# Chapter 1
# Philosophy and Engineering: Setting the Stage

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**Abstract** Philosophical inquiries into technology are still rare and most investigations are of a recent nature. This contribution introduces a number of general themes that are investigated in the volume *Philosophy and Engineering*. It pays attention to the difference between philosophy of technology and philosophy of engineering, discusses possible definitions of engineering and the relation between science, technology and engineering. An inventory of philosophical issues in engineering is offered and attention is paid to how engineers and philosophers can cooperate to make the new area of philosophy of engineering a success.

## 1.1 Introduction

Philosophy and engineering seem to make a strange couple. Whereas science and, to a lesser extent, technology have spurred dedicated philosophical investigations, philosophical reflection on engineering is still rare. Philosophy of science is now a well established discipline and even if the philosophy of technology is still a maturing discipline, it has its own society (SPT: Society for Philosophy and Technology) and journal (Techne). A philosophy of engineering is as yet non-existent. One area of philosophical reflection seems, nevertheless, to be an exception: ethics. Engineering ethics has developed since the 1980s as a more or less specialised effort, first mainly oriented to teaching ethics to engineering students, but increasingly also as research on the ethical dimensions of engineering (see Davis 2005 for a good overview of the area).

One might wonder what, if anything, would distinguish the philosophy of engineering from the philosophy of technology. The answer obviously depends partly on how we define technology and engineering vis-à-vis each other. As the

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contributions to this volume testify there is no agreement on this issue. Most authors, nevertheless, seem to agree that engineering and technology are distinct topics. As a first approximation we might characterize engineering as an activity that produces technology. Producing is here to be understood very broadly, including such activities as research, development, design, testing, patenting, maintenance, inspection, and so on. As we will see below, this is a first approximation at best. Nevertheless, it has the virtue of suggesting an agenda for philosophical reflection on engineering that is distinct from at least the traditional philosophy of technology. It means a shift away from philosophical reflection on technology as such, technological objects and the social, cultural and political impacts of these towards attention on what engineers actually do. This shift fits in with what has been called the empirical turn in the philosophy of technology (Kroes and Meijers 2000; Achterhuis 2001). This fit with the empirical turn in philosophy of technology raises again the question whether we need a philosophy of engineering distinct from the philosophy of technology. Nevertheless, it seems clear that engineering raises a number of issues that deserve more philosophical scrutiny than they have received as yet.

### *1.1.1 The 2007 Workshop on Philosophy and Engineering*

This volume is the outcome of the first Workshop on Philosophy and Engineering (WPE) that was held in October 2007 at the Technical University Delft. The workshop itself grew out of a gathering of a number of philosophers and engineers at the Engineering Systems Division of MIT in 2006 that was headed by Taft Broome, Howard University. The Delft workshop brought together 81 participants, 40 paper presentations, 5 posters, 6 invited speakers, and attendees from 14 different countries. As far as we are aware this was the largest organised activity bringing together engineers and philosophers in the last two decades. This volume contains a selection of the papers that were presented at the workshop.

WPE was organized not only out of the conviction that engineering raises philosophical questions, but also that fruitfully dealing with those questions requires the involvement of both engineers and philosophers. It has to be recognized, however, that the cultures of engineering and philosophy are quite different (see Goldberg's contribution to this volume). Whereas philosophers like to reflect and to problematise, engineers are action-oriented and want to solve instead of create problems. Philosophers often value conflicting perspectives on an issue, whereas engineers want to avoid ambiguity. For philosophers language is the main medium; engineers often prefer to draw diagrams or make sketches and are engaged with the material world. Engineers make fancy PowerPoint presentations where philosophers read their papers presenting at best one black-and-white slide. Philosophers judge contributions to their discipline mainly by the soundness of arguments, while engineers often stress criteria like effectiveness and efficiency in solving a certain problem. Given those differences, it is to be expected that engineers and philosophers tend to disagree about what makes a good contribution to the new field of philosophy and engineering. Therefore it was decided to organize the workshop in three distinct subject areas or (as we chose to call them) “demes”: philosophy, ethics and engineering reflection.[1] Each deme had its own review and selection procedure. For the first deme, the deme chairs were philosophers and for the third engineers; the ethics deme combined philosophers and engineers, testifying of the more mature status of engineering ethics and the experience in this area with interaction between engineers and philosophers. One might object to this set-up that it results in irrelevant philosophy and in contributions of engineers that do not meet the traditional philosophical criteria for quality. Even if this objection makes some sense, we feel that at this stage of the effort, this strategy is the best.

## 1.2 Towards a Philosophy of Engineering

Since a philosophy of engineering is still to be developed, there is not a commonly agreed set of problems that define the field. Still, based on the workshop and earlier philosophical reflections on engineering, we can identify a number of topics that belong to the philosophy of engineering. Below, we sketch a number of such topics to give an impression of what a philosophy of engineering might look like, without the aim of being complete or exhaustive.

### *1.2.1 What is Engineering?*

A first issue is how to define engineering, an issue that emerges in several contributions to this volume. All contributors agree that design is central to engineering (see e.g. the contributions by Davis, Luegenbiehl, Didier, Moses and the recent volume *Philosophy and Design* edited by Vermaas, Kroes, Light and Moore). Beyond this, disagreement seems to rule. Durbin, for example, looks at engineering as guild, suggesting that engineering is not or at least not necessarily based on science and mathematics, whereas Luegenbiehl defines engineering as “the transformation of the natural world, using scientific principles and mathematics, in order to achieve some desired practical end” (Luegenbiehl, this volume, p. 153). As he notes, this definition “reflects the modern scientific foundation of engineering, rather than the crafts tradition” (Luegenbiehl, this volume, p. 153).

Li Bo-cong and Didier include other actors than just engineers in the engineering community like managers, other technologists, workers and investors. Davis, who wants to distinguish engineers from other technologists, would probably disagree: engineering is what engineers do in their capacity as engineers.

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[1] In biology, a deme is another word for a local population of organisms of one species that actively interbreed with one another and share a distinct gene pool. If demes are isolated for a long time they can become distinct subspecies or species. Definition from: http://en.wikipedia.org/wiki/Deme_(biology).

In fact, the contributors do not agree on the best approach to defining engineering. Luegenbiehl gives a stipulative definition (see above). Mitcham and Mackey in contrast propose a linguistic philosophical approach to characterising engineering:

> what engineering is might be better determined by how the word "engineering" and its cognates and associated terms (such as invention, innovation, design, technology, science, etc.) are used, especially in relation to each other. From a linguistic philosophical perspective, it would be appropriate to begin not so much with our experiences of engineering but with the words we use to talk about such experiences (Mitcham and Mackey, this volume, p. 55).

Davis in his contribution criticizes both philosophical definitions of engineering and a linguistic approach. With respect to the latter he remarks that "[t]he term 'engineer' (or 'engineering') is no guarantee that what is in question is an engineer (or engineering)" (Davis, this volume, p. 16). This is so because, for example, locomotive engineers are not engineers in the sense we are interested in here. Moreover, in some languages, there are no clear distinctions between engineers and technologists. With respect to philosophical definitions of engineering, Davis argues that

> [a]ll attempts at philosophical definition will: a) be circular (that is, use "engineering" or a synonym or equally troublesome term); b) be open to serious counter-examples (whether because they exclude from engineering activities clearly belonging or because they include activities clearly not belonging); c) be too abstract to be informative; or d) suffer a combination of these errors (Davis, this volume, p. 17).

As an alternative he proposes a historical approach:

> engineering, like other professions, is self-defining (in something other than the classical sense of definition). There is a core, more or less fixed by history at any given time, which determines what is engineering and what is not. This historical core, a set of living practitioners who—by discipline, occupation, and profession—undoubtedly are engineers, constitutes the profession (Davis, this volume, p. 16).

In relation to ethical reflection, a major issue is, as noted by Luegenbiel, whether a definition of engineering should "emphasize the requirement of engineering activity to benefit humanity" (Luegenbiehl, this volume, p. 153) or should choose a more value-neutral approach. The first approach is prominent in traditional engineering ethics where engineering is conceived of as a profession (see e.g. Davis 1998) and it also seems at work in the contributions by Gunn and Bowen. Luegenbiehl and Didier in their contributions prefer a more value-neutral approach. Luegenbiehl does so because he is interested in global cross-cultural ethical principles for engineering, and a more value-neutral approach to defining engineering "avoids having to deal initially with the questions of culturally based ideas of benefit and harm." (Luegenbiehl, this volume, p. 153) Nevertheless, he believes that "some value element is unavoidable, in that I assume that engineering activity should leave the world no less well off and that disbenefits created by engineering not be catastrophic in nature." (Luegenbiehl, this volume, p. 153)

According to Didier, engineering has in history had both morally positive and negative (and value-free) connotations. She prefers to conceive of engineering not as a profession that by definition makes a positive contribution to society but rather as an activity that can be ethically evaluated. Didier's proposal has the advantage of not assuming a culturally-bound notion of profession. (As she argues the Anglo-Saxon notion of profession does not have a clear counterpart in France.) Moreover, her neutral definition opens the ways to ethical reflection on engineering activities like design (see the contribution by Robison and see Van de Poel 2001) and innovation (see the contribution by De Kreuk et al.) that are somewhat neglected in traditional engineering ethics. It might also broaden the discussion about the responsibilities of engineers beyond what is stated in codes of ethics for engineering (see e.g. the contributions by Coeckelbergh and by Pols).

### *1.2.2 The Relation Between Science, Technology and Engineering*

An issue that is related to the definition of engineering is how to understand and characterize the relation between science, technology and engineering. This issue surfaces in several contributions to his volume. Despite differences, there is at least one point of agreement: engineering is not applied science. Pitt looks at the real-world interaction between science and engineering and suggests that science may depend on engineering rather than the reverse. Moses argues that design differentiates engineering from science and mathematics. Broome suggests that engineering employs a different (formal) language game than science and mathematics, one in which there is room to express error and incertitude.

Li Bo-cong argues for what he calls the trichotomy of science, technology and engineering: science, technology and engineering are three distinct though related activities. According to him, the core activity of science is discovery, of technology invention and of engineering making. Science produces scientific knowledge like theories; technology produces technological knowledge, like patents and blueprints for an invention and engineering produces the actual material products. Two things are worth noting about Bo-cong's account in relation to other possible accounts of the relation between science, technology and engineering. First, what he calls technology, some others would call engineering science (as distinct from natural science). Aspects of engineering science, and differences with natural science, are discussed in the contributions by De Vries and Pirtle. Second, Bo-cong conceives of technology as an activity, rather than as the product or object of engineering.[2] In his book *Thinking Through Technology*, Mitcham describes two other common conceptualisations of technology, in addition to technology as object and technology as activity, i.e. technology as knowledge and as volition (wilful or purposive action). Each of these conceptualisations of technology foregrounds different philosophical questions and each would probably account for a somewhat different relation between technology and engineering and, hence, between the philosophy of technology and the philosophy of engineering.

[2]Note that engineering activities like inspection, research, etc. do not produce technology, but still may be said to have technology as the object.

### 1.2.3 Other Philosophical Issues in Engineering

The issues discussed above are largely conceptual: how to best define and understand engineering, technology, and science and how to understand their relation? Such conceptual questions may also be asked about specific activities and concepts in engineering like design, function, invention, creativity and patents. For example, Vermaas in his contributions sets out the ICE-theory that tries to solve a number of conceptual (and metaphysical) issues with respect to technical functions. In addition to conceptual issues, engineering raises a range of other philosophical questions.

One additional kind of issue is *epistemological*: what is the nature of engineering knowledge and the justification of such knowledge? The seminal work here is still *What engineers know and how they know it* by Walter Vincenti – an engineer and historian of technology. Vincenti distinguishes different types of engineering knowledge. (For a recent discussion of epistemological issues see Houkes 2006.) The contributions by the philosophers De Vries and Pirtle in this volume also address epistemological issues.

Another kind of issue is *methodological*, i.e. questions about the methods employed in engineering and their adequacy and justification. The engineer Billy Koen has argued in his book *Discussion of the Method* that all methods in engineering are fundamentally heuristic in nature (see also his contribution to this volume). Philosophers have critically examined a number of methods used in engineering like multi-criteria decision-making (Franssen 2005), design methods (Vermaas and Dorst 2006) and quality function deployment (Van de Poel 2007). In this volume, one of the pioneers of systems engineering, Joel Moses, discusses different approaches in systems engineering. The philosopher Ottens provides a critical analysis of methods in systems engineering for the design and management of socio-technical systems. Engineer Abbott discusses a number of issues in software development.

Engineering also raises *metaphysical* and *ontological* issues, for example, about the status of design or functions. It might seem that such issues are less relevant to practising engineers than, for example, conceptual, epistemological and methodological issues. Vermaas in his contribution, for example, suggests that the ICE-theory for technological functions that he and Houkes developed needs to be stripped off from its philosophical assumptions to make it relevant to engineering. Despite Vermaas' scepticism, engineers have engaged in applied ontology as a means for developing (better) design methods, databases of engineering parts and the like (e.g. Kitamura et al. 2006).

Engineering obviously also raises *ethical* issues, as is witnessed by the development of engineering ethics. As argued above, some authors in this volume further extend the scope of engineering ethics. Again, this is an area to which both philosophers and engineers have made a contribution. Typically, the main textbooks in engineering ethics are written by a combination of philosophers and engineers (Vesilind and Gunn 1998; Martin and Schinzinger 2005; Harris et al. 2008).

Engineering does not only raise new philosophical problems, it might also sometimes shed new light on existing philosophical questions. McCarthy in her contribution suggests that an examination of engineering knowledge would create new insights into existing epistemological questions. With respect to ethics, it might be argued that engineers in the design process deal with conflicting values by creatively thinking of new designs and innovations that soften or even solve existing value conflicts (Van de Poel 2005). This is a way of dealing with value conflicts that has been overlooked in the philosophical literature on value conflict. The later, indeed, suggests another important theme for philosophical reflection in engineering: creativity and innovation.

The above list of issues may be a bit biased towards an analytical approach to the philosophy of engineering. As the contributions by Durbin and by Mitcham and Mackay illustrate other approaches are possible as well.

### *1.2.4 Interaction and Cooperation Between Philosophers and Engineers*

The above overview shows that both engineers and philosophers have been and are working on conceptual, epistemological, methodological, ontological and ethical issues in engineering. This is not to say that they have always done so in cooperation or that they always agree on the quality standards for such work. Above, we have suggested that they do not necessarily do so, and this is in fact underlined by the experiences described by Vermaas in his paper. Still, this volume also shows examples of good cooperation between engineers and philosophers, for example in dealing with ethical issues in innovation (De Kreuk et al.) and in developing teaching materials for engineering ethics (Kroesen and van der Zwaag). Typically, the main examples of fruitful cooperation between engineers and philosophers are from ethics.

One might wonder what would be required for a further fruitful cooperation between philosophers and engineers. As earlier noticed, philosophers and engineers come from different (academic) cultures. Cooperation then seems to require some changes in the mind-set of both disciplines. For philosophers, it requires at least the willingness to pay attention to the reality of engineering practice; the empirical turn in the philosophy suggests that at least some philosophers are now making this move. For engineers, it would require a willingness to reflect on their own practices even if this is not immediately useful or even undermines current practices. (This is not to say that philosophical reflection cannot be useful for engineering eventually, but one should not expect immediate results.) Goldberg in his contribution to this volume suggests that engineering is now increasingly facing a global crisis that spurs, at least temporarily, a turn to philosophy.

The further cooperation between philosophers and engineers, and more generally the philosophical reflection on engineering, will be facilitated by the continuation of the WPE workshops.

## 1.3 The Contributions

### *1.3.1 Philosophy*

The first part contains nine contributions to the philosophy deme. Davis in his contribution discusses how to define engineering. He applies the historical approach, which he proposes, to understand the differences (and similarities) between engineering and architecture. Li Bo-cong discusses the relations between science, technology and engineering and the importance of a distinct philosophy of engineering.

The next two papers – by Durbin and by Mitcham and Mackay – discuss various approaches to the philosophy of engineering. Durbin's paper is more historical: he gives an overview of approaches to the philosophy of engineering that can be found in the SPT community. Mitcham and Mackay distinguish six different possible approaches to the philosophy of engineering: phenomenological, postmodern, analytic, linguistic, pragmatist, and Thomist. They argue for more attention for the linguistic approach.

Vermaas in his papers describes his experiences as a philosopher cooperating with engineers. He argued that the ICE theory that he and Houkes developed for technical functions is not immediately relevant for engineering practice and can only be made more relevant by making is philosophically less interesting.

The next five contributions all focus on more specific philosophical issues in engineering, in particular in engineering science. Pitt discusses and criticizes the characterisation of engineering as applied science. He suggests that most of today's science cannot be conducted without what he calls the "technological infrastructure," in the making of which engineering plays a major role.

De Vries discusses the nature of generalization in the engineering sciences. It is often suggested that generalisation in engineering is more difficult than in science due to the action-oriented nature of engineering. De Vries studies four cases of generalisation in the engineering sciences and suggests that these exemplify three different generalisation patterns in engineering: from artefact-token to artefact-type, from artefact to function and from artefact to artefact-structure.

Pirtle is interested in the role of models in engineering. He discusses three examples of models in engineering: flush riveting, control volume analysis. and the models used in the failure analysis of the New Orleans levees. He argues that models in engineering have not yet received the philosophical attention they deserve and that an important philosophical question is whether models in engineering and science are different enough to require a different (philosophical) understanding.

Ottens discusses the limits to systems engineering through the example of electric power systems. He argues that the current approaches in systems engineering relegate certain system elements, like the users and legislation, to the environment of the system, while these elements may be crucial for the proper functioning of the system.

### 1.3.2 Ethics

The second part contains ten contributions to the ethics of engineering. Gunn describes engineering as the oldest profession and one of the most demanding ones. He discusses the importance of integrity in the ethics of engineers. Like Gunn, the contributions by Bowen and by Luegenbiehl start with the traditional responsibilities of engineers as laid down in codes of ethics, but both try to extend this traditional perspective. Bowen is interested in an aspirational engineering ethics that prioritises people. In doing this, he draws from unusual sources for engineering ethics: Buber and Levinas and MacIntyre's virtue ethics. Luegenbiehl is interested in ethical principles in a global context. He argues that this requires a new foundation of ethical principles on the basis of the nature of engineering. Luegenbiehl's efforts in effect move in an opposite direction as Bowen's. Whereas Bowens tries to enlarge the scope of responsibilities of engineers (by including doing good), Luegenbiehl looks for a minimal version that is globally acceptable.

The responsibility of engineers is also an important theme in the contributions by Coeckelbergh and by Pols. Coeckelbergh argues that traditional approaches to responsibility assume transparency in the relation between action and consequences and between my action and what is under my control. Such transparency is, however, usually absent in engineering. He looks for a solution in approaches that foster moral imagination and takes inspiration from two philosophers of technology: Jonas and Anders. Pols discusses how, and under what conditions, responsibility is transferred from the designers of an artefact to the users. In doing so, he combines philosophical work on responsibility with recent insights from the philosophy of technology about design.

Didier presents a French perspective on engineering ethics, which is illuminating because, as Luegenbiehl also notes, engineering ethics is still largely an American affair. She suggests that the focus of engineering ethics is nevertheless already widening from engineering as a true profession to engineering as a type of activity that raises ethical questions.

The next two contributions by Robison and by De Kreuk et al. indeed mark such a widening of the scope of engineering ethics. These contributions focus on activities, i.e. design (Robison) and innovation (De Kreuk et al.) that are central in engineering but have until now only received limited attention in engineering ethics. Robison suggests that "benign by design" would be a fundamental ethical principle for engineering design. De Kreuk et al. describe the uncovering of ethical issues in the innovation process of a new sewage treatment plant. This happened in close cooperation between engineers and ethicists, while the cooperation was fruitful in recognizing ethical issues and improving design decisions, it also introduced new ethical issues, especially about the role of ethicists in such cooperation.

The papers by Kroesen and Van der Zwaag and by Danielson also deal with cooperation between ethicists and engineers. Kroesen, a philosopher, and Van der Zwaag, an engineer, describe the development of a new role play game for teaching engineering ethics. Robison describes a computer platform for doing experiments in the ethics of technology that extends the cooperation between engineers and others in three directions, i.e. by including social scientists, the public and other technologists.

### *1.3.3 Reflection*

The reflection part contains contributions by practising engineers. Goldberg asks the question why engineers and philosophers are now meeting. He suggests that a discipline is more willing to consider philosophical questions as it faces a crisis. According to him, engineering is now facing such a crisis, which will turn the engineering mind to philosophy for at least some time.

McCarthy discusses the work of the philosopher and former engineer Wittgenstein. She argues that there are interesting correlations between Wittgenstein's approach to philosophy and the engineering approach: both try to dissolve or overcome certain problems. She illustrates this by applying the two approaches to epistemological questions about engineering knowledge and more general philosophical issues in epistemology.

The next two contributions, by Moses and by Abbott, are good examples of professional engineers reflecting on their own discipline. Moses discusses three major approaches to the design and architecture of large scale engineering systems. Abbott describes a number of issues in software design and development.

The contributions by Broome and Fritzsche try to characterize engineering in relation to issues of determinacy and indeterminacy, certitude and incertitude. Broome is interested in the formal language games employed by engineers on the one hand and scientists and mathematicians on the other. Fritzsche discusses engineering as determinate operation, even if we cannot fully escape indeterminacy in practice.

The final two contributions take up ethical issues in engineering. Koen discusses how engineering can take up the challenge of sustainability and ultimately the survival of the human species. He is especially interested in what types of engineering heuristics would be needed to deal with this issue. Moriarty discusses an approach for the ethical assessment of engineering projects based on Borgmann's notion of focal product.

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