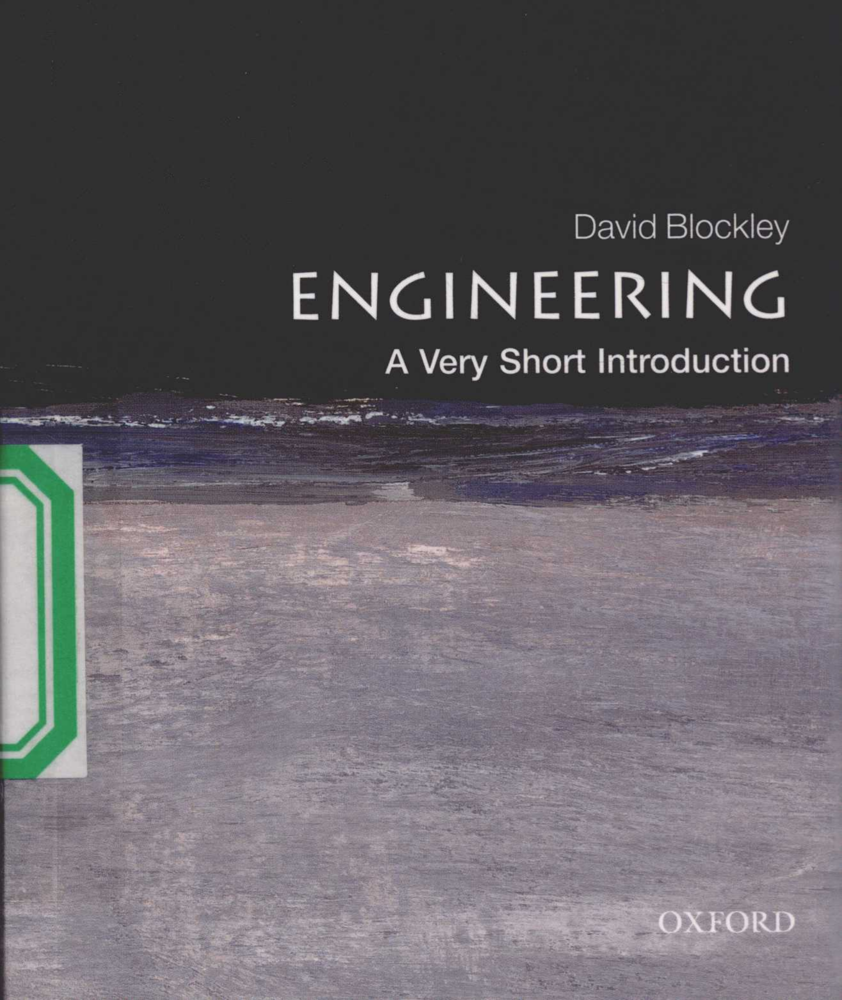
David Blockley

ENGINEERING

A Very Short Introduction



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Preface

The purpose of this book is to explore, in non-technical language, what engineering is all about. The central message is that engineering is intimately part of who and what we are. We will explore the role of engineering in the modern world through the story of its history and relationships with art, craft, science, and technology. We will see how engineers utilize natural phenomena to embrace human needs. The story continues – so we look at some of the contributions engineers will have to make in the future in order to sustain and promote human well-being.

A recent UK parliamentary committee defined engineering as 'turning ideas into reality' – succinct but perhaps not that helpful. A dictionary definition is 'the art, science, and craft of changing a dream into a reality through conception, feasibility, design, manufacture or construction to operation and eventual decommissioning of something that fulfils a human need'. Engineering is the discipline of using scientific and technical knowledge to imagine, design, create, make, operate, maintain, and dismantle complex devices, machines, structures, systems, and processes that support human endeavour.

Such definitions are necessarily brief, and so they cannot convey the massive contribution engineering makes to modern life. Engineering is part of almost everything we do – from the water we drink and the food we eat, to the buildings we live in and the roads and railways we travel on; from the telephones and computers we use to communicate to the television, radio, music, and films that entertain us; from the bicycles and cars we ride to the ships we sail in and the aeroplanes we fly, from the gas and electricity we rely on to the power stations that generate the energy; from the X-ray machines that help doctors diagnose diseases to the heart pacemakers and artificial hips that help many people have a better quality of life. Unfortunately, it isn't all good. Engineering also contributes to the weapons we use to kill each other and the carbon dioxide emissions that threaten the planet.

The range of subdisciplines within engineering is large – there are over 30 different professional institutions in the UK alone that qualify engineers. Many, but not all, countries require state or provincial registration. Engineering activities vary from the 'one-off' massive infrastructure projects of civil engineering, including roads, bridges, reservoirs, and buildings, to the mass production of small mechanical and electronic components such as pumps, valves, pipes, motors, and integrated circuits and their assembly into larger manufactured products such as washing machines, cars, and aeroplanes. Over the last 200 years, these subdisciplines have tended to grow apart as scientific knowledge and technical achievement have seemed unstoppable. However, the complexity arising from the needs of the modern world has required a new coming together of specialists into teams that can tackle large projects in an integrated way. The modern engineer needs to work to achieve long-term sustainable development. We have become vulnerable to unexpected events, such as the ash cloud from an erupting volcano in Iceland that stopped all air traffic in northern Europe in April 2010 and the effects of the earthquake and consequent tsunami damage to a nuclear reactor in Japan in 2011. Coping with the massively complex interdependencies between systems is one of the major engineering challenges of the 21st century.

Engineering is a big subject and, like me, almost all engineers specialize to an extent. The choice of what and what not to include is entirely mine. I am sure that some will think I have not done justice to a particular subdiscipline, skirted over, or even missed out altogether, something essential. I have tried to be sufficiently representative to give the non-engineer reader a sense of scope, but I have also included some technical detail in order to give a sense of depth as well. Inevitably, I have left large gaps. I am fortunate to have been helped by many people. First and foremost, I would like to thank those who helped me make the book more accessible to a wider readership. Anne Thorpe read the whole book and made very many suggestions as to how it could be improved. Likewise, Joanna Allsop also read some of the text and made some suggestions. Angela Hickey explained to me some of the niceties of operatic voice control. Tim Cripps helped me with heart pacemakers. Simon Fieldhouse put me in touch with some developments in dentistry. Michael Liversidge helped me interpret some of the Italian artist engineers, such as Leonardo da Vinci, and Richard Buxton helped on some classical Greek words.

I would like to thank a number of engineers who were very generous of their time to help me to cover their specialist areas. Joe Quarini was an enthusiastic guide through thermodynamics and steam engines. He, Sandy Mitchell, and particularly Neil Brown helped me make some sense of jet engines. Mike Barton, Derrick Holliday, and Duncan Grant were very friendly, willing advisers on electromagnetism. Mike and Derrick read drafts and were particularly patient when I peppered them with many questions. Figure 15 was arranged by Derrick and photographed by Richard Walker, and Figure 17 was provided by Mike. Joe McGeehan helped me with wireless communication and David Stoten with control engineering. Patrick Godfrey read and commented on Chapter 6 – systems thinking. Bob Baird and Mike Rogers read the whole book to help me incorporate some chemical engineering and to give a North American perspective. Mike provided Figure 20. Robert Gregory also read the whole text,

made several suggestions, and supplied Figure 9. Figure 1 is reproduced by kind permission of Trevor Harrison, warden of Selsley Church, UK. Figure 2 is an Evia pacemaker and is printed with the permission of Biotronik, a leading global company in the field of biomedical technology with a focus on electrotherapy of the heart and vascular intervention. Figure 6 is reproduced by kind permission of the Technical Director of Caudwell's Mill, Rowsley, Derbyshire. Finally, I would like to thank Rolls-Royce plc for permission to use Figures 10 and 11. The copyright of these images is owned exclusively by Rolls-Royce plc.

Finally thanks are due to Latha Menon at Oxford University Press who had the idea for this book, Emma Marchant, Elmandi du Toit, and Carol Carnegie also at OUP, Subramaniam Vengatakrishnan at SPi Global, copy-editor Alyson Silverwood and proofreader Kay Clement. Last, but by no means least thanks to my wife Karen for her unfailing love and support and endless cups of tea.

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Chapter 1
From idea to reality

Engineering is, in its most general sense, turning an idea into a reality – creating and using tools to accomplish a task or fulfil a purpose. The word 'engineer' derives not, as you might imagine, from being-someone-who-deals-with-engines but rather from its Latin root *ingeniarius*, Old French *engignier*, and Middle English *engyneour* to mean someone who is ingenious in solving practical problems. Man's ability to make tools is remarkable. But it is his ingenious ability to make sense of the world and use his tools to make even more sense and even more ingenious tools, that makes him exceptional. To paraphrase Winston Churchill, 'we shape our tools and thereafter they shape us'. Tools are part of what it is to be human. In the words of Henry Petroski, 'To engineer is human'.

Yet for many, there is a disturbing cloud. Once tools were simple common sense – almost all were understandable to the intelligent layperson. Since the Industrial Revolution, the interior workings of many tools have become mysterious, complex, and opaque to all but specialists. The culture of opposition between the arts, religion, science, and technology has widened and is often antagonistic. Matthew Crawford has accused engineers of hiding the works, 'rendering many of the devices we depend on every day unintelligible to direct inspection'. On the other hand, Brian Arthur has described a process he calls 'structural deepening' in which engineers inevitably add complexity as they strive to enhance performance. There is an increasing realization that science, technology, engineering, and mathematics (STEM) are intertwined in a way that needs disentangling. This is urgent because engineering is so intimately part of who we are that effective democratic regulation requires us to understand something of what engineering offers, what it might offer in the future, and, perhaps most importantly, what it cannot ever deliver.

Our journey through engineering will be broad and deep. We will explore in this chapter the relevance of engineering to many aspects of modern life, including fine art and religious faith. Depth will be manifest in later chapters, as we investigate how complex physical processes have been harnessed, for example to make a transistor. We will discover the excitement of facing difficult and important challenges, such as the spanning of a large river with a big bridge. We will become more contemplative in the final chapter, as we probe the creative thinking needed to engage with the new age of systems complexity and the need for a fresh approach to dealing with uncertainty.

All through history, people have expressed their awe, wonder, spirituality, and faith by making tools – especially for religious ritual. It was one way of coping with fear, pain, and the mysteries of the unknown. Pyramids connected this world to the afterlife. Church art, paintings, and sculpture were ways of creating a mood for devotion and the telling of the Christian story. From ancient tablets of stone to present-day LCD (liquid crystal display) screens, from horse-drawn carts to space rockets, from stone arches to cable-stayed bridges, from pyramids to skyscrapers, from the moveable type of the printing press to the integrated circuits of computers, from the lyre to the music synthesizer, from carrier pigeons to the internet, our tools have become ever more powerful and conspicuous.

Imagine waking up in the morning, attempting to switch on your light or radio, but finding that everything provided by engineers