Int. J. Engng Ed. Vol. 17, No. 6, pp. 496–501, 2001
Printed in Great Britain.

0949-149X/91 $3.00+0.00

The Status of Engineering in the Age of Technology: Part I. Politics of Practice*

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Historians of modern times characterise the world at the beginning of the 21st century as entering a new era, one principally defined by a constantly advancing technology. The place of the engineer in this new technological society, however, does not seem to be notable to the historical view. This paper argues that it is the changing base of industrialisation from production to consumption that has diminished the prestige and prominence of engineers; for the decision what to make to sell is not an engineering one. Engineering is now captive to managerial agenda driven by the market, and engineers exercise power only within that mandate. The paper proposes that, if the profession aspires to change this and to play an influential role in developments of this remarkable age, it must first acknowledge that technological action is now socially constructed. It then has to commit itself to rebuilding the foundations of engineering education on the central principles of human affairs as well as on its traditional attachment to the physical world. What is needed is nothing short of a new vision for engineering in the future, a radical shift in the culture of professional engineering.

INTRODUCTION

'THERE CAN be no serious doubt that in the late 1980s and early 1990s an era in world history ended and a new one began' [1]. Hobsbawm comes to this startling conclusion in his historical account of the *Short Twentieth Century, 1914 to 1991*. For Hobsbawm the third quarter of this remarkable century marked the end of the seven or eight millennia of human history that began with the invention of agriculture in the Stone Age. What he called the Golden Age from 1947 to 1973 had, for the first time in history, created a single increasingly integrated and universal world economy which ended the long era when the overwhelming majority of the human race lived by growing food and herding animals. By the end of the decades that followed, from 1973 to 1990 (his Crisis Decades), the world was incomparably richer, its population several times larger than ever before and its material transactions enormously increased. These few years, at the end of one of the most calamitous centuries the human race has ever known, saw an 'extraordinary scale and impact of . . . economic, social and cultural transformation, the greatest, most rapid and most fundamental in recorded history' [1]. The changes the world experienced were as profound as they were irreversible and, it seems, inexorable.

Johnson [2], also an historian writing about this tumultuous period, argues too that the world reached a watershed at the century's end. To him the century saw the testing, on a colossal scale, of Rousseau's ideas that human beings could be transformed for the better by a political process. The result was dreadful destruction of life and property, an utter failure of 'the engineering of society for lofty purposes'. Johnson cites the Chinese experience from the late 1940s in which Mao Tse-tung called for thought reform as a vital precondition for the thoroughgoing democratic transformation and progressive industrialisation of the country, promising a direct, immediate and essentially political solution to its plight. But experience exposed this belief as a fallacy [2]. In fact, continues Johnson, there are strong grounds for concluding that ideological politics was a primary contributor to human misery throughout the century. Now Mao Tse-tung and other 'social engineers'—Lenin, Hitler, Pol Pot, Honecker, Ceausescu, to name but a few—are largely discredited in history and execrated in their own homelands. Their horrendous failures have brought to an end this age of politics, and it has now passed, just like the age of religion before it. Thus Johnson too sees the emergence of a new age.

Both Hobsbawm and Johnson are clear about the main features of this new age. Hobsbawm's new world is one filled with a revolutionary and constantly advancing technology, one in which a global economy driven by this technology operates across state frontiers ('transnationally') and therefore also increasingly across the frontiers of state ideology. Johnson's world is characterised by a loss of faith in the state as an agency of benevolence, and disillusion with the ideas of socialism and collectivism. However, concomitant with this rejection of social planning, other developments 'not only advanced the frontiers of high technology, thus making possible the kind of long

* Accepted 9 June 2001.

distance space probes common in the 1980s and 1990s, advanced laser surgery and devastating military technology employed in the Gulf War, but also introduced mass-manufactured, low-cost devices which affected the life and work of hundreds of millions of ordinary people . . . Machines, often of astonishing complexity, now entered and often dominated the lives of the masses' [2]. In short, this new era is the age of technology. Technology, not religion or ideology, now holds centre stage in the affairs of mankind.

It is of great concern to this engineer, therefore, that neither of these eminent historians remark on, let alone explicate, the role of the engineer in this new world. In fact Hobsbawm seems to conflate engineering, science and technology in the main, content to acknowledge the role of 'technology' in producing the enormous triumphs of a material progress. Johnson uses engineering largely as a perjorative term in the sense of social engineering, although he does mention the part played by the San Francisco engineers Henry Kaiser, Henry Morrison and John McCone in raising America's arms production during World War II. These three became folk heroes for a time, and figured in wartime propaganda recitals of the tremendous productive capacity of the American economy, undoubtedly the real engine of the Allied victory. But in general neither engineers nor engineering appear in these histories as formative influences in a world that saw industrial production rise 1,730 times in the period 1705 to 1971 [2]. So, while individual engineers may earnestly relate to Tredgold's 1828 definition of engineering as the art of directing the sources of power in nature for the use and convenience of man, and while there is abundant evidence that such sources have been and continue to be 'directed' on a massive scale, learned opinion outside the profession does not seem to find the need for our inclusion in these great processes of fundamental social change. What has happened since Florman's [3] Golden Age of Engineering in the late nineteenth and early twentieth centuries when through increasing, and transparent, practice in the burgeoning industrial community engineers 'grew in prestige, power, accomplishment and self-satisfaction'? What is the nature of this new world in the age of technology wherein engineers do not rate a place in its history?

INDUSTRIAL MODERNITY

Veliz [4], in a fascinating comparison of culture and economy in English and Spanish America, argues that it is the creative vitality of an ongoing Industrial Revolution born in England that continues to shape our modern world. He claims that to describe the closing decades of the twentieth century as post-industrial is incorrect and misleading as well as inelegant! On the contrary, 'vigorous relentless change remains the characteristic *sine qua non* of the modern industrial ambit'. Veliz too sees the modern era as something entirely new in human history, proposing that 'at some time or another this century the world crossed a barely perceptible but real threshold into a period during which the cultural traits and artefacts generated by the English-speaking peoples, especially during their Industrial Revolution, have been consolidated as principal strands in the fabric of knowledge, affectations, beliefs and Tocquevillian ''habits of the heart'' on which rest the quality of our civilization' [4]. This industrial modernity, moreover, is not simply driven by a capacity to produce great quantities of goods at lower prices for distribution through an increasing and increasingly global market. Although Marx was convinced that the mode of production determined the general character of the social, political and spiritual processes of life, Veliz argues that the crucial problem of industrialism now is not how to produce things but rather what to produce. It is this fact that distinguishes the modern world. It is characterised by an immense flow of major and lesser innovations which ceaselessly adds complexity and diversity to the leading countries of a world 'that is certainly not tottering on the brink of dissolution' [4].

Expanding on this theme Veliz locates this ongoing, creative and vital Industrial Revolution in the USA. This primary centre of industrial modernity invests and produces, copiously and continuously, new cultural traits, artefacts and signifiers useful, acceptable or attractive to the great multitudes of the modern world. It is the immense variety of goods and services and their appeal to the mass of worldwide consumers that marks our society, so that rather than Marx's 'above all else . . . production predominates' we now have 'the dog of production is wagged lustily by the tail of consumption' [4].

I suggest that it is this fundamental shift in the nature of industrialisation that lies behind the disappearance of the image of the engineer as a mover and shaker in contemporary society. It is not because the engineered world is faltering towards a post-industrial twilight in which the technologies of the past merely provide a basic infrastructure on which other, more up-to-date, visions are rising. Indeed the reverse is true: the modern world is increasingly and ever more powerfully shaped by a revolutionary technology. Rather, it is the singular fact that what to make to sell is not an engineering decision. In an age when how to make something was primary to both ideology and industrial principle, the engineer was king (though very rarely queen!). Today the decisions to produce the manifold goods 'that satisfy someone's wishes, real or imagined, legitimate or contrived, elegant or tasteless' [4], are mostly beyond the power of engineers to influence. As a consequence, the engineering that empowers and permeates so many aspects of modern society

becomes all but invisible, and engineers themselves perform off stage, out of the limelight.

A CAPTIVE PROFESSION

A life in the shadows cast by the bright lights of the consumer world in this age of technology is, however, not really incongruent with what seems to be a characteristic absolutely intrinsic to engineering practice. Engineering, as a participant in technological action, is always one step away from the marketplace for its capabilities. While its contributions may have been more explicitly acknowledged in an earlier time, it has always operated under what Ferguson [5] calls the 'inescapable condition of engineering in all ages'; that is, patronage. Given the nature of engineering work, harnessing significant human and material resources to achieve a technological, commercially viable outcome that deliberately changes the physical world, the patron is essential in two fundamental ways. First, the patron or client establishes the intention, deciding on particular grounds what shall be done. Second, the patron provides the wherewithal to accomplish that purpose. Technological action is contingent on both. Unlike art or science there is no purpose to engineering without them. Decisions about the market for engineered products, at once declaring opportunity and justifying commitment, are thus removed from engineering work itself. It is the patron who energises professional work towards a specific goal, not what the engineer might know or can do.

Furthermore, these days the patron is most likely to be a large corporation. According to Winner [6] the social history of modern technology shows a tendency, perhaps better termed a strategy, to reduce the number of centres at which action is initiated and control is exercised. So while the consumer society is characterised by mass but individual consumption it is also characterised by many large, complex business and government enterprises which play a dominant role in determining what is to be consumed. The modern corporation flourishes in fact on the basis of the legitimacy it gains from its ability to provide a continuous stream of attractive goods and services for a mass of consumers. Such enterprises are the major employers of engineers and, if to this majority are added those working for kindred consultancies or suppliers, it is clear that most engineers work within a management structure dominated by the requirement to provide profitable operation of the consumer culture. What engineering is done within the corporate world is therefore determined by the wishes of the patron, expressed through managerial agenda.

To Goldman [7], it is this reality, the pervasive dependent state of professional engineering practice, that undermines the characterisation of engineering as the primary agent of technological change. Of the belief that engineering drives technology, a belief ubiquitous in the profession, he argues that it disguises the actual subordination of engineering to the institutional dynamics of technological action. To him technological action is a social process in which engineers participate rather than something engineers do. Furthermore, technological action itself is decision-ruled, non-unique (and therefore selective) and powered by managerial value judgements. He adds that the problems to which engineers respond, and the determination of what will constitute acceptable solutions to these problems, come neither from engineering nor from science, but from this managerial dimension of technology. By internalising the interests of the patron or the client, engineers thus become 'captive' to the social process of technological action. Their work and its effects are subsumed by the commercial imperative of consumption that drives that action. If power is understood as the ability of persons or social groups to accomplish their goals [6], it would seem then that engineers, as a group defined as possessing a special knowledge and skills base, possess little power to influence how that expertise is ultimately put to use.

POWER AND PRACTICE

Of course many, if not most, engineers aspire to and gain positions within the management structure of their patron company. The transition from an early focus on technical matters to a clearly management role, and a subsequent progression up through management ranks of increasing responsibility, is seen as a normal and desirable career development. With it goes higher status and remuneration. It might be argued, therefore, that engineers do find themselves in positions of authority from which their engineering will can be imposed. However, as Goldman [7] points out, the subordination of technical knowledge to the value structure of managerial decision-making is not changed even if the managers are engineers. As managers, they of necessity must represent the interpretation of value judgements in relation to the interests of those on whose behalf they manage. Even if the owner of a company is an engineer, the judgement of what might profitably be done must always override what might be seen as intrinsically technically challenging and interesting but without a market. It remains the patron's parochial conception of the value of technological action, rather than technical possibilities, that the engineer manager responds to. Positional power is held and exercised only on this mandate.

It could also be argued that, within a technology-based enterprise, the operating managerial agenda themselves will be conditioned and constrained, even if indirectly, by the knowledge base and particular technical attachments of the engineers participating in its technological

programme. On this argument the patron's decisions will in effect be circumscribed to conform to a particular technical culture, and the company's engineering elements, by defining that culture, thus exercise a form of influential power. There is no doubt that this happens, as is evidenced by persistent characteristics of certain brand name products. However, as Goldman [7] again notes, the determination of which direction development of a certain knowledge base will take, or which of a range of products will be realised, is made on the basis of economic, institutional, political, social and personal value judgements. Against these, technical fashions may be swiftly submerged.

There is, however, one feature of technological action that is often claimed to be driven by engineering. Goldman acknowledges 'the limitless cleverness of engineers' [7], remarking that there seems to be no point at which engineers will stop improving upon solutions to problems they have taken up. This fairly distinctive attribute of engineers creates another form of influential power, based as much on personality as on knowledge and expertise. The microelectronics industry provides many an illustration of this but even here, as Goldman says, the marketing strategies adopted by the patron companies are expressive of a deliberate and carefully calculated managerial restraint of the latent cleverness of their engineers. The so-called technological imperative, while no doubt deriving from clever ideas, is in fact always associated with a commitment, one that is essentially non-technical, to employ capital to exploit knowledge in a particular way. Engineers do indeed exercise power then, both positional and influential, but not as members of a group possessing certain engineering competencies. They do so rather as participants in patently political decisions. Engineering practice is deeply embedded in a decision-ruled, non-unique social process; it is fundamentally political.

THE POLITICAL ENGINEER

It is abundantly clear then that in the age of technology the power to direct technological action does not derive from knowledge bases located purely within its technical ambit, nor indeed even from the ability to manage that content efficiently. Technological action is dominated by the value structure of its decision level which in turn is a selective response to the values present in and shaping the life of a community. The 'community' at this century's end is increasingly global in its outlook and outreach and, also increasingly, has shown itself to be vastly attached to the 'habits of the heart' engendered by an ongoing industrial revolution. This is the nature of the engineer's world. Modernity thrives on perpetual technological change driven by a manner of conceiving the world to which, indisputably, engineers in the past have made enormous contributions, but engineering practice is now conditioned by the integration of technical knowledge within prevailing personal and social values and their institutional embodiments [7]. But engineers themselves do not seem to place their work in this basically political context.

Outside the profession the contribution engineering makes in contemporary society appears to be even less clearly apparent. According to Goldman [8, 9], engineering has long been treated with condescension in western culture and this continues today, even among those intellectuals who have discovered the cultural significance of science and, very recently, of technology. Perhaps it is this neglect that has led to two popular characterisations of modern engineering—as applied science and as the primary agent of technological change—both of which misrepresent its theory and its practice. Neither recognises the essentially political nature of engineering practice. Perhaps it is not very surprising after all then that scholarly interpretations of history might also not distil a distinctive intellectual framework for engineering *vis-à-vis* science and technology. Instead of occupying an honoured place in the history of this most remarkable century, could it be that that special species, the engineer-as-engineer, is in danger of extinction in the minds of both engineers and of observers outside the profession? For engineering too seems to be at a watershed.

If we are content to define our role as instrumental problem-solvers, setting our expertise in a derivative technical and management ambit, we can reinforce our existing relationships with society. In a world whose basic social fabric is more and more intricately woven of technological threads we become the specialist makers and fixers of that cloth. As a profession, our training and ethos already fit us well for that role. The future holds enormous challenges and exciting technical opportunities as the ongoing, creative and vital Industrial Revolution transforms our global communities. We will certainly have a place in that world, but perhaps not in its history. For the fate of engineers in contemporary society shows that knowledge is not power. We will not be in a position to determine what our fine cloth will be used for.

On the other hand, if the profession aspires to a formative role in that society, to have a powerful influence on the way our particular expertise might transform it in the future, it may have to redefine its relationships with this society. If we choose this second path, accepting that it is our responsibility to participate fully in decisions about what shall be made of the technological cloth, then two things are clear. Firstly, the necessary initiatives for change will come only from within engineering itself. Secondly, the outcome of the process of change could be a substantially transformed profession. In fact, much of our heritage may have to be respectfully retired as we create a new vision for engineering in this age of technology.

But where do we begin and where might the future take us if we choose this path?

TRANSFORMING THE PROFESSION

In Veliz's industrial modernity it is the modern corporation, through which technological action is energised towards specific goals, that is the primary driving force in the creation of the material and cultural forms and attachments that so characterise our times. Furthermore, it is the corporation that now mostly provides the intention and wherewithal for engineering work, so if we seek a locus for the political transformation of the profession it is to our place and future within the corporate structure that we must look.

Schein [10], in searching for explanations for the failure of some (most) organisations to learn how to learn, finds that in every organisation there coexist three particular cultures: the operator, the engineer and the executive. He defines a culture in this circumstance as 'a set of basic tacit assumptions about how the world is and ought to be that is shared by a set of people and determines their perceptions, thoughts, feelings and, to some degree, their overt behaviour'. A culture manifests itself at three levels: deep tacit assumptions, espoused values and day-to-day behaviour. Schein sees two elements in the formation and style of the three separate cultures in any organisation, one arising from the unique experiences of its members as it comes into being and develops and the second arising from what he calls 'occupational communities' that cut across organisations. He believes the engineering culture in most companies is strongly influenced by the second of these. He also believes that much of the failure of certain corporations to thrive can be laid at the feet of dysfunctional interactions among the three cultures. They do not really understand each other very well and often work at cross-purposes. Perhaps here too lies the specific reason for the diminished power and influence of the engineering profession in contemporary industrial society. Its shared outward focused set of assumptions, values and behaviours is basically dysfunctional in the modern corporation. As a consequence, it is politically ineffectual and increasingly sidelined in the determination of directions for technological action.

The essential character of this cultural dysfunction was captured succinctly by Schein in his reporting of a sign in the parking lot of a company that did have a dominant engineering culture: 'Maximum Speed Limit—5.8 miles per hour'. Expanding, he describes the engineering culture:

> *Engineers and technocrats of all persuasions are attracted to engineering in the first place because it is abstract and impersonal. Their education reinforces the view that problems have abstract solutions and those solutions can, in principle, be implemented in the real world with products and systems that are free of human foibles and errors. Engineers, and I am using this term in the broadest sense, are designers of products and systems that have utility, elegance, permanence, efficiency, safety, and maybe, as in the case of architecture, even aesthetic appeal, but they are basically designed to require standard responses from their human operators, or, ideally, to have no human operators at all [10].*

Set against this is the reality expressed by O'Brien [11], in a series of essays about character and the corporation, that, in matters of corporate and institutional governance:

> *Since it is people who make the decisions and perform the actions that determine a company's results, human beings are the most important influence on a corporation's performance in the competitive market place and consequently on its long term financial achievements. Thus, there should be better understood principles for their governance and development as there are for deciding financial and physical matters [11].*

Here then is the nub of the transformation. The profession has to attract in numbers people whose primary concerns are 'the central principles of human affairs by which we choose to live our lives and guide our organisations' [11]. The outline of the divide at the watershed where the profession now stands is thus very clearly defined. On one side lies familiar territory in which the dominant features are composed of a bedrock of the physical sciences, interpreted through mathematical abstraction, overlain with technological know-how and capped with operational management skills. This country in the past has been attractive to generations of would-be engineers but not so congenial to travellers of other persuasions. The topography on the reverse slope, on the other hand, is much more varied. Its base rock is a conglomerate of both the physical and social sciences, cemented together by the social determinants of technological action. It carries a thick cover of professional good practice deriving from responsibly placing technical capabilities within the prevailing social context. The top layer here is commitment to good governance and human development, a commitment to do the right thing as well as to do the thing right. Furthermore, this side of the divide is crowded and cosmopolitan and many different voices compete. To transform the profession to give it too an influential voice in industrial modernity, it is to here that engineering education needs now to shift and rebuild its place for the future. Residing here, engineering education promises to create a new breed of professional, from the beginning deeply attached to the 'central principles of human affairs' as well as to the potential for human material advancement.

AN EMERGING CULTURE

If we choose to follow the second path, through what to many is still a mostly unfamiliar territory, inevitably we embark on the generation of a new

culture for engineering. We have defined ourselves throughout the generations that have led up to this new age principally in terms of our material achievements. In a sense we have been resolutely apolitical, inclined to seek legitimacy in what we can design and produce. Our loyalties, as members of one of Schein's occupational communities, have been to ideals of technical excellence that have universal appeal and, we thought, both universal and particular relevance. The engineering departments of the companies and instrumentalities that employed us in large numbers were safe havens in which career progression was orderly and respectful of our technical competence. But modern corporate roles demand something quite different and it is apparent that we either seize the new opportunities or become increasingly powerless. Our new and emerging cultural identity must be rooted in the realisation that technological developments in the new age begin and proceed in the political context, one not defined in the narrow sense of party politics or government action but, in a much deeper way, in the sense of connection with the very life of an ordered community. We surely must retain our allegiance to technical excellence but our assumptions, values and behaviour must now also be 'congruent with the basic, deeper and higher attributes of human nature' [11]. We must reach out to engage this astounding world in a fundamentally political way.

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