cal and medical systems is beginning to dramatically increase the health of vast sectors of the world population, and the synergy of engineering and education through advances in information and telecommunications technology, to improve skills and job opportunities globally. At the same time, however, developments in mechanization and automation may tend to diminish both employment opportunities and person-to-person, face-to-face interactions by interposing machines. Also, as dependency on technology grows – and as technology becomes less well understood and operated to its maximum capacity – society is placed at increasing risk by technological failures and design faults, whether of logistical supply systems for water, food, energy and vaccine, or of other critical infrastructures and systems. The risk is aggravated by the ever-greater interdependencies of our engineered world. Engineering in its entirety is, in effect, a social enterprise that has made modern society possible, with all its potentials and risks, and is nurtured in turn by society (Sladovich, 1991)[16]. It extends the physical and economic capacity of society by enhancing the reach of society's components and capabilities of its members, and by creating new methods and instruments for agriculture, the production of goods, communication, defence, offence, exploration of space and the oceans, and of the preservation and utilization of nature's resources from land to energy, water and materials. Engineering's evolving and deepening interaction with the other components of society and its increasing ability to intervene in biological processes have become a key factor in determining the future of our species.

16 Sladovich, H.E. (ed.). 1991. *Engineering as a Social Enterprise*, National Academy Press, Washington, DC.

2.4 Engineers and social responsibility

2.4.1 The big issues

Stuart Parkinson

Engineering has immense capacity to help provide benefits to society – as the other contributions in this Report demonstrate – but it also has a similarly large capacity to be used to cause harm. It helps to provide basic needs such as water, food, shelter and energy, and does so on the scale necessary for industrial society to function. But engineering has also contributed to the huge increase in the destructiveness of weaponry and warfare seen over the centuries, to increases in inequality and to the global damage inflicted on the world's ecosystems.

Tsunami reconstruction housing.

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As an engineer, it is crucial to understand this dual nature of the profession and to be vigilant regarding your own role and that of your employers so that you maximize the chances of a positive contribution to society. In essence this is what it means to be a socially responsible engineer.

Engineering and war

In promoting engineering as a career, the professional institutions are quick to point out the critical role that engineering plays in helping to provide benefits to society, for example:

> *'Today, it is true to say that virtually every aspect of our daily lives is enabled or aided in some way by engineers. Engineers make things happen, they turn ideas into real products and they provide the solutions to life's everyday practical problems.'*[17]

However, they are less quick to highlight the ways in which technology has been engineered – in close collaboration with the sciences – to contribute to many of society's ills. Perhaps the starkest example of this is demonstrated by the increase in the lethality of weapons over the twentieth century. Researchers at the University of Buenos Aires have estimated that the 'lethality index' – defined as the maximum number of casualties per hour that a weapon can inflict – increased by

17 Young Engineers website. http://www.youngeng.org/index.asp?page=66 (Accessed: 4 May 2010).

a staggering sixty million times over the course of the century, with thermonuclear warheads mounted on ballistic missiles representing the zenith of destructiveness.[18] Indeed, as is well known, these weapons have given us the power to destroy human civilization and much of the natural world in a very short space of time.

However, the controversies that surround military technology are related to a much broader set of issues than just the raw power of a given weapon. For example, it is important to realize that most people who die in wars are actually killed by smaller, simpler technology such as guns and other small arms – and war still kills hundreds of thousands of people across the world each year.[19] While many engineers justify their work on military technology by arguing it contributes to national security, the situation is far more complex. For example, regulation of international arms sales is generally poor, with weapons finding their way – both legally and illegally – to governments with bad human rights records and to war zones. With about 75 per cent of war casualties being civilians, this is especially disturbing.[20]

One overarching issue related to military technology especially relevant to engineers is what economists call the 'opportunity cost', i.e. the loss of skills and resources from other important areas that are currently used by the military. Indicators of this opportunity cost are not hard to find. In 2006, global military spending was a massive US$1.2 trillion.[21] This is greater than the combined size of the economies of the world's 110 poorest countries,[22] and nearly twelve times the global level of official development aid[23] – a level of aid which still falls well short of that needed to achieve the Millennium Development Goals.[24] Indeed, resolutions proposed annually at the UN General Assembly since 1987 have highlighted the desire of the majority of the world's governments for cuts in military spending to be used to help fund international development. This has become known as 'disarmament for development'.[25]

Another comparison of particular relevance to engineers is spending on research and development (R&D). In 2006, the governments of the world's wealthiest countries[26] spent US$96 billion on military R&D compared with only US$56 billion on R&D for health and environment protection combined.[27]

Engineering and pollution

Engineering and technology is also a key contributor to global environmental problems, such as climate change and loss of wildlife. For example, industrial society now emits the equivalent of about 50 billion tonnes of carbon dioxide each year[28] – with the burning of fossil fuels being the main culprit. The resulting climate change is predicted to have huge impacts on both humans and wildlife over the coming decades and beyond – with many millions of people at risk. Indeed, a recent report by the World Health Organization estimated that climate change could already be responsible for 150,000 extra deaths every year.[29]

Engineering and technology are also key contributors to the global loss of wildlife through their role in activities ranging from industrial deforestation to industrial fishing. The rate of species extinction across the world is now estimated to be more than 100 times the natural level, with the consequence that we are now in the midst of a 'major extinction event' – something that has only happened five times before in the five billion year history of planet Earth.[30]

But of course engineering is playing a key role in helping to understand and tackle global environmental problems as well. For example, in the case of climate change, energy efficiency and renewable energy technology are playing increasingly important roles in helping to cut greenhouse gas emissions – and so mitigate the threat – while other technologies such as flood defences are allowing society to adapt to some of the changes which are already happening. Other examples can be found elsewhere in this Report, many showing that technology and innovation alone cannot save us; such solutions must be engineered to suit society.

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Waste management.

18 Lemarchand, G. 2007. *Defense R&D Policies: Fifty years of history*. INES Council and Executive Committee meeting, June 2–4 2007. Berlin, Germany. http://www.inesglobal.com/ (Accessed: 4 May 2010).

19 Smith, D. 2003. *The Atlas of War and Peace*. Earthscan, London. pp. 38.

20 Ibid. 22.

21 Stalenheim, P., Perdomo, C., Sköns, E. 2007. *Military expenditure*. Chp. 8 of SIPRI (2007). SIPRI Yearbook 2007: Armaments, Disarmament and International Security. Oxford University Press/SIPRI. http://yearbook2007.sipri.org (Accessed: 4 May 2010).

22 This was calculated using figures from International Monetary Fund (2007). *World Economic Outlook database*. http://www.imf.org/external/pubs/ft/weo/2007/02/weodata/index.aspx (Accessed: 4 May 2010).

23 This was calculated using figures from UN (2007). *The Millennium Development Goals Report 2007*. UN, New York. pp.28. http://www.un.org/millenniumgoals/pdf/mdg2007.pdf (Accessed: 4 May 2010).

24 The eight Millennium Development Goals (MDGs) include trying to halve extreme poverty by 2015. For a discussion on the shortfalls in development aid needed to achieve the MDGs (See footnote 23).

25 Dhanapala, J. 2007. Disarmament and development at the global level. Statement at the IPB conference, *Books or bombs? Sustainable disarmament for sustainable development*. November 2007. http://www.pugwash.org/reports/nw/dhanapala-sean-macbride-prize.htm (Accessed: 4 May 2010).

26 Countries of the Organisation for Economic Co-operation and Development (OECD).

27 OECD. 2007. *Main Science and Technology Indicators 2007*. OECD, Paris. http://www.oecd.org/

28 Emissions of greenhouse gases (GHGs) are generally expressed in tonnes of 'carbon dioxide equivalent' as different GHGs have different warming properties. Figures are from the Intergovernmental Panel on Climate Change (2007). *Climate Change 2007: Synthesis Report*. Fourth Assessment Report. Summary for Policymakers. http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf (Accessed: 4 May 2010).

29 World Health Organization. 2003. *Climate Change and Human Health – risks and responses*. http://www.who.int/bookorders/anglais/detart1.jsp?sesslan=1&codlan=1&codcol=15&codcch=551 (Accessed: 4 May 2010).

30 UNEP. 2007. *Global Environmental Outlook 4*. Chp. 5. United Nations Environment Programme. http://www.unep.org/geo/geo4/media/ (Accessed: 4 May 2010).

However, a lack of resources is again impeding the speed at which the world faces up to these urgent environmental problems. And again, a comparison with military spending is a useful reminder of the resources which could be made available. For example, the Institute for Policy Studies recently published a report comparing the United States government budget allocated to 'military security' with that allocated to 'climate security'. It found that the military budget was 88 times the size of that devoted to tackling the climate problem.[31] The UK organization, Scientists for Global Responsibility, carried out a similar comparison, this time between the government R&D budgets of the world's wealthiest countries. They found a very similar imbalance between military and renewable energy R&D spending.[32]

Is the engineering profession doing enough?

Given such disturbing facts, it is worth asking whether the engineering profession is doing enough to fulfil its obligations in terms of social responsibility. As entries in this Report show, there is a great deal of positive activity across the profession, but there remain areas where there is a need for improvement.

The most obvious example is arguably the close relationship between the engineering profession and the military. Given the controversies discussed above, related to military technologies and the size of military budgets, one might expect to hear more criticism from within the profession about how its skills are deployed. Yet it is very hard to find cases of, for example, professional engineering institutions criticizing the government policies that cause such problems.

For example, during the recent debate in the UK over proposals to replace the Trident nuclear weapons system – proposals criticized by the then UN Secretary General[33] – the main comment from the Royal Academy of Engineering (RAE)[34] was simply that there needed to be sufficient investment in skills and infrastructure to ensure timely delivery of the US$40 billion project. Such a muted response sits uncomfortably with the RAE's recently launched 'Statement of ethical principles' which encourages engineers to have 'respect for life… and the public good.'[35]

Indeed, with the active encouragement of UNESCO, professional engineering and scientific institutions have in recent years begun to adopt and promote ethical codes for the profession, which highlight the importance of principles such as social justice and environmental sustainability. Yet, when there are clear conflicts between these goals and the military and commercial interests, which are so intertwined with the engineering profession, the principles seem quickly to be compromised.

Standing up for social responsibility

Over the years there have been a number of engineering and science organizations which have, in frustration with governments and professional institutions, tried to promote greater social responsibility within the science and technology arenas.

In 1957, the Pugwash Conferences on Science and World Affairs was formed in response the early nuclear arms race.[36] These conferences – which continue today – bring together scientists, engineers and others from across the world to discuss solutions to global problems. These discussions have been important in sowing the seeds of major arms control treaties.

A more radical organization, the International Network for Engineers and Scientists for Global Responsibility (INES), was set up in 1991 arguing that the professions should play a much greater role in supporting peace, social justice and environmental sustainability.[37] It has over seventy member organizations in more than thirty countries.

Influential individuals from the engineering and scientific communities have also spoken out urging the professions to adopt a more radical position. For example, in 1995 former Manhattan Project scientists, Prof. Hans Bethe and Prof. Joseph Rotblat called on all engineers and scientists to refuse to work on nuclear weapons projects.[38] More recently, Jayantha Dhanapala, a former UN Under-Secretary General and currently Chair of the UN University Council, called on engineers and scientists (among others) to refuse to work for the world's top twenty-five military corporations, until the 'disarmament for development' agenda is seriously acted upon.[39]

Becoming an active member of, or otherwise engaging with, one or more of the engineering campaigning groups or non-governmental organizations would be an important contribution to the social responsibility agenda for any engineer, and it should be recognized as such in career and professional development schemes.

31 Pemberton, M. 2008. *The budgets compared: military vs climate security*. Institute for Policy Studies. http://www.ips-dc.org/getfile.php?id=131 (Accessed: 4 May 2010).

32 Parkinson, S. and Langley, C. 2008. Military R&D 85 times larger than renewable energy R&D. *SGR Newsletter*, No. 35, pp.1. http://www.sgr.org.uk/

33 Annan, K. 2006. Lecture at Princeton University. 28 November 2006. http://www.un.org/News/Press/docs/2006/sgsm10767.doc.htm (Accessed: 4 May 2010).

34 RAE. 2006. Response to *The Future of the Strategic Nuclear Deterrent: the UK manufacturing and skills base*. http://www.raeng.org.uk/policy/responses/pdf/Nuclear_Deterrent_Consultation.pdf (Accessed: 4 May 2010).

35 RAE. 2007. *Statement of ethical principles*. http://www.raeng.org.uk/policy/ethics/principles.htm (Accessed: 4 May 2010).

36 Pugwash Conference on Science and World Affairs. http://www.pugwash.org/

37 International Network for Engineers and Scientists for Global Responsibility (INES). http://www.inesglobal.com/

38 Rotblat, J. 1995. Remember your humanity. Nobel lecture, Oslo. December 10. In: Braun et al (2007). Joseph Rotblat: Visionary for peace. Wiley-VCH, Weinheim, Germany. pp. 315–322.

39 Dhanapala, J. 2007 (See footnote 25).

Indeed, a key aspect of being an engineering professional is to actively seek opportunities that have a positive impact on global problems such as war, pollution, poverty or climate change. This is the heart of social responsibility in engineering.

2.4.2 Engineering Social Responsibility

David Singleton

As engineers of the built environment, we have a significant impact upon the world around us. This is both an opportunity and a responsibility. The way that all of the world's inhabitants live, and the living standards that we have come to expect form a part of our quality of life, which in turn is influenced by the infrastructure around us; much of that infrastructure is shaped by our engineering.

Our challenge as engineers, now and in the future, is to provide infrastructure to rural and semi-rural communities in the developing world. Also, with increasing urbanization, we face additional challenges in terms of how we can economically provide infrastructure in new urban areas; how do we retrofit existing infrastructure, and how do we accomplish all this in a responsible and sustainable manner?

With half of the world's population now living in urban areas, urbanization has been and will continue to be a rapid process with virtually all the forecasted population growth in coming years taking place in urban areas in less developed countries. Forecasts for 2050 show that 70 per cent of the world's population will be urban; some 6.4 billion people will live in urban areas (the equivalent of the world's total population in 2004) and most of this population will be concentrated in Asia (54 per cent) and Africa (19 per cent). China will have the largest urban population at 1 billion in 2050.

Urbanization is generally defined as the process of growth as a proportion of a country's resident urban population. The terms 'urban areas' and 'cities' are often taken to mean the same thing, but urban areas include towns and other smaller settlements. For example, half of the world's urban population lives in settlements of fewer than 500,000 people, while megacities – generally defined as having rapid growth and a total population in excess of 10 million people – house only 9 per cent of urban inhabitants.

Arup[40] has carried out significant research into the forces of urbanization and we have a clear understanding of the impact of urbanization on society and the positive role that it can play in social and economic development. Concentrating the

40 A global firm of consulting engineers, designers and planners. http://www.arup.com

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Kyzyltoo water supply, South Kyrgyzstan – infrastructure in rural and semi-rural areas.

world's population into urban settlements gives sustainable development a better chance through economies of scale on various fronts. By contrast however, cities can draw together many of the world's environmental problems. Cities provide both an opportunity and a challenge in terms of infrastructure provision.

It is important to understand the challenges associated with urbanization and to see these in terms of opportunities for change. Long-term planning for urban areas needs to be considered holistically. Any town or city has many components or urban 'ingredients' and there are complex relationships between them such as: facilities, in terms of physical infrastructure; systems and utilities required by an urban area to function; services that urban residents need; and the desirable attributes an urban area should possess.

Whether in developing or developed countries, the physical infrastructure associated with urbanization is concerned with much more than basic services; infrastructure can make people's lives better, especially when viewed in terms of the service it provides. It is not simply about putting pipes and drains in the ground but about 'public health' through the provision of clean and safe water and sanitation, it is not just about designing and constructing good, safe and reliable transport but about providing 'accessibility' or even 'mobility' to employment and education and about determining and meeting the need to transport people and freight more efficiently. Good infrastructure makes people's lives better in the here and now. Accessible highways better connect towns and cities, effi-