and there was some criticism (quickly put down by the Institution) of engineers lending their names to projects for significant sums of money. One of the members who was not happy with the Institution was George Stephenson, and he was instrumental in forming the Institution of Mechanical Engineers in 1847. The Institution of Electrical Engineers followed in 1871.

Despite the great contributions engineers made to the British economy, their social status remained generally low, and their Institutions did not attain the prestige of the Royal Society. This was partly due to the insistence of training through the apprenticeship system and the rejection of an emphasis on science and mathematics, and partly a result of the British class system, where status was measured in the distance from manual labour and the attainment of a classical education, so that the idea of an elite engineer was almost a contradiction in terms [13]. The first national engineering society in the **United States** [9] was the American Society of Civil Engineers (ASCE), founded in 1852 as the successor to the Boston Society of Civil Engineers founded a few years earlier. It was followed by the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME) in 1871, and then in rapid succession the American Society of Mechanical Engineers (ASME) in 1880 [15], the American Institute of Electrical Engineers in 1884 (which later merged with the Institute of Radio Engineers in 1963 to become the Institute of Electrical and Electronic Engineers, IEEE) [16], and the American Institute of Chemical Engineers (AIChE) in 1908. Today there are more than 30 engineering societies and institutes in the US, and many of them have, by their substantial funding, been able to make a significant contribution to the social standing and influence of engineers through high-quality publications and standards work.

At the conclusion of this historical overview we should mention another type of organisation that has arisen in most countries with significant technologically activity since WW2, and that is the academies of engineering and/or technological sciences. In particular:

France:	Académie des Technologies, 2000
Germany:	Deutsche Akademie der Technikwissenschaften (acatech), 2007
UK:	Royal Academy of Engineering (RAEng), 1976
US:	National Academy of Engineering (NAE), 1964

A main purpose of these academies is to provide expert advice to government on matters involving technology, including occasionally aspects of the influence of technology on the development of society, as reflected in their mission statements:

> AdT: The Academy of Technology's mission is to lead reflections, make proposals and issue opinions on matters relating to technology and their interaction with society. To this end, it provides expertise, foresight and leadership by using, where appropriate, the skills of guest members. The Academy of Technology examines the issues brought before it by members of the Government. It may itself take up any subject within its mission.
>
> acatech: acatech provides expertise for political decision-making processes on the basis of a double mandate from the federal as well as the regional governments in Germany.
>
> RAEng: The object of the Academy shall be the pursuit, encouragement and maintenance of excellence in the whole field of engineering to useful purpose in order to promote the advancement of the science, art and practice of engineering for the benefit of the public**.**
>
> NAE: The mission of the National Academy of Engineering is to advance the well-being of the nation by promoting a vibrant engineering profession and by marshalling the

expertise and insights of eminent engineers to provide independent advice to the federal government on matters involving engineering and technology.

As such, they constitute a component of the social impact of engineering. The significance of this component is another matter; one issue is that the engineering community often has somewhat differing views of the consequences of applications of technology, which society then interprets as untrustworthiness.

1. *Formation d'Ingenierie en France*, at https://fr.wikipedia.org/wiki/Formation_d%27ing%C3%A9nieurs_en_France, which quotes data from https://archive.org/stream/annuairedelensei1892paul/annuairedelensei1892paul_djvu.txt
2. https://de.wikipedia.org/wiki/Bergakademie .
3. https://de.wikipedia.org/wiki/Technische_Hochschule
4. https://de.wikipedia.org/wiki/Technische_Universit%C3%A4t
5. https://de.wikipedia.org/wiki/Liste_der_Fachhochschulen_in_Deutschland
6. A main source for this historical material is http://technicaleducationmatters.org/2009/05/10/book-references/, another source is https://en.wikipedia.org/wiki/Universities_in_the_United_Kingdom#History
7. Engineering in Society, Panel on Engineering Interactions With Society, input to the Commission on the Education and Utilization of the Engineer, National Research Council, National Academy Press, 1985.
8. Noble, D.F, *America by design: science, technology, and the rise of corporate capitalism*, Alfred Knopf, 1977.
9. *Engineering in Society*, The National Academies Press, 1985.
10. Grayson, L.P, *The Making of an Engineer*, John Wiley & Sons, 1993.
11. https://fr.wikipedia.org/wiki/Ing%C3%A9nieurs_et_scientifiques_de_France
12. Kocka, J, *Kultur und Technik. Aspirationen der Ingenieure in Kaiserreich*, in *Themenportal Europäishe Geschichte, 20012*, available at http://www.europa.clio-online.de/2012/Article =568, last accessed on 07.03.2016.
13. An article that discusses the relationship between engineering, society, and culture in France, Germany, and Britain is the one by Downey, G.L. and J,C. Lucena, *Engineering Cultures*, in *Science, Technology, and Society*, S. Restivo (ed.), Oxford University Press, 2005, pp. 124-129.
14. Buchanan, R.A, *The Engineers: A history of the engineering profession in Britain*, Jessica Kingsley Publishers, 1989.
15. https://www.asme.org/about-asme/engineering-history
16. www.ieee.org/about/ieee_history.html

5.2 The Australian Perspective

If one were to characterise the development of engineering in Australia as briefly as possible, it could be as "against all odds". Starting out as a convict settlement, the initial concern was sustaining itself, with a focus on agriculture and the construction of dwellings and such infrastructure as roads, bridges, harbours, and water supply. Once this initial stage was completed, and an increasing proportion of the population consisted of free citizens, either freed convicts of settlers, the home government saw the Australian colonies as sources of raw materials for British industry and as markets of the products of that same industry; manufacturing in the colonies was discouraged. Added to this was the traditional British disdain for manual labour and an accompanying veneration of a classical education, as well as a minimal government involvement in technical education and industrial development as compared with, say, France and Germany. It was therefore not surprising that the only engineering disciplines that prospered were civil/structural engineering and mining engineering, areas of industry where the products could not be imported, and that has been the case until recently, when software caused a revolution in the engineering profession.

That there was, nonetheless, the development of a significant amount of technology and its applications, and of a manufacturing industry, with the associated mechanical, electrical, and chemical engineering disciplines, was due to a general pioneering spirit of "giving it a go", much like in the US, only under much less favourable conditions. Before there was any formal engineering education available, farmers, tradesmen, and others came up inventions for overcoming local problems, such as the mallee roller, the stump-jump plough, and the stripper, which together expanded the cultivation of wheat into the hot and low-rainfall areas of the country, and the Dethridge wheel for measuring irrigation water flow. A farmer's son, Hugh V.

McKay, patented a stripper-harvester in 1885, and the production facility, the Sunshine Harvester Works, was for many years the largest factory in Australia. A very successful invention was the thrust bearing developed by A.G.M. Michell, but unfortunately the company for its manufacture was established in Britain. These, and many other contributions to mechanical, electrical, chemical, and food processing technology, are described in a history of technology in Australia, published by the Australian Academy of Technological Sciences and Engineering [1].

Reading about these pioneers, their innovations, their hard work and economic sacrifices, and, in most cases, their ultimate failure, the picture that emerges is one of a society lacking a manufacturing industry culture – a “smokestack” culture. From the beginning, the industrial culture has been based on the construction trades, farming, and mining; all of them in some way associated with the land and what it can be used for. And due to the society’s start as a government enterprise, a central characteristic of this culture has been its dependence on the government; success was in no small measure dependent on reaching a profitable arrangement with government, as is so convincingly documented in the book *The Fatal Shore*, by Robert Hughes [2]. This is very different to the colonisation of the US; compared to that country, Australia never had a truly free economy.

Early technical education in Australia was, not surprisingly, based on the British approach of apprenticeships augmented by evening classes at Schools of Art or similar institutions, of which the Sydney Mechanics' School of Arts, established in 1833, is an early example. Despite the importance of mining and the goldrush of the 1850s, formal mining education and training was only established in 1870, with the opening of the Ballarat School of Mines, followed by the South Australian School of Mines and Industries in 1889, and a School of Mines at Sydney University in 1893 [3].

The first university to establish an engineering school was the University of Melbourne, which awarded certificates in engineering from 1866, followed by a chair in engineering in 1883. The University of Sydney, despite having been established in 1850, just three years ahead of the University of Melbourne, did not formally establish a School of Engineering until 1884, when W. Warren was accorded the title of Professor of Engineering. In the period until the end of the Second World War, four more universities were created and accredited – Adelaide 1874, Tasmania 1890, Queensland 1909, and Western Australia 1911.

As of 2015, Australia had 43 accredited universities, of which 11 are listed as having Schools of Engineering, although most of the universities offer numerous course in various disciplines of engineering. Of the 11 Schools of Engineering, five are among the 100 highest ranked in the 2014-2015 Times Higher Education World Universities Subject Rankings – Engineering and Technology [4]:

University	Score	Rank
University of Melbourne	62.8	37
University of Queensland	62.7	39
University of Sydney	60.4	46
Monash University	60.2	48
University of New South Wales	54.2	63
University of South Australia	51.5	69

An important trend in the development of engineering education in Australia has been the conversion and/or absorption of some of the early technical institutions into universities, as exemplified by the present-day University of Technology, Sydney. It originated from the Sydney Mechanics' School of Arts (the oldest continuously running Mechanics' Institute in Australia), which was established in 1833. In the 1870s, the SMSA formed the Workingman's College which was later taken over by the NSW government to form, in 1882, the Sydney Technical College. In 1969, part of the Sydney Technical College (the part that had not already provided the seedling for what is now the University of New South Wales) became the New South Wales Institute of Technology (NSWIT). It was reconstituted as the University of Technology, Sydney (UTS), in 1988.

Education of technicians was generally provided by technical institutions, now called institutions of Technical and Further Education (TAFE), but as a result of the development described above, there is a degree of overlap between TAFE and universities. As a result of this, but also partly as a result of ideological pressure, there has been a "blurring" of the border between technician and engineer, as discussed below.

The earliest engineering society in Australia was the Engineering Association of New South Wales, founded in Sydney in 1870 with initially 56 members. predominantly mechanical engineers [5]. Its membership increased steadily, and from 1887 it published a journal, the Minutes of Proceedings. In 1906 the Association received a grant from the estate of P.N. Russell that was used to establish and maintain a library.

The Australasian Society for the Advancement of Science was formed in Sydney in 1888, to a large extent through the efforts of Prof. A. Liversidge [3], and it had an architectural and engineering section. However, although the society has been operating until the present, it has never had many engineers involved in its activities. Another peripheral (to engineering) organisation was the Royal Society of New South Wales, started as the Philosophical Society of Australasia in 1821 and in 1866, Queen Victoria granted Royal Assent to the Society and it was renamed as *The Royal Society of New South Wales*. The Society was incorporated by an Act of the New South Wales Parliament in 1881 [6]. In 1891 the Society formed an engineering section that was active for a number of years, and a number of engineering papers were published in the *Journal and Proceedings of the Royal Society of New South Wales*.

In Victoria, the Victorian Institute of Engineers was formed in 1889, again mainly by mechanical engineers. However, the Philosophical Institute of Victoria, which was formed in 1854, and the Royal Society of Victoria in 1859, published a number of significant engineering papers in its journal during its early years.

A development somewhat analogous to the establishment of the alumnus associations of the *grandes écoles* in France was the formation of University engineering societies, at Sydney University in 1895 and at Melbourne University in 1899. These societies encompassed all the engineering disciplines, and their alumni provide a significant support for the universities as well as fulfilling a social role for the alumni themselves.

The first national engineering organisation was The Australian Institute of Mining Engineers, formed in 1893, which now operates as the Australasian Institute of Mining and Metallurgy. The omission of "engineers" is due to the formation of the Institution of Engineers, Australia (IEAust) in 1919, amalgamating most of the engineering associations, but not the Institute of Mining Engineers, which wished to emphasize the mining more than the engineering. Consequently, when considering the professional association of engineers in Australia, it is not unreasonable to focus on the IEAust. There is another organisation, Professionals Australia, formerly the Association of Professional Engineers, Scientists and Managers Australia (APESMA), but this is an employee association (trade union) registered under state and federal industrial relations acts. This makes it a trade union for the purposes of worker-employer bargaining; Professionals Australia is affiliated with the Australian Council of Trade Unions (ACTU) [7].

The IEAust was incorporated by Royal Charter in 1938, and is now trading under the name Engineers Australia (EA). However, since the end of the last century, 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 5.5 % Technologists and Associates, so that EA represents only about one quarter of the Professional Engineers in Australia.

It is evident that this classification, and the introduction of the concept of the engineering team already disrupts the relationship between engineer and engineering, as only persons in the first group can be identified as engineers, while at the same time those in the other two groups are identified as somehow related to engineering. Or, in other words, "engineering" has lost its meaning as the process performed by engineers, and, indeed, it has lost any precise meaning at all. But, even worse, identifying the first group as "Professional Engineers" implies that there are other groups of persons that can be identified as engineers, just not "Professional", although these other groups remain undefined. The current situation is therefore that there is no accepted and operable definition of either engineer or engineering, and so the foundation on which an image and understanding of these two concepts could be presented to society is simply missing, a deplorable situation when considering the definitions in Section 2. Furthermore, to add to the confusion, and perhaps partly in response to the litigious nature of Anglo-Saxon societies, EA has introduced the notion of Chartered Status for each of the three groups. Chartered status requires demonstration of Continuing Professional Development (CPD), but is otherwise mainly a money-making scheme for EA, as is true of the various Registers of engineering team members maintained by EA.

An important function of EA is the certification of courses within engineering curricula; a function similar to that exercised by ABET in the US. Accreditation is usually carried out on a five-year cycle, and the requirements are those of the International Engineering Alliance, as documented in the Washington Accord, the Sydney Accord and the Dublin Accord. On a more general level, there is a gradual adjustment to and integration with the Bologna Process, with its defined three cycles of Bachelor, Masters, and Doctorates, as well as a recognition of UNESCO's International Standard Classification of Education 8-level scheme, so that Australian engineering education is well established internationally.

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 to engage in the social discourse, which would mean applying engineering skills to social and political problems, but appears not to consider this to be in its remit.

So, with this as background, what can we say about engineers as a group within Australian society? There are two quite distinct aspects to this issue. The first is the impact of engineers on society resulting from their work, and in this regard the verdict would have to be favourable. Look around you, and almost everything you see owes its existence to engineers to a greater or lesser degree, and while much of this is imported, where Australian engineers have been involved, particularly in the civil/structural/mining engineering disciplines, the results are excellent. Through what might be characterised as their "narrowly professional" work, engineers make a very significant contribution to the quality of life in Australia.

The second aspect is the role and impact of engineers on society outside of their "narrowly professional" work. To what extent do they partake in the discussions and actions that determine the development of society, and to what extent are they recognised as significant partners in this?

The latter question is the central one, because it is the lack of visibility that is the first stumbling block on the path to a more effective involvement of engineers in society. This invisibility has several reasons, some of which lie with the engineering profession and some with society, but one that is easily recognisable is the inherited intellectual pecking order. As we saw earlier, at the time of colonisation, a classical education was preferred, and this was easily reflected onto a legal or medical profession and, in time, also onto the sciences. Engineering always had a “bad smell’ of the tradesman and manual labour, and the “scientification” of engineering which took place in the second half of the twentieth century reflected a desire to join the club. (This is also reflected in the name of the academy – Academy of Technological Sciences and Engineering – just Engineering would not sound important enough.) However, the result is that engineering lost its identity, and today the activities of engineering are most often presented as science. Science is fairly well established in the public mind, whereas most people have no idea what engineering entails, and its achievements are rarely reported. In Australia this was exemplified recently with the tabling of two statements on “Science and Innovation” in the House of Representatives [8], where engineering was almost ignored, and which missed the fact that technology is created mainly by engineers, and that innovation, that is, bringing a novel and profitable product to the market, involves only a relatively small scientific effort, and that its success depends much more on the engineers involved than on the scientists.

Besides the invisibility of engineering to the general public, it is difficult to quantify the contribution of engineers to Australian public life. Take, for example, the delegates to the 1891 Constitutional Convention; their backgrounds or professions were as follows:

Lawyers/judges	16
Business people	10
Farmers	6
Engineers	4 (incl. 2 surveyors)
Soldiers	3
Minister	1

Given the state of engineering in the colonies at that time, this proportion seems fair enough. But if we look at the composition of the Federal ministry as of 5 April 2016, we find that out of the 22 ministers, 12 are lawyers, and not one is an engineer.

On the subject of engineers in politics, there is perhaps one development that might help to explain the lack of engagement, and that is the change of politics into a business. It used to be that politics was something one would engage in after a successful career in some profession or business activity, which provided the connection to the people to be represented and a first-hand insight into their issues and concerns. But increasingly, politicians go straight from their education into a political organisation, be it a labour union, as staffers to politicians, or as members of party administrations or the various think-tanks that have sprung up, from which they are then catapulted into the role of politician through some form of a pre-selection process. Politician has become a profession in itself, with politicians members of a new industry sector (not to be confused with public administration). This would generally not be an attractive career path to engineers, and by the time they might want to enter politics, they are not part of the club.

Another reason why engineers have a very weak voice in public affairs is that they do not have their own means of communicating with the public. The academy and EA generally restrict their communications, in the form of submissions and reports, to matters concerned directly with technology and its application, and only rarely get involved in the social implications. Academics have their own university websites and newsletters, including some partially funded by the government, such as The Conversation, and newspapers rarely, if ever, have engineers as regular columnists.

1. *Technology in Australia 1788 – 1988*, Australian Academy of Technological Sciences and Engineering, http://www.austech.unimelb.edu.au/tia/contents.html.
2. Hughes, R, *The Fatal Shore*, Collins Harvill, 1987.
3. The history of Australian Schools of Mining, as seen from the perspective of establishing one at Sydney University, is detailed in the biography of Archibald Liversidge, *Imperial Science Under the Southern Cross*, by Roy MacLeod, The Royal Society of NSW and Sydney University Press, 2009.

4. Australian Education Network, http://www.australianuniversities.com.au/.
5. Much of the information in this section comes from the newsletter of the Australian Society for History of Engineering and Technology (ASHET), vol. 2, no. 4, available at http://www.ashet.org.au/.
6. http://royalsoc.org.au/society.history.htm.
7. https://en.wikipedia.org/wiki/Professionals_Australia.
8. Macfarlane, I. (2015). *Science and Innovation: Building Australia's Industries for the Future*, and B. Shorten, *Response*, Hansard, OzParltHR-17Aug15.docx. Quoted in Aslaksen, E.W, *Technology and the Practice of Engineering*, Chapter 17 in *The Engineering-Business Nexus*, S.H. Christensen et al (eds.), Springer, (in Press).

6 Social Aspects of Engineering

6.1 The Project Team

In the twentieth and early twenty-first centuries many of the leading figures in engineering were known by name, such as Eiffel, Siemens, Diesel, Edison, Bell, Marconi, and Ford, and the products associated with them were, to a significant extent, the results of their individual, personal efforts. Today, it is unusual for an engineers to have that sort of dominant role, and the public would have no idea of who had been involved in creating such highly visible products as a 747 aircraft or a Mercedes car. In subsection 2.3 we said that engineering is structured into projects. However, of the people involved in executing a project, engineers usually only account for a small proportion. Furthermore, the roles of the various professions and trades, as well as their importance and relationships to each other depend on the industry sector. If we, at a high level of characterisation, consider industry to consist of two parts – the manufacturing industry and the construction industry – then the major difference as far as the engineering team is concerned is that in the manufacturing industry the project participants remain relatively intact over numerous projects, and their relationships, as well as the processes involved in executing the projects, are fixed and well documented. Whereas in the construction industry, the project participants change from one project to the next, and the project organisation, even though it may have many general features, is essentially created to cater for the specific requirements of each project.

Leaving this difference aside, at least for now, then within any typical project organisation, engineers are required to interact with a number of other members, including, besides other engineering disciplines, technologists, drafters, project support and management staff, owner's representative, and the debt provider's representative. Some of these interactions are part of performing the engineering tasks, and they are shown as heavy lines in Fig. 6.1, whereas others are related to the many non-technical actions an engineer needs to undertake in order to integrate the engineering into the overall project.

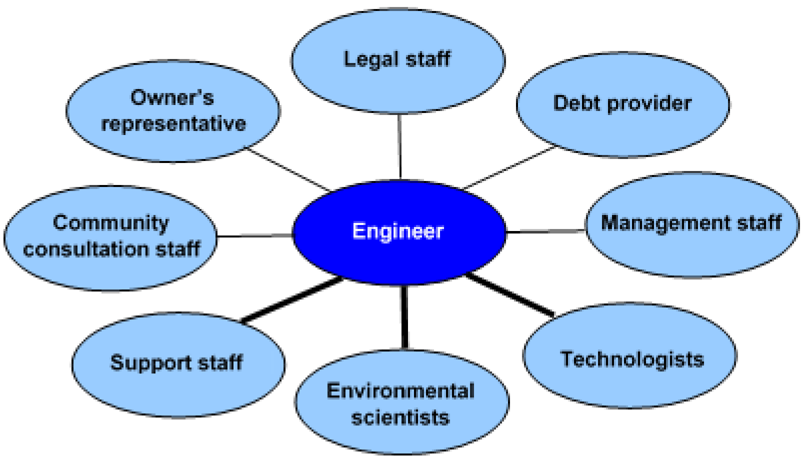

Figure 6.1 The interactions between engineers and other members of the project organisation. Interactions related to technical activities are shown as heavy lines.

The project team constitutes a mini-society, and in most cases this society has a well-established formal structure, consisting of such functional elements as project management, design, construction, test and evaluation, and maintenance. These may be subdivided as appropriate for the size and complexity of the project, and arranged in a hierarchical, network, or matrix structure, or possibly a combination of these, all with defined interactions. As far as the engineering element is concerned, i.e. the central element in Fig. 6.1, it is often subdivided into the relevant disciplines, plus an engineering management function, and the interactions are regulated by a number of formal processes, such as interdisciplinary design reviews and change control procedures.

However, many of the activities engineers have to engage in as members of this society are social rather than technical activities. In most project organisations there remains considerable scope for negotiation and compromise regarding the details of different roles, and individual personalities and modes of operation need to be recognised and negotiated in a manner that results in the best overall project outcome. Furthermore, as in most societies, the interactions among the members lead to a structuring of the team into groups whose members have characteristics in common. The most obvious of these is the professional background, so that, for example, members of engineering disciplines, or members with a management/business background, tend to form social groups, but there are many other characteristics that lead to social structuring across professional boundaries, ranging from religion, race, and language to sport. All of these can have a significant effect on team effectiveness – both positive and negative. Positive, in that these informal interactions can lead to valuable cross-fertilisation of ideas and insights; negative, in that they can block the formal flow of information.

A result of the continuous transformation of technology, as well as the current exponential increase in volume, is that, in the sense of understanding, maintaining, and being competent in using, various actors relate to different parts of technology, as illustrated in Fig. 6.2. The *technical workforce* includes technologists, technicians, drafters, and trades persons; all persons that require access to the combined knowledge and resource bases, that is, technology. This structuring is defined formally, and to a large extent also in practice, by education and training, but experience and individual interest and aptitude can result in a significant blurring of the boundaries. Engineers are the practitioners of the professional process of engineering, and the engineering disciplines, such as civil, chemical, electrical, and mechanical engineering, are distinguished by the subdivision of the resource and knowledge bases reflected in their education.

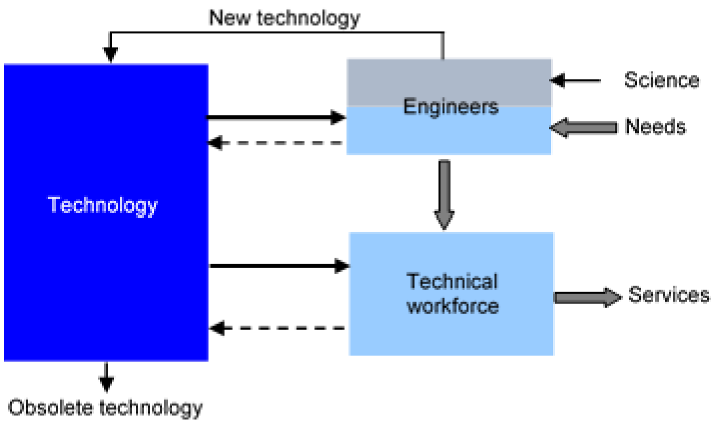

Figure 6.2 The interaction with technology by engineers and the technical workforce. The dotted arrows indicate that all engineering projects provide some input to technology in the form of experience, and the subdivision of the engineers illustrates the two types of engineering projects (see below).

A notable aspect of Fig. 6.2 is that it indicates the dynamics inherent in the relationship between engineering and the technical workforce, as well as within these two components of the project team. This dynamic is driven in part by the continuous development of new technology, but to a large extent from the relentless striving of engineers for more cost-effective solutions to society's needs. The application of this new technology initially requires the involvement of engineers, but once successful application has been demonstrated and documented, eventually even embodied in standards, the further application can be handled by the technical workforce. In this manner there is a continuous downward flow of knowledge and experience in Fig. 6.2, which is accomplished in part by the transmission of knowledge between members of the two components of the project team, and in part by the downward movement of people. The latter can be observed as experienced engineers focus more on applying their experience than on developing new technology.

In the previous Section we saw how engineering is always embedded in a project. In the context of a specific project, industry encompasses everything directly involved in executing and completing that project. The inclusion of the word "directly" is important, and for now an intuitive understanding is hopefully adequate. For example, the machine tool operator that goes to work every day on the project is directly involved, whereas his wife, who stays at home and manages the family life is only indirectly involved. The debt provider (e.g. bank) is directly involved, whereas the people who put their savings into the bank are only indirectly involved.

The meaning of "industry" in a general sense, without reference to any particular project, is then simply everything directly involved in executing and completing projects. This industry has an internal structure; it consists of legal entities called *enterprises*, and examples of such enterprises are private companies, public companies, sole traders, incorporated joint ventures, and government bodies or corporations. Projects are carried out within a legal framework created by the enterprises directly involved in the projects and the interfaces between them, which take the form of *contracts*. The nature of this framework varies significantly, from the case where multiple projects are performed completely within a single enterprise to the case where a single project is performed through the involvement of numerous enterprises in a framework containing several types of contracts, such as alliance contracts, lump sum contracts, and cost-plus contracts. This framework defines not only who does what, how, and when, but also who carries the liability for the various possible deviations from the agreed project performance.

Within this framework, each engineer is *employed* by an enterprise. This is also a contractual relationship, defining rights and obligations of both parties. Besides requirements for ethical behaviour, a central requirement is for the engineers (as for any employee) to support the aims of the enterprise, and irrespective of other aims, the aim of any enterprise must be to make a profit, without which it will generally not survive. Thus, the individual engineers on a project find themselves enmeshed in a set of relationships and requirements that may be complex and, in many cases, somewhat contradictory. This is illustrated in Fig. 6.3, and we need to keep this picture in mind. In articles and presentations considering the interaction between engineers and society, one can sometimes find that this discussion proceeds as if it were a direct interaction, as e.g. in the case of doctors and patients. As we shall see, that is the exception; the majority of that interaction, and thereby the engineer's ability to provide value to society, takes place within the industrial environment outlined above.

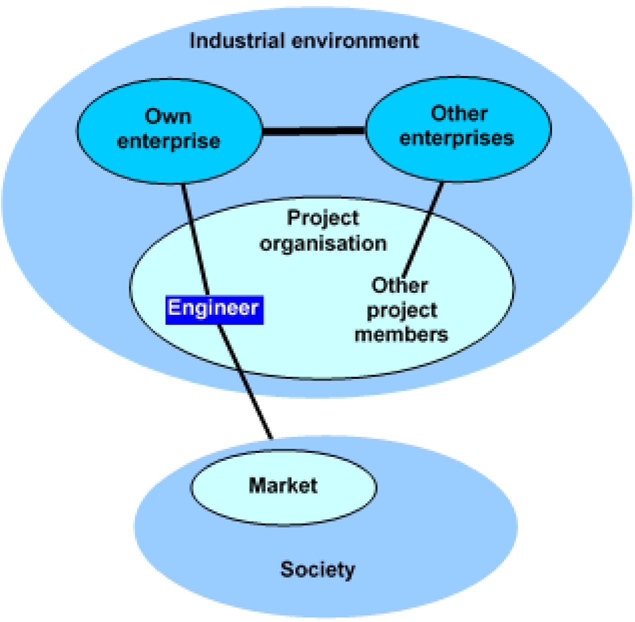

Figure 6.3 The industrial environment, in which the individual engineer is enmeshed in a complex set of requirements arising from the contractual relationships between all the participants,

6.2 Interaction with Society

In Section 3 we reviewed some of the literature on the relationship between society and applications of technology, and it is clear from this that, as the main creators of technology, engineers must have a strong interaction with society. To develop an understanding of this complex, and, as we saw in subsection 4.2, largely indirect relationship between engineers and society, there are a couple of approaches. One is to continue, or extend, the exploration of the relationship between society and applications of technology, but less from the philosophical and sociological perspectives than with an explicit emphasis on the role of engineering, and we shall pursue that later in this section. Another approach, and one that might be more natural for engineers to adopt, is to look at the *content* or type of the interaction between engineers and society, and it is useful to adopt a high-level framework, based on the definition of engineering provided in subsection 2.3, and illustrated in Fig. 6.4.

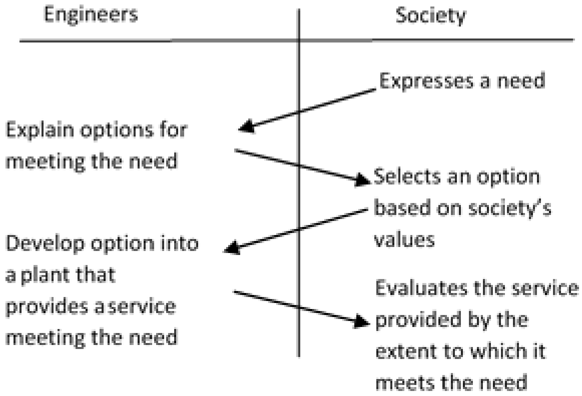

Figure 6.4 Two levels of the interaction between engineers and society, based on the content of the interaction.

There are a number of points to note about the process depicted in Fig. 6.4:

a. The term "society" means all of or any group within society, such as a particular segment or market, an industry, a company, a government body, etc.
b. The term "service" must be understood in a wide sense. It is whatever is required to satisfy the need; it may be a service in the narrower sense, such as education, health, or transport services, it may be providing infrastructure services, such as electricity, gas, water, and waste water services, or it may be providing products, such as food, clothing, houses, cars, toys, etc.
c. The term "plant" means the physical object that provides the service. It usually consists of a combination of equipment, structures, and organisations, in widely varying proportions, and includes all activities required to provide the service, such as design, manufacturing, operations, maintenance, sales, etc.

What this simple picture suggests is that the interaction between engineering and society may be thought of as taking place on two levels, or as being of two kinds, although in any particular project it may be difficult to completely separate the two. At the upper level, engineers provide advice and information to society, and the value of this activity is measured by the extent to which it supports society in making decisions about the best options. Of course, in making such decisions, a great deal more than engineering advice and information is often required, but the engineering component would be dominant, and so it is the responsibility and duty of the engineers to ensure that the advice and information is complete, accurate, and unbiased. The use of the expression "advice and information" is important, because while information is factual and can be verified, advice is based on experience and involves the engineers' judgement, and it is in providing (or withholding) advice that ethical issues arise.

At the lower level, the activity of the engineers is to ensure that the selected option provides its specified service at the lowest overall cost, where "overall cost" includes not only acquisition, operating, and maintenance costs, but also cost of environmental impact, of accidents, of blocking future options, etc, and so this provides a more clearly defined measure of value. While still involving experience, this activity is much less dependent on judgement, as it is heavily circumscribed by standards, legislative requirements, and, generally, by technology.

The two-level picture presented above, while useful in developing an understanding of the value of engineering, does not account for what is the most important aspect of the interaction of engineers with society: the *interaction channel*. In the great majority of projects, engineers do not interact directly with society, but through the intermediary of industry, and this indirect mode of interaction is one of the main differences between engineering and two other professions; medicine and law (refer also to subsection 4.2). This difference has been pointed out by various authors [1] and is alluded to in an essay by Mitcham [2], to which we shall return below. Again, a simplified picture is useful, and we can consider the interaction channel to be one of three types. In the first type, engineers interact directly with society through involvement in public inquiries, by providing articles in newspapers and magazines, by appearing on TV panels, etc. In the second type, which is quasi-direct, engineers provide advice and information to public institutions and departments, such as defence and various infrastructure (energy, water, transport, etc.), and, perhaps most importantly, through education. In the third and most common type, engineers work within the industry structure required to realise a project; a framework that involves many other people besides engineers, including politicians, business men, lawyers, financiers, marketing and sales personnel, technicians, tradesmen, and labourers, so that what society experiences is often influenced only to a limited extent and in an indirect manner by engineers. And, what is equally important: society has little insight into and understanding of exactly what this extent and manner are. These three types of interaction channels are illustrated in Fig. 6.5.

Type	Description			
Direct	Engineering	Society		
Semi-direct	Engineering	Public	Society	
Indirect	Engineering	Industry Production – Marketing – Sales – Support		Society

Figure 6.5 Three types of interaction channels between engineers and society.

While the first two channel types are more or less direct, even here the engineers are imbedded in an industry structure. The education industry has its own agenda, as does the consulting industry, and engineers are, just as in the third type of channel, constrained by the agendas of their employers. It is the employment situation that is a main difference between engineering and the two other professions (although the independence of doctors and lawyers is being eroded, too), as discussed briefly in [3]. 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".

Through the two first channels, engineers can be seen to provide engineering input to public policy and advice to policy makers. This role is discussed in a recent paper by Mitcham [4], in which he refers to a book by R. Pielke Jr [5]. That book is concerned with science policy, but it distinguishes four basic roles of an adviser that would seem to be equally applicable to any profession and, in particular, to engineering. These roles are: pure knowledge exponent, advocate, arbiter, and honest broker, and an important measure of these roles is the level of professional knowledge involved in the interaction. It is highest in the case of the pure knowledge exponent – so high, in fact, that the interaction is probably close to useless. It is also quite high in the case of the honest broker, as society will be required to have an in-depth understanding of the implications of the options put forward. The arbiter essentially performs requirements elicitation in order to bring society's understanding of the issues involved to a point where society can make its own decision, employing and (hopefully) imparting a modicum of professional knowledge along what can be a lengthy process. The least use of professional knowledge in the interaction is in the case of the advocate, but it is also the case most susceptible to industry interference, making the engineer a salesperson for particular industry interests.

The problem today is that, even in cases where there is no conflict with being part of industry and where engineers would like to provide society with a better understanding, there is no effective means of doing so. The information channels have been withering away over the last hundred years or so, during which the role of engineers changed from the shining knights spearheading society's way into a glorious future to invisible intellectual labourers, following in the path of the workers of the industrial revolution, anonymously providing the fuel for industry's relentless drive to transform society into a consumer society, with Growth as the Holy Grail and with marketing and advertising as its handmaidens. As a result, and despite such highly visible successes as the moon landing, the Internet, and the mobile phone, engineering as a profession, and engineers as individuals, have lost their position of trust, authority, and acceptance within society, and with it, the channels of communications. For example, the major daily newspapers have columnists and occasional contributors from numerous different professions, but rarely from engineering.

At this point we need to make a slight detour and note that the problem of the low effectiveness of the communications channels is not only due to the position of engineers in society; there is a part to this problem that is not limited to engineering, but experienced also by all branches of science. This is what we discussed in Chapter 3 as the impact of ICT on society, and the fact that information is becoming a commodity with no other value than its market price and it ability to generate a return on investment. We introduced the work of Schiller [6,7], who also said that we are becoming "media rich, but information poor", and that meaningful and useful information is being swamped by trivial, chopped-up newsflashes and advertising. (Refer also to the work of Garnham introduced in Chapter 3.) The result of this is that while there are more communications channels than ever, they are increasingly ineffective as a means of communication between engineering and society.

The diminishing role of engineers in society has been recognised and discussed for decades, an example is the paper delivered by Sutcliffe at the IEAust Engineering Conference in 1986 [8]. He correctly identified most of the symptoms of the problem, but did not identify the employment situation and the role of industry as the main causes, nor did he suggest what practical measures could be taken to improve the situation. An interesting aspect of this paper is the implied view of engineering as elevated above business, and that the requirements of engineering excellence should take precedence over such mundane issues as cost and schedule. This is exactly the view that has done much to diminish society's regard for engineering, and while it is not a view accepted by the engineering community in general, it can still be perceived in both the education and published work of engineers.

An important aspect of the relationship between engineers and society is *alienation*; a concept attributed to Hegel, but developed in much more detail by Karl Marx, as described and analysed by Wendling [9]. Marx was concerned about the alienation of workers (or the proletariat), but the analysis provided by Wendling is highly relevant to the present work; we just have to specialise workers to engineers and capitalism to industry. Basically, alienation means that humans lose (or are alienated from) part of their essence as humans by the conditions in which they find themselves, and for Marx, this alienation had five overlapping dimensions: theological, political, psychological, economic, and technological. For each dimension, there is a corresponding metaphysical object into which the human essence is alienated: God, the state, ruling class ideology, the commodity, and the industrial machine.

In the case of engineering, engineers are being alienated from the essence of engineering, which most definitions of engineering manage to capture in a more or less satisfactory manner as the development and application of technology for the benefit of mankind, by being embedded in the metaphysical object of industry. Industry has its own ideology and norms, described by such concepts as profit, value, turnover, growth, return on investment, efficiency, loyalty, etc, 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.

The result of the poor state of the relationship between engineers and society is that society is not receiving the greatest possible benefit from the engineering profession, but before we go on to consider what should change that, we should ask: Does society really care? Is the current situation a matter of ignorance or is it simply a matter of "can't be bothered"? Observing how the democratic political process is lurching along under the influence of small special-interest groups due to a lack of interest on the part of the majority of citizens, is it reasonable to expect society to engage in a dialog with engineers regarding what are, in most cases, relatively complex technical matters? The answer is that of course it is not to be expected, nor feasible, for society at large to engage with engineers on a professional level; the engagement has to be based on *trust*. And this is perhaps the core of the whole issue of providing value: We have arrived at a point where engineers are not seen as trustworthy when it comes to considering society's best interests. A reason often given for this is that in any particular case, we find engineers supporting opposing solutions. In the case of renewable energy, some are for nuclear, some are against, some are for solar panels, others are against, and so on. But should that necessarily be a problem? If we compare with the legal profession, in any case before the court, the prosecution's team of lawyers will argue that the defendant is at fault, the defence team will argue that the defendant is blameless; that is what they are employed for, and nobody thinks that we should distrust lawyers for that reason. Correspondingly, engineers put forward the views of a case that suit their industry employers.

The big difference is that in the legal case there is then a judge (or a panel of judges) that decides, and society accepts that decision (possibly subject to an appeals process) and, by implication, acknowledges the trustworthiness of the judicial system. In the engineering case, there is no corresponding person or body, and it is left to a body, usually comprised of politicians, executives representing their industries, engineering academics with no practical experience, business people, and lawyers, hand-picked by whoever is in charge, to make decisions on matters that require a detailed understanding of, and experience with, the process of engineering. None of these participants have an interest in transferring the decision-making to an impartial and suitably qualified body, and so it remains for society to re-establish their trust in engineers by demanding it.

Thus, there needs to be a change in that society must want to avail itself of the support and active participation of engineers in addressing its problems, and this will only occur if society is willing to accept the advice provided, and that acceptance can only be based on trust. It is paradoxical that, at a time when engineering has a greater influence on the development of society than ever before, engineering has become almost invisible to society.

This raises a further question: Why would society want to change the current situation and engage with engineers? In the developed part of the world, life is good, and getting better, is it not? Depending on one's definition of "better", yes, but there is a growing realisation that the current model of "western" society, with its three characteristics of growth, waste, and inequality, is unsustainable, and that in the changes that will be necessary in order to avoid a cataclysmic convulsion, engineers will have to play a significant role. Many of the issues involved in these changes, such as energy generation, storage, and use, the life cycle of the artificial (as used by Simon [10]) and the balance between acquisition and maintenance, and an understanding of technology growth and maturity, are complex, and their assessment requires the education and experience that only engineers can provide. But while there is a growing realisation and even an in-principle acceptance of this, there is the problem that many of these issues have timescales of tens of years, and so in practice the most appropriate solutions are ignored in favour of short-term fixes, a situation not helped by a political environment with election cycles of just a few years. This again highlights an issue in the relationship between engineers and society: the role of industry. Industry is producing all the items that enable a society where its members can explore their intellectual potential and pursue a fulfilling life, but it also has an inbuilt momentum that requires it to keep producing and generate a return on investment, constantly seeking out new opportunities and promoting anything that can make a profit, irrespective of any overall benefits to society or long-term effects (as long as they are within the law). That is the nature of industry; it is up to the members of society, as consumers, to become more discerning. Just as democracy only works well in a society where its members are well informed and have the educational background to assess the information, the capitalist free market system only works well where the consumers make the effort to discriminate between well-founded advice and product promotion.

The issue of engineering's relationship to society is discussed by Mitcham [2] under a different and somewhat narrower perspective: Is the education of engineers adequate for them to fulfil their obligations with regard to public safety, health, and welfare? He concludes that it is not, stating "a philosophical analysis of engineering reveals a substantive inadequacy, not to say incoherence or contradiction, in the profession: a commitment to public safety, health, and welfare that is incapable of enactment". He then goes on to illustrate this by a comparison with medicine and law: "The first-order ends of health and justice operative in the professions of medicine and law, respectively, are not enclosed within some second-order end of public good; they are the public good. In engineering, by contrast, the first-order technical end, however defined, which was once assumed to be itself a public good, is now conceived as subordinate to a second-order end that is not operative in the profession itself." This analysis pinpoints the problem, but then relates it to an inadequacy of the engineering education, which, in our opinion, is a "second-order" source of the problem. Firstly, one has to ask: Why is "the technical end" no longer considered a public good? Surely, more than ever, it is technology that is underpinning our daily life? Secondly, the assertion that the commitment to public safety, health, and well-being is not "operative in the profession itself" needs some careful qualification. There are certainly many examples of this commitment; one of the most outstanding one is provided by a great engineer, Gustave Eiffel, who constructed the Eiffel Tower in the 1880s without a single fatality and with concern for the safety of the public using the tower [11]. It is important not to sheet home to "the profession" what is really a feature of industry. And, thirdly, while the analysis correctly assesses the issues relating to engineering education as it applies to public safety, health, and well-being, this needs to be put into the context of engineering education in general and its appropriateness for addressing all the issues relating to the application of technology in our society.

A well-known example of the interaction between engineers and society, and of how this interaction is modified by industry as an intermediary, is the issue of standardisation. Engineers see standardisation as a means of rationalising the industrial design and production processes and lower the cost of products to society; it is also something desired by society for a number of reasons, including ease of replacement, reduced need to learn new operating instructions, and greater ability to maintain and repair products. However, industry often sees standardisation as detrimental to branding, differentiation, market position and, in the end, to their profits. Here is a conflict of interest only too familiar to all of us in the form of the variety of chargers for mobile electronic devices. This conflict was also recognised and detailed by Veblen in his two publications, *The Theory of Business Enterprise* [12] and *The Engineers and the Price System* [13], and has been analysed in an article by Knoedler and Mayhew [14].

Let us now return to the other approach to understanding the interaction between engineering and society that was mentioned at the very beginning of this section – the interaction effected through applications of technology to the processes taking place in society. (This is an extract from [15], where the subject is treated in more detail.) There are a vast number of processes taking place within society, and following our system approach we start, at level 0, by representing this complex collection as a single entity, hiding all the complexity. There are many ways of partitioning this entity, and as the first level we partition the processes into two groups: institution processes and people processes, as illustrated in Fig. 6.6. The first are processes that produce goods and services, as well as remuneration in various forms; the second are processes directly related to people, such as work and consumption. This is not a simple partitioning, as the example of a subsistence level farmer demonstrates, but even here it is possible to think of the farm as the institution which produces products, and the farmer receiving remuneration in the form of produce and also consuming these. Obviously, this very high level model cannot account for anything but a stationary process, where the value of the goods and services must equal the remuneration.

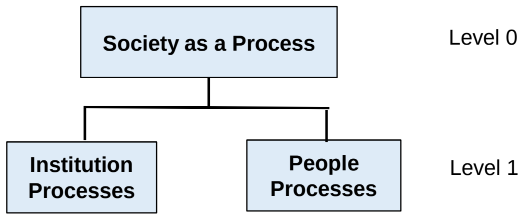

Figure 6.6 The first level of partitioning society as a process, into institution and people processes.

In the next level of partitioning, we can represent each group by two processes, as shown in Fig. 6.7. If we for a moment disregard the group of Capital processes, then the Figure represents the economy in a very early and primitive society, a society in which the raw materials used for production, such as land, timber, minerals, etc. were *free* to be exploited; there was no *ownership* of the resources. The closed loop (b,c) represents a fundamental aspect of any society, starting with a single family. The husband would hunt, and the wife would collect roots and berries, each one providing for the other. If the society expanded to encompass two families, and one was skilled in making stone tools, then the other family had to be skilled in something else, for example, making pottery, and so they could exchange products. This mutual economic dependence is a basic characteristic of any society, and one of the major "binding forces" in our thermodynamic analogy, but it tends to become obscured by the complexity of modern society.

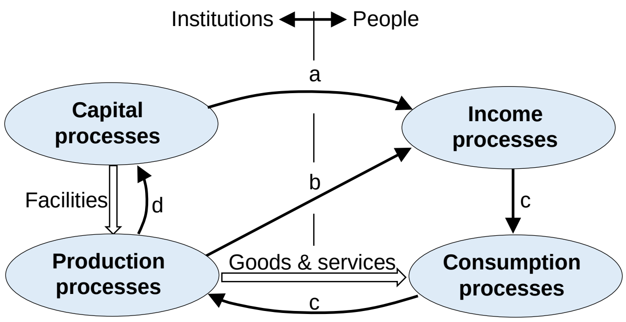

Figure 6.7 The second level breakdown of society into four groups of steady-state processes, two institution processes and two people processes. The four arrows labelled a, b, c, and d, are monetary flows.

The major change in the development of society came with the introduction of *ownership*. This ownership has two very distinct components. One is the ownership of something the owner has created, such as a dwelling or a tool; it is created as part of the Production processes, and is reflected in our model by *d* being greater than $c – b$. The other is the ownership of resources; that is, ownership of something the owner has had no part in creating, and the combined value of these assets is what we call *capital*. This introduces the group of Capital processes in Fig. 6.7; they are the processes that convert capital, C, as the measure of ownership, into production facilities. and allow the owners to extract an income stream, *a*. The production process then uses people to convert the facilities, the payment for which is included in *d*, into goods and services, for which the consumption process returns a revenue stream, *c*. It is very important to recognise that, in this picture, the material input to the production processes (raw materials, construction elements, etc.) play no part; the inputs of one operation are just the outputs of another one. The revenue represents the value *added* by the application of capital and labour. For their role in the production process (which includes maintenance), the people receive an income stream, *b*; this is part of the income process. At any one point in time there is the requirement that $c = a$

+ *b*, which is now the expression of the mutual economic dependence mentioned above, and the only interesting feature of this "steady-state" model is the fraction a/c. In a technically primitive society, this ratio will be very small, as *a* is almost zero, just the value of some simple tools and structures. In a technically advanced society, the ratio will be much greater, as *a* represents the return on a very sophisticated infrastructure and, most importantly, the in-ground value of the raw materials (which in this generalised sense includes land), which in this society are no longer freely available, but tied to owners. In the limit, one could conceive of a society where the production process is fully automated and labour has been eliminated and replaced by robots, and ownership is the only parameter defining the individual lifestyle (via the consumption process). A capitalist utopia, but a human nightmare. Society is turned into a giant game of Monopoly!

What we can discern already at this high level of description is the significant influence technology has on the development of society. The obvious influences are labour-saving devices, increased mobility through mechanised transport, etc, but there are two less obvious ones. One is the fact that technology is the driver of capitalism and its requirement for increasing consumption, the other is a more subtle, or at least more difficult to describe and quantify, manner in which technology influences our world view and the relationships that define the structure of society. One such influence is on our attitude to Nature. Instead of valuing Nature as the environment in which our existence unfolds, the power of technology leads us to view it as something to be exploited, as a commodity. This was perhaps first expressed explicitly by Heidegger [16] in his work *The Question Concerning Technology*, but has since been addressed from various points of view by many authors, including Ellul [17] and Habermas [18]. In short, technology is entering into the definition of what it is to be human, and we are evolving into a biotechnological species.

1. Aslaksen, E.W. 2013. *The System Concept and Its Application to Engineering*, Springer, 2012, sec. B2.1, which refers to works by S.C. Floorman and by P. Galloway.
2. Mitcham, C, *A Philosophical Inadequacy of Engineering*, The Monist, vol. 92, no. 3, 2009, pp. 339–356.
3. Aslaksen, E.W. 2012. *An Engineer's Approach to the Philosophy of Engineering*, Abstracts of fPET-2012, the Forum on Philosophy, Engineering and Technology conference, hosted by the University of the Chinese Academy of Sciences in Beijing, November 2-4, 2012.
4. Mitcham, C. 2012. *Engineering Policy: Its Scope and Limits*, Forum on Philosophy, Engineering and Technology 2012 (fPET-2012), University of the Chinese Academy of Science, Beijing, 2-4 November.
5. Pielke, R. Jr, *The Honest Broker: Making Sense of Science in Policy and Politics*, Cambridge University Press, 2007.
6. Schiller, H.I, *Who Knows: Information in the Age of Fortune 500*, Ablex, 1981.
7. Schiller, H.I, *The Packaged Consciousness*, Cyrano's Journal Online, 1982, available at http://www.cjournal.info/packaged.html (last accessed on 04.01.2015).
8. Sutcliffe, G, 1986, *Engineers in Society – Will Anyone Read This Paper?* IEAust Engineering Conference, Adelaide.
9. Wendling, A.E, *Karl Marx on Technology and Alienation*, Palgrave Macmillan (2009).
10. Simon, H.A, 1996, *The Sciences of the Artificial*, 3rd ed, MIT Press.
11. Harvie, D.I, 2004, *Eiffel – The Genius Who Reinvented Himself*, Sutton Publishing.
12. Veblen, T, *The Captains of Industry and the Engineers*, p.61, in *The Engineers and the Price System*, B.W. Huebsch, Inc. New York (1921).
13. Veblen, T, *The Theory of Business Enterprise*, Transaction Books, 1904, available from Internet Archive.
14. Knoedler, j. and A. Mayhew, *The Engineers and Standardization*, Business and Economic History, vol. 23, no. 1, 1994.
15. Aslaksen, E.W, *A Story About Us: Evolution and the Individual*, Gumbooya Pty Ltd, 2015, available online at www.gumbooya.com.
16. Heidegger, M, The Question Concerning Technology, 1977, available online at http://simondon.ocular-witness.com/wp-content/uploads/2008/05/question_concerning_technology.pdf.
17. Ellul, J, *The Technological System*, The Continuum Publishing Corp, 1980.
18. Habermas, J, *The Future of Human Nature*, H. Beister and W. Rehg (transl.), Polity Press, 2003.

-, 2015, *The Relationship Between Engineers and Society: is it currently fulfilling its potential?*, Journal and Proceedings of the Royal Society of New South Wales, vol. 148, nos. 455 & 456, pp. 28-43.

6.3 Social Responsibility

Whenever we engage in a social activity – an activity that involves an interaction with other members of society – we need to be conscious of the fact that such an activity has consequences through its influences on those members, and that it therefore places an obligation on us to ensure that those consequences are "good". That is, an action is *ethical* if its consequences are "good"; this is the central idea of *consequentialism*, which J.S. Mills thought was "the doctrine of rational persons of all schools" [1]. But how do we define "good" consequences? And, even more problematic, how do we determine what the consequences of any given action will be? Not only do consequences lie in the future, which endows them with an inherent uncertainty, but they depend on numerous factors, such as the background and current situation of the members with whom we interact, the dynamics of the social structure in which they are embedded, and so on. In order to approach this highly complex collection of interconnected issues, we shall proceed from the understanding that ethics is something that was discovered and developed by humans. I discussed this briefly in an earlier monograph [2], where it was identified as being part of *secular humanism*, and have taken it up again in a current monograph [3], where it is related to the concept of *identity*. The same approach is treated in much more depth and detail by Kitcher [4] who identified it as *pragmatic naturalism*. The two views have much in common, the main difference is that Kitcher sees the development emanating from an altruistic disposition in human nature, whereas I see it as a consequence of the will to survive.

The earliest societies had a very simple structure and a very low rate of evolution, so that the consequences of actions were reasonably predictable. The simplest and most direct way to regulate social behaviour was therefore to formulate rules for actions, generally in the form of prohibited actions, as in the Ten Commandments, but also as positive commandments, such as the golden rule of "do unto others as you would have them do onto you". These rules have survived, in various guises, until today, and they form what we might call the 1st order of ethics. It is also a view of ethics as a matter of doing ones duty and following a set of rules, irrespective of the consequences, and goes under the name of *deontology*.

However, as societies became increasingly complex, the consequences of actions were sometimes difficult to predict, and such simple, black-and-white rules were then not adequate or appropriate for making a judgement on whether an action was ethical or not. Not only was ethics expanded to include considerations of consequences and the factors determining them, but a completely new aspect was introduced: uncertainty, and with it the concept of *risk*. If an action would generally lead to a desirable outcome, but could, under certain circumstances, have a very bad outcome, then, how large would the risk, as the product of probability of occurrence and severity of the outcome, have to be before the action was considered unethical? These considerations can be viewed as context-dependent modifications of the simple rules, and form what we might call the 2nd order of ethics.

Now fast forward to the present society – the information society – and we find a further complication. In addition to physical actions, such as stealing, committing adultery, or killing, a rapidly increasing proportion of the interaction between members of society is in the form of information exchange. The ethical question is not (or, certainly not primarily) concerned with the action of exchanging information, but with the content of the information and its consequences. And the consequences now involve an additional stage: First, the recipient of the information evaluates it on the basis of its own knowledge and belief, what in [3] was called its identity, and as a result undertakes one or both of the following activities: modifies its identity, and takes an action (which can be a physical action or a further information exchange). Only as the result of this action is there then a consequence from which one can decide if the original information exchange was ethical or not. The additional considerations regarding how information will be interpreted and actioned form what we might call the 3rd order of ethics.

A complementary perspective on ethics emerges if we realise that, as society evolved, the focus of ethics has shifted from The Good Life to The Good Society. In the city-state of Athens, society had a fixed, highly paternalistic structure, so there was little reason to consider that actions would have any effect on this structure, and ethics was focused almost entirely on the lives of male citizens within that structure. There were many views of what constituted a good life, including a life of luxury and one of heroic deeds, but the best known view is that associated with Socrates, Plato, and Aristotle: a life of contemplation and self-examination, governed by reason – very much an inner life, but also a virtuous life in the interaction with other members of society. This focus on The Good Life in the form of the actions of the individual persisted until a century or two ago; for example, Kant saw The Good Life consisting largely of doing one's duty. But with the increasing complexity of the structure of society and level of interaction between these structural components, and the associated dynamics of society, it has become clear that ethics has to include a social aspect. The shift of the focus of ethics from The Good Life to The Good Society is a reflection of the development of the human species from individuals to members of society, and the "species" is now rapidly being reduced to a single specimen: the global society. It is on its consequences for that society that an action can be deemed to be ethical or not, and so The Good Life has to be replaced by The Good Society as the evaluation criterion.

But what is The Good Society? How can it be defined in terms that make it a useful evaluation criterion? There is a large, and developing, body of work related to these questions, starting, say, with the book *The Good Society* by W. Lipmann [5], then *Marxism and the good society* (Burke, Crocker, and Legters, editors) [6], one by J.K. Galbraith [7], a collection of papers, *Shared Values, Shared Future: Re-imagining the Good Society* [8], and to the recent book by Shiller, *Finance and the Good Society* [9], just to mention a few. A common feature of this body of work is that it is primarily concerned with what the good society should result in and with the symptoms of a society that does not deliver these results; there are very few constructive, realistic suggestions as to what such a good society should be – what its structural components and the interactions between them should be. For example, in the paper *Libertarian capitalism and the new challenges for the left* [8], McKnight states "Libertarian capitalism is a deregulated economy, where the ethic of competition is elevated above all else. It is a society defined by choice, self-interest and a narrowly conceived economic efficiency. Central to this is the belief that the free operation of the market is the key to the good life, which is largely defined in consumerist terms. It is a society in which all other values are sacrificed to the needs of business to make profits. It is a society in which disproportionate power lies with a wealthy elite." That may be so, but what should society look like in order not to have these defects?

Galbraith [7] does recognise the importance of the structure of society, but does not see any realistic alternative to the present structure (of American society), although, in discussing the autonomy and power of the military in the US, he states "we have here perhaps the largest and most evident intrusion on the standards of the good society." Similarly, Shiller [9], who essentially sees a smoothly functioning economy as the main measure of a good society, believes that the current financial structure is about right, it just needs better regulation. Altogether, many of the authors see economic well-being as the most important measure of the good society, a view that dilutes the meaning of The Good Society.

Two different measures can be put forward if we change our understanding of what The Good Society is. As an expression of our understanding of ethics, The Good Society is something that evolves. It is not a fixed version of society, defined by some divine or other authority, towards which we progress; to paraphrase Kitcher [4], it is the current state of The Good Society project. Thus, the important issue becomes the development process; if the process is right and is allowed to operate unhindered, we will have The Good Society at any point in time. Now, this seems only to have shifted the problem from defining The Good Society to defining the development process, but here a simple argument can be brought to bear: The history of humanity over, say, the last 10,000 years, is one of increasingly larger and more complex societies; a development that brought with it numerous problems of how to organise and control the interactions of the members so as to achieve, on the average, a greater fulfilment of the needs and desires of the members. And most of us would agree that this has been achieved; the life of the average human has increased in richness and fulfilment, albeit that this richness is very unevenly distributed and that there have been many setbacks along the way. So, what has been driving this development? What determined the path from the cave to where we are today? Unless we invoke some divine or supernatural power, it can only have been us, and the faculty that determined the path was the individual's ability to understand and evaluate its social environment and take adaptive action, which is the definition of intelligence. The process governing the development of society is the unrestricted exercise of society's collective intelligence, and one measure of the extent to which an action is ethical is the extent to which it promotes (or at least does not frustrate) this. This is a characteristic that can be represented by a quantitative parameter, and a corresponding methodology and simple data model was proposed in [10].

On this basis, we can make the following statement: As intelligence is critically dependent on receiving the full and correct information about the social environment, The Good Society is a society that does not interfere with the flow of information between its constituents. To see what this implies for engineers and for their social responsibility, we return to the importance of technology and its applications in society, as discussed in Section 3. This importance is, of course, reflected onto any consideration of The Good Society, as recognised e.g. by L.R. Graham in the article *Science, Soviet socialism, and the good society*, Chapter 9 in [6]. He uses Solzhenitsyn's play *The Candle in the Wind* to raise the question of the role that science should play in any future "good" Society. "It is a question that has, in recent years, been asked in many places (e.g. [11] and [12]): To what degree should scientific inquiry and technological application be limited in order to protect certain human values? It is becoming increasingly clear in all countries that any person who is interested in the issue of what a future "good society" would look like must ask about the proper roles of science and technology. - If we could be certain that science and technology were merely tools to be used according to unchanging societal values, we might be able to accept the earlier simple formulas."

By its ability to manipulate and control information, information technology provides unprecedented means of influencing the evolution of society. Obvious applications of these means can be observed in the media on a regular basis, but this is only "the tip of the iceberg" of what is possible today, and only a shadow of what will be possible tomorrow. Most of the public discussion about technology and ethics is focused on genetic modification, social effects of automation and robotics, social, health, and safety effects of mobile communications, and the like, while ignoring "the elephant in the room" – information manipulation (accessing, withholding, modifying, etc.). It is the responsibility of the engineers involved in the development of this technology to make society aware of its capabilities and possible applications, and of the dangers involved.

1. Mill, J.S, *Collected Works*, University of Toronto Press, 1970, vol. 10, p111. This reference is quoted in [4], and that work contains relevant details of Mill's work.
2. Aslaksen, E.W, *A Story of Us – Evolution and the Individual*, Gumbooya Pty Ltd, 2015, available online at www.gumbooya.com.
3. -, *Technology and the Stability of Society*, Gumbooya Pty Ltd, 2016, available online at www.gumbooya.com.
4. Kitcher, P, *The Ethical Project*, Harvard University Press, 2011. I feel that this book provides the philosophical complement for the simpler and technology-focused view of ethics presented in my work.
5. Lippmann, W, *The Good Society*, Little, Brown & Co, 1937.
6. *Marxism and the good society*, J. Burke, L. Crocker, and L.H. Legters (eds), Cambridge University Press, 1981.
7. Galbraith, J.K, *The Good Society*, Houghton Mifflin Company, 1996.
8. *Shared Values, Shared Future: Re-imagining the Good Society* – Collected Papers 2007-08, SEARCH Foundation, 2008. A series of Roundtable discussions around Australia.
9. Shiller, R.J, *Finance and the Good Society*, Princeton University Press, 2012.
10. Aslaksen, E.W, *A Measure of The Good Society*, Gumbooya Pty Ltd, 2015.
11. *Limits of Scientific Inquiry*, Daedalus, J. Am. Academy of Arts and Sciences, S.R. Graubard (ed.), Spring 1978.
12. *Ethics for Science Policy*, report from a Nobel Symposium, T. Segerstedt (ed.), Pergamon Press 1979.

6.4 Engineering as Political Action

This final subsection of the monograph introduces what is probably an unusual view of engineering – engineering as political action – and it is inspired by the work of someone who knew nothing about engineering – Hannah Arendt. As we have seen, through its subjugation to the demands of industry in its accelerating development and application of technology, the profession has lost much of its influence and contribution to society, and it is these lost values that Arendt's work places in a philosophical framework that provides a complementary view to that of engineering as an economic activity. In her book, *The Human Condition* [1], Hannah Arendt presented an analysis, and her view, of the situation in which humanity found itself in the middle of the twentieth century. The book consist of six chapters:

I The Human Condition
II The Public and the Private Realm
III Labor
IV Work
V Action
VI The *Vita Activa* and the Modern Age

and this subdivision of the subject matter can, with a certain amount of interpretation, be reflected onto engineering. Each of these chapters contains insights that illuminate corresponding problems and concerns with the current state of engineering, and the following is basically excerpts of these chapters, tailored to the present purpose.

The Human Condition. Under the human condition Arendt understands essentially the environment in which humanity finds itself, and she points out how this environment has two components: One, the conditions under which life has been given to man, the natural environment in which early man found himself. Two, self-made conditions that men constantly create and which, their human origin and their variability notwithstanding, possess the same conditioning power as natural things. It is interesting to note that Arendt recognised the interaction between technology and humans, and that this leads to humans with a socio-technological behaviour, well before this became a subject of significant research, as e.g. in [2,3,4,5]. These more recent works use such concepts of a humans as *hybrids* of "purely" human and technical characteristics, and technical *mediation*, but this is very similar to conditioning.

One aspect of this conditioning is the changed use and value of speech; the use of speech appears as a central characteristic of human behaviour throughout the book, and she states "speech is what makes man a political being". The importance of speech, in the sense of debate or discourse, and its intimate connection with thought, is also discussed in another of her books, *Between Present and Future* [6], where, in the essay *Truth and Politics*, she also cites Kant's remarks that "the external power that deprives man of the freedom to communicate his thoughts deprives him at the same time of the freedom to think", and "we think, as it were, in community with others to whom we communicate our thoughts as they communicate theirs to us".

The Public and Private Realm. Three concepts recur throughout the book. Two are in a sense opposites, *private* and *public*; the third, *politics*, is closely related to the distinction between the first two. All three of these are introduced and explained in terms of life in ancient Greece. There, private life took place within the household, which consisted of the head of the family, his wife and children, and any number of slaves. The household constituted the social organisation, its purpose was to provide for the necessities of life through production and consumption, and the master of the house was its absolute ruler. There was no concept of freedom or associated action within the household; freedom was found in the public realm, the *polis*, in the verbal interaction between equals, not ruled and not ruling. The purpose of the public activity was to develop and expose the "good life", and as far as the members of the polis were concerned, household life existed for the sake of the public life, which was politics, and consisted of speech and action.

Now, Arendt realised, of course, that the organisation of the Athenian city state could not survive, and would not be suitable as societies developed in size and also in the application of technology, although the latter point does not appear very explicitly in the two referenced books. But she uses ancient Greece to illustrate that in making the transition to the modern age, we have lost the understanding that the purpose of mastering the necessities of life in the private realm should be to support a higher activity in the public realm. Instead, there is no longer a clear division between household (private) and politics (public), we have extended the social life and the private realm to the whole of the nation, and it has become a giant household. As in the household of old, there is no longer any freedom and no scope for action, only innumerable and various rules, all of which tend to "normalise" its members, to make them behave, and to exclude spontaneous action and outstanding achievement. The truly political has almost disappeared, politics has become a business, and being a politician is just another job. And modern equality (based on conformism) is very different from the Greek ideal; behaviour has replaced action.

Modern economics is a science because society's members behave according to fixed rules, like natural laws. This supports the rise of statistics and the importance of the mean; outliers are rare. This statistical uniformity is by no means a harmless scientific ideal; it is the no longer secret political ideal of a society which, entirely submerged in the routine of everyday living, is at peace with the scientific outlook inherent in its very existence. Arendt sees society as reducing man to an animal; its purpose is to meet the demands of life, and we have all become labourers. Which leads directly into the subject matter of her next chapter.

Labour. In this, as well as the next two chapters, Arendt frequently refers to Karl Marx, who she sees as the culmination of a line of thought, started perhaps by Locke and progressed via Adam Smith, that held labour to be the supreme world-building capacity of man, and she quotes Marx as "Labour is the eternal natural necessity to effect the metabolism between man and nature". Marx thought that the ability to labour, i.e. to transform nature for our sustenance, was the defining characteristic of man, not thought or speech, and he saw the end-state as one in which labour had become almost unnecessary and all the free time would be spent on "hobbies" in what are, effectively, isolated private realms. Arendt realises the fallacy of this prognosis, and that instead of labour becoming superfluous, we have all become labourers, and she advocates for a return to participation in the (truly) public domain in order to overcome the present state of affairs. This state of affairs is one in which all products have become necessities of life, and whatever we do, we are supposed to do for the sake of "making a living"; such is the verdict of society, and the number of people, especially in the professions who might challenge it, has decreased rapidly.

An interesting view on this, and one that recognises the role of *leisure* in the required balance between production and consumption, is contained in an article by de Gournay [7], where he discusses the concept of leisure; it only exists as "negative work". Where there is no organised work, there is no leisure, as exemplified by the classical housewife. The time outside work is used for organising the work (making connections, attending seminars, exhibitions, etc.), further education, and community life (volunteer work). Leisure has only assumed its full importance and significance in societies where work has been set up as the sole dominant value, to the exclusion of all others, whether religious, family, or community. In non-industrialised societies, leisure, with its own budget for consumption, does not exist. This does not mean that people work more, but quite simply that besides work, and in place of leisure, there are other social activities which are as important as work, namely religious rites, festivities tied to local customs, and symbolic exchanges. This is why all Western political theories, which aim to abolish work – after having set up work and productive capacity as the basic valued of humanity – err through lack of imagination (and Marxism does not escape this criticism), in that they are unable to envisage any substitute for work other than its negative – leisure.

The problem has become how to attune individual consumption to an unlimited accumulation of wealth, and since mankind as a whole is still very far from having reached the limit of abundance, the mode in which society may overcome this natural limitation on its own productivity can be seen on a national scale. The solution consists in treating all use objects as though they were consumer goods, so that a chair or a table is now consumed as rapidly as a dress, and a dress is used up almost as quickly as food. This mode of intercourse with the world, moreover, is perfectly adequate to the way they are produced. The industrial revolution has replaced all workmanship with labour, and the result has been that the things of the modern world have become labour products to be consumed, instead of products which are to be used.

In this chapter Arendt introduces the term "division of labor", and it is important to realise that she does not mean the division according to the nature of the work or the skills required or any other criterion; she means the division of the labour into identical pieces, so that workers can be assigned as required by the amount of work, much as one would turn a tap on or off according to the flow of water required. It is in this sense that she laments that division of labour, entirely appropriate to the labouring process, has become one of the chief characteristics of modern work processes; that is, of the fabrication and production of use objects. Division of labour rather than (we might now say "in addition to") automation has replaced the rigorous specialisation formerly required for all workmanship. Workmanship is required only for the design and fabrication of models before they go into mass production, which also depends on tools and machinery. But mass production would, in addition, be altogether impossible without the replacement of workmen and specialisation with labourers and the division of labour.
This leads already into the next chapter, but Arendt first reflects this state of affairs onto the previous chapter by saying that the emancipation of labour and the fact that the *animal laborans* was permitted to occupy the public realm has resulted in there being no true public realm, but only private activities displayed in the open.

Work. Work is the activity characteristic of the craftsman, the trained specialist, of *homo faber*. The ideals of that work are permanence, stability, and durability, and the objects produced – the human artefacts, or the world – do not disappear through their proper use; they are not consumed. They give the human artifice the stability and solidity without which it could not be relied upon to house the unstable and mortal creature which is man. Whereas labour is concerned with satisfying consumption, work produces things for the world in which we live. They are things we use, like a chair or a table, but they also include tools and instruments, and because they are not consumed by use, they provide a continuity and an enduring ability, and so represent a value in themselves.

Work is still required, both to produce tools and to develop the models on which mass production is patterned, but even this work has become only a link in the chain of production for consumption, and it is also a diminishing part of the chain. The only "worker" left in a labouring society is, strictly speaking, the artist.

Action. Action is a concept peculiar to Arendt, and not altogether easy to place in our customary vocabulary. It consists of word and deed, because without the accompaniment of speech, at any rate, action would not only lose its revelatory character, but, and by the same token, it would lose its subject, as it were; not acting men but performing robots would achieve what, humanly speaking, would remain incomprehensible. Speech is the means of communication and allows men to cooperate; not as in team-work, but as in creation, a new beginning. The performance is the work. With word and deed we insert ourselves into the human world, and this insertion is like a second birth, in which we confirm and take upon ourselves the naked fact of our original physical appearance. This insertion is not forced upon us by necessity, like labour, and is not prompted by utility, like work. Its impulse springs from the beginning which came into the world when we were born and to which we respond by beginning something new on our own initiative. To get a better understanding of the concept of action, we need to remember that Arendt developed and illustrated it using ancient Greece and the city-state as a template. Action is what took place in the *polis*, and is related to the realm of human affairs, which consist of the web of human relationships that exist wherever men live together. It is a new beginning in these affairs, and its power is what keeps the public realm, the potential space of appearance between acting and speaking men, in existence. Power preserves the public realm and the space of appearance, and as such it is also the lifeblood of the human artifice, which, unless it is the scene of action and speech, of the web of human affairs and relationships and the stories engendered by them, lacks its ultimate *raison d'être*.

A central aspect of action is its revelatory character; the actor has to reveal himself, has to have the courage to stand up amidst his peers. And he has to commit himself, so there is a heroic side to action. The importance of political (i.e. public) commitment has also been noted by other authors, e.g. Luria [8] when he says "The Golden Rule cannot be expected to prevail automatically in the affairs of society. An efficient ethics in society can come into being only when personal choices become political commitments, and individual commitments become collective commitments. The hope for a more just society where the output of science and all understanding is used for purposes collectively agreed upon – a society with true political legitimacy – must first become a political commitment on the part of individuals to make it become so."

The Vita Activa in the Modern Age. The outcome is what is euphemistically called mass culture, and its deep rooted trouble is a universal unhappiness, due on one side to the troubled balance between labouring and consumption and, on the other, to the persistent demands of the *animal laborans* to obtain a happiness which can be achieved only where life's processes of exhaustion and regeneration, of pain and release from pain, strike a perfect balance. The universal demand for happiness and the widespread unhappiness in our society (and these are but two sides of the same coin) are among the most persuasive signs that we have begun to live in a labour society which lacks enough labouring to keep it contented. For only the *animal laborans*, and neither the craftsman nor the man of action, has ever demanded to be "happy" or thought that mortal men could be happy.

In this evaluation of the *vita activa* in the modern age, it needs to be kept in mind that it was published in 1958, and that therefore one of the now very prominent characteristics of the vita active, the influence of ICT, could not have been foreseen by Arendt at that time. It does not invalidate the basic thrust of her arguments nor the structure put forward; indeed, in some respects ICT has intensified the problems she identifies, as described e.g. by Garnham [9,10] and Schiller [11,12] (see also subsection 3.4) But it does mean that she focused on mechanisation and the automation of mechanical equipment and processes, and that therefore the labourers affected were "blue collar" workers, whereas today we are additionally faced with the replacement of "white collar" workers by computers and sophisticated software.

To summarise, then, Arendt structures human activity – the *vita active* – into three "layers": labour, work, and action, as indicated in Fig. 6.x. This figure is meant to indicate that each layer is supported by the one(s) below it: work depends on labour for fulfilling life's demands, and action depends on both labour and work, the latter for providing the world we live in. However, it also indicates a downward flow, in that action provides (or should provide) the framework in which any human activity takes place, and work provides the models and tools for labour.

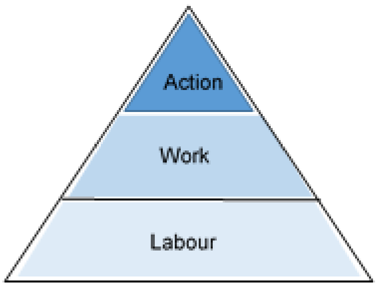

Figure 6.x An illustration of Hannah Arendt's partitioning of the *vita activa*.

Turning now to engineering under the perspective of *Vita Activa*, the process of engineering and *vita activa* are both processes performed by humans, and although the purposes as well as the details of the activities included in these processes are different, the structure of the *vita activa* developed by Arendt, as illustrated in Fig. 6.x, can be reflected onto the process of engineering. For the corresponding structure of the process of engineering we shall use the one developed in subsection 4.1, in which the process is structured according to the capabilities of the persons performing it. The practitioners of the process of engineering identified in that publication are engineers, technologists, drafters, and trades persons; for our current purposes it will be convenient (and not constitute a limitation) to combine drafters and trades persons into one group: technicians.

If the organisational environment, or culture, in which the *vita activa* takes place is the nation, then the corresponding environment for the process of engineering is industry. Industry has its own "culture", in the form of ideology and norms, described by such concepts as profit, value, turnover, growth, return on investment, efficiency, loyalty, and so on, and these norms appear as natural features of society, rather than as something imposed on society. Consequently, it is not surprising that Arendt's description of the *vita activa* as it currently is in our society applies equally to the process of engineering as it currently is in industry and as it was described in subsection 4.1. What is interesting, and perhaps somewhat surprising, is that her three components of the vita activa - labour, work, and action – and their characteristics can be mapped with such a degree of correspondence onto the process of engineering.

Starting at the top, with *action*, this corresponds to activities of the engineer; that is, to *engineering* in its proper sense, as the activities that engineers are meant to do, rather than the activities most engineers are engaged in today. The core of engineering is the creativity that arises out of an understanding of how the properties of nature, as determined by science, can be related to needs that society identifies as a result of its evolution, but this understanding needs to include the wider implications of pursuing a particular course of action, as well as the responsibilities of the engineering profession with regard to these implications. That understanding is best developed in a discourse among equals in an unrestricted forum; the equivalent of the *polis*, and as with the action in the *polis*, this discourse requires the engineers to reveal themselves and to commit to political (i.e. public) action. The forum, or "space of appearance" as Arendt called it, requires a certain infrastructure and associated maintenance, and while part of this can be provided by ICT, there is no substitute for a local component in the form of speech. The discourse must not be seen as a means to achieving a particular end; the discourse is an end in itself.

In addition to the public role, the men of Athens had the role of rulers over their families; the corresponding role for the engineers is that of creating new solutions to meeting specific needs and directing the effort required for their realisation; this also includes the research and development involved in advancing technology. According to Arendt, the men of Athens were able to keep these two roles separate, and not let considerations regarding the necessities of life encroach on their deliberations into the realm of human affairs and its web of human relationships. There is, in principle, no reason why engineers should not be able to effect the same separation, and not let considerations of their industrial employment and current projects encroach on their public (i.e. within the profession) deliberations.

Turning now to the next component of *vita activa*, *work*, the equivalent component within the process of engineering is the work that we have identified as performed by technologists; in reality it is the work performed by the overwhelming majority of engineers today. It is part of the work of converting stakeholder requirements into products; work characterised by high degree of standardisation of both processes and construction elements. Consequently, it requires above all a good knowledge of these standards, and while it is possible that in some cases a better solution could be found by departing from these standards, the effort and delay required and, above all, the risk involved in departing from standards would generally make such departures uneconomic. An increasingly significant aspect of the technologists' work is the complexity of the stakeholder requirements, so that handling complexity is an important skill. The methodology is called systems engineering, and the technologists' work can be broadly summarised as converting the stakeholder requirements into a system whose components can be synthesized from standard construction elements. This involves both design activities, such as concept design, system architecting, reliability and maintainability analysis, life cycle costing, and the like, and management and coordination activities. Many of these and related activities are supported by software applications, and familiarity with these applications is an increasingly important part of the technologist's skills.

Included in the technologists' activities are many related to the maintenance of equipment and systems once they go into operation, such as maintenance planning, condition monitoring, spare parts provisioning, and the like. Also included in the work performed by technologists is the development of new construction elements, and this is perhaps the closest equivalent of the craftsman in earlier times. Just as the craftsman developed the models for reproduction, the technologist develops the construction elements for mass production.

The final component of *vita activa* is *labour*, and the equivalent part of the process of engineering is the work performed by the group of persons we have labelled as technicians, which includes technicians, drafters, and a number of other, specialised support staff. These activities can be most simply summarised by saying that they result in all the data and information required to produce and, where applicable, maintain the products of industry. This is where the bulk of the effort in the process of engineering is located, it is the one most regulated by standards, and it is the one most susceptible to automation as the standards are realised by software applications coupled to databases containing ever greater parts of technology.

So, what does this correspondence imply for engineering? As an integral part of our modern society, engineering is both a cause and a result of the current state of society and the direction in which it is evolving. Therefore, from the correspondence of engineering with the *action* part of *vita activa* identified above, the analysis presented by Arendt should be a cause for concern and provide a wake-up call for the engineering profession. In a vicious circle of consumption and production we have almost all become labourers, and similarly, under the demands of industry for lower cost and shorter time to market engineers have become mostly technologists and technicians. Production has become an end in itself and not primarily a means to a better life. And these two developments, in society and in engineering, are both symptoms of the same underlying cause: the role of capital as a source of income. In order to produce a return on investment, a production facility must produce more than its intended product; it must provide an additional return in the form of a profit to the capital providers. This return can be accumulated to provide more capital, which requires more return, and so on, providing a feed-back loop, and thereby introducing a time-dependence into the economic system. This can also be expressed by saying that the algebraic equations governing the money flows associated with labour have been augmented by differential equations associated with capital.

The issue here is not that we should do away with capital; in a modern society that is no more possible than it is to do away with money in favour of a barter system. The issue is that we need to acknowledge the inherent unstable nature of the capitalist mode and the need for control. And the larger and more complex the economic system becomes, the more control it needs, as Fig. 6.x is intended to illustrate. The *laisser-faire* ideology on the far right of politics is a combination of stupidity (in ignoring the obvious warning signs) and an appalling lack of basic mathematical knowledge.

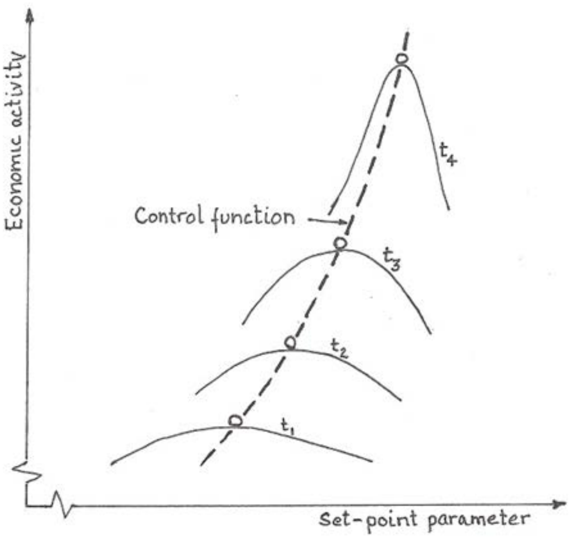

Figure 6.x Illustration of the economy stability problem. The stable (or desirable) operating condition is parameterised by the set-point, which is a function of the size of the economy, shown as the control function. The little ball at the top of each stability curve represents the economy, and left to itself, the smallest disturbance will make it roll down one of the sides. As the economy grows over time ($t_1 < t_2 < t_3 < t_4$), the stability becomes more and more precarious, and more effort is required in order to balance the economy at the top of the curve.

Engineers, as a highly educated group in society, and placed right in the middle of the engine driving the economic expansion, should play a significant role in determining the direction in which society develops. That role is what Arendt identified as political action, and the two central features of action identified by her – *freedom* and *plurality* – are equally central to engineering. Freedom is not the freedom of choice, which implies that there is an existing set of options to choose from. It is the freedom to be creative, to explore and to start something new, and, above all, to produce something unexpected. This is also related to the revelatory nature of action; it requires the actors to reveal themselves. The actions and speech need to represent the thoughts

of the actors, without being passed through a filter of accepted conventions in order to avoid repression.
The meaning and importance of plurality is twofold. One part is the one emphasized by Arendt, that action needs something to act on. To an extent it is the same way that a performing artist needs an audience, but it is more than that. Or, it is more than the entertainment aspect of acting. The purpose of action is to introduce something new and unexpected, and for this it requires the presence of other actors who can judge what is being presented and incorporate it into the knowledge base supporting their own actions. The action is like a seed, which can only become a new beginning if it falls on fertile soil, which is the condition of plurality. Plurality implies both equality and distinction; the fact that all engineers are sufficiently alike to understand one another, but yet no two of them are ever completely interchangeable.

The other part, well known to engineers through their familiarity with systems, is that a plurality of actors, interacting through speech and action, can result in actions beyond the abilities and intents of the individual actors; actions that *emerge* as a result of the interactions. And speech, as presented among equals in a space of appearance, plays an essential role in this regard; it is the form of interaction most conducive to allowing new recognitions to emerge. As it is at present, the main means of communication and interaction within the engineering profession, and within science as well, is through papers published in journals and at conferences, and through books, and while this is valuable, it is largely a one-way interaction - a reporting of work completed. For this purpose it is reasonably well suited; it is less well suited for an interaction about matters that are not so sharply defined within the current engineering paradigm.

The relevance of Arendt's political philosophy for engineering is that in addition to activities currently included in the process of engineering, there needs to be activities concerned with the process itself and thereby with the affairs of engineers as a major component of human affairs. Engineers must be engaged in the process of engineering, but they must not be consumed by it. When engaged in the process of engineering, engineers display their competence and their skills, and while this may involve considerable creativeness, much as a work of art does, they are basically displaying *what* they are, as opposed to *who* they are as individuals. By becoming completely absorbed in the process of engineering, in the cycle of production and consumption, engineers have become part of the species *animal laborans*, albeit as a very sophisticated version of that species. And instead of being a significant participant in shaping the evolution of society, the engineering profession is practically invisible to society, except through its products.

As is the case with almost any subject, the Internet contains numerous articles related to the work of Hannah Arendt, including, of course, one in Wikipedia. In particular, for anyone who does not want to work their way through Arendt's original work, there is an excellent article by Maurizio Passerin d'Entreves in the Stanford Encyclopedia of Philosophy, http://plato.stanford.edu/entries/arendt/ .

1. Arendt, H, *The Human Condition*, Chicago University Press, 1958.
2. Foucault, M, 2000, *What is enlightenment?*, in *Ethics, Subjectivity and truth: Essential works of Foucault 1954-1984*, (P. Rabinov, ed.), Penguin, pp. 303-319.
3. Latour, B, 1993, *We have never been modern*, Harvard University Press.
4. Ihde, D, 1990, *Technology and the lifeworld: From garden to earth*, Indiana University Press.
5. Verbeek, P.-P, 2005, *What things do: Philosophical reflections on technology, agency, and design*, Pennsylvania State University Press.
6. Arendt, H, *Between Past and Future*, The Viking Press, 1961.
7. de Gournay, C, *Leisure and Cultural Activities in the Information Society*, chapter 25 in *Information technology: Impact on the way of life*, L. Bannon, U. Barry, and O. Holst (eds.), Tycooly Int'l Publishing Ltd,
8. Luria, W.E, 1985, *The Single Artificer*, chapter 3 in *Responsible Science – The Impact of Technology on Science*, Nobel Conference XXI, K.B. Byrne (ed.), Harper & Row.
9. Garnham, N, 1987, *Concepts of Culture: Public Policy and the Cultural Industries*, in *Studies in Culture: An Introductory Reader*, A Gray and J. McGuigan (eds.), Arnold, pp. 54-61.
10. -, N, 2001, *The Information Society: Myth or Reality?*, Bugs, Globalism and Pluralism Conference, Montreal September 19-22.
11. Schiller, H.I, 1981, *Who Knows: Information in the Age of Fortune 500*, Ablex.
12. Schiller, H.I, 1982, *The Packaged Consciousness*, Cyrano's Journal Online, available at http://www.cjournal.info/packaged.html (last accessed on 04.01.2015).