move into the INDEST-fold. This is easier said than done. A move is on to persuade UGC-affiliated institutions to join hands with INDEST. However, unless the peculiar needs such as the bouquet of journals in type of subjects and other infrastructural requirements for hosting INDEST, of proposed invitees such as universities are met, convincing more members to join would prove an uphill task. In its present structure, INDEST does not cater to the needs of medical professionals, agricultural scientists and many others. The consortium does provide the possibility of raising library access from about 100 e-journals to nearly 4000 from among the selected list of publishers that provide largely for engineering disciplines. Being very much in a fledgling stage, there have been several concerns raised about INDEST from within its own members; for example, the management institutes. There are, of course, several access restrictions that have been negotiated feverishly with publishers for each category of INDEST members. The bargaining chips are still on the table, and more the number of INDEST members, greater is the bargaining power and higher business volumes for publishers. Sustainability of the whole exercise is an important aspect, and then there is the big question of whether 'teamwork', so much lacking in the Indian psyche, would finally jettison the consortium. INDEST, in order to perform its administrative mechanisms for tackling the needs and issues ahead, has a poorly oiled machinery with its headquarters located at Delhi, while the coordinator behind the effort is located at Mumbai and so on.

Now, a final thought. 'What happens on withdrawal of service – temporary or otherwise, to the state of libraries?' This is anybody's guess. However, INDEST appears confident and does not foresee such a calamity, while sceptics abound on the periphery.

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Mashelkar elected Foreign Associate of US National Academy of Engineering

R. A. Mashelkar, Director-General, CSIR, has been elected Foreign Associate of the National Academy of Engineering, USA, in recognition of his 'outstanding engineering contributions and exceptional leadership and management of the Indian national laboratories'.

The election to the National Academy of Engineering is among the highest professional distinctions accorded to an engineer. Only 165 Foreign Associates from around 30 countries have been so honoured in the last 40 years so far. Only three Indian engineers have received this prestigious honour so far, namely late Dr Satish Dhawan, late Dr Jai Krishna and Dr R. Narasimha.

MEETING REPORT

How to live with the Genie: Toward meaningful governance of science and technology[†,*]

My cousin is a doctoral student of environmental policy at a major research university in the United States. An engineer by training, he has most trouble explaining his research to fellow Indians. In a university where there are no fewer than half a dozen students of Indian origin in each engineering department, he is the sole Indian student in his doctoral programme. Fellow students – typically engineers from the best of India's colleges – when told that he investigates the role of policy in governing the environment, science and technology, ask with disdain or sympathy, 'Why would anyone do that?' 'Will you get a job after you finish?' and, worse, 'You really wanted to come to America!' Such incomprehension of the motivation to study policy, let alone understand policy, from Indian engineering graduates who otherwise fill classrooms in American universities, write abstruse code in the Silicon Valley, design the next-generation devices, work for Fortune 500 companies, and are celebrated for their intellect[1], is compelling, albeit anecdotal, evidence of the failure of Indian engineering education to produce multidimensional individuals.

I was no different four years ago when I arrived in the US to start my Ph D programme at the Pennsylvania State University. Indeed, as I wrote somewhere else, 'Technology, as I knew it from a scientist father and as an undergraduate student of chemistry at the University of Delhi, was an integral and powerful constituent of the Western model of development. Technology, indeed, was a necessary response to the world's myriad [2]. Fate, however, intervened and I took a course whose instructor, Carl Mitcham, then a professor at Penn State's Science, Technology and Studies Program, was influential enough to persuade

†Dedicated to my mother, Sujata Venkateswari, who let me, albeit grudgingly, read everything but textbooks.
*A report on the conference 'Living with the Genie' held at Columbia University, New York City in March 2002 and organized by the Centre for Science, Policy and Outcomes.

me to take a close and hard look at the fundamental and philosophical basis of technology and its impacts on society. I am fortunate that Mitcham has since mentored and inculcated in me a lasting commitment to science, technology and society (STS) issues, even as I continue to practice engineering research.

Living with the Genie

The pursuit of this commitment took me to Columbia University where the Center for Science, Policy and Outcomes (CSPO) was organizing 'Living with the Genie' (hereafter, the Genie). The Genie's theme was the question: '[I]s the immense transformational power of new knowledge and innovation governable by society through reflection or choice, or must we accept the contrary, that to a considerable extent this power will always govern us?'[3].

Ordinarily, the Genie would have been called a conference. After all, numerous scholars, academicians, policy makers and analysts, administrators and students had gathered to exchange views and ideas. However, '[t]o encourage new ways of thinking about this question and the myriad [and multidisciplinary] issues it implicates,' the organizers called it an [4]. And an event it was. The Genie was set amidst artistic and philosophical interpretations of the technology–society interface. For example, registration involved scanning one's palm which generated a supposedly unique barcode. In another case, seated along with the panelists was a human in a hazardous waste-handling suit. Also featured during the conference were high-tech forms of art and music, virtual reality terminals, and a short but compelling film to set the Genie's agenda.

The Genie sought 'no prepared talks' and instead emphasized the need for 'spontaneous explorations.' The crux of the Genie was a set of six 'conversations', each of which had six panelists and one moderator. Together, they created a discourse that set the agenda for a series of informal participant discussions between the conversations. These conversations along with several papers and other resources are available on the event website (http://www.livingwiththegenie.org). Here, I present glimpses of the Genie because it seems as relevant – perhaps, more important – to India as it is to the developed world.

Lessons from the past

The first conversation asked, 'What can we learn from past scientific and technological transformation of society?' and if 'human choice [was] reflected in the scientific transformations that have continually remade society'. Kathy Schick, Professor of Anthropology at the Indiana University, said that the historical growth of science and technology has been predominantly reactive and a response to the growing presence of science and technology in human life. Schick noted that the incorporation of science and technology in human society and life started about two-and-a-half million years ago with simple origins in stone tools. The implications, however, were not simple in that the tools enabled hunting animals and incorporated protein in human diet. The increased protein consumption has since tripled the size of the human brain, making it one of the fastest growing organs in the history of life on earth. Of this time period, the last 40–100,000 years have seen social and technological progress, as derived from the organization of languages, ethnicities and countries ('software change'), outgrow biological or 'hardware change' in humans.

While fathoming the implications of the use of tools might have superseded the intellectual capacity of the original humans, we now know that science and technology can transform into systems and embed themselves into our lives quickly and rapidly. Daniel Sarewitz, conversation moderator and managing director, CSPO, wondered if specific examples existed when conscious effort might have changed the course of science, either during its evolution or once it had been embedded in human life.

Shiv Visvanathan from the Centre for the Study of Developing Societies in Delhi responded to this forcefully by refusing to view the embedding character and similar 'negative aspects' of science and technology as 'externalities' of the research process which can be fixed or repaired. For Visvanathan, science is an 'organized evil' whose manifestations amongst others include the 60 million refugees from dams in India that at one point of time, along with scientific laboratories, were 'temples of modern In

Bill Joy, Chief Technology Officer of Sun Microsystems, did not share Visvanathan's opinion of modern scientific research. But he demanded that science take responsibility and felt that its practice needs 'therapy' to become more sensitive to the human enterprise. This is vital because scientific research and innovation are governed by market mechanisms, which fail miserably when end-products cannot be monetized. Joy also convincingly argued that laws (and perhaps policies?) alone would not change or influence science or technology, because the latter evolved faster than the former.

Joy has always evoked curiosity amongst science policy wonks mainly because of the contradictions that he purportedly lives for. Here is a man whose designation – Chief Scientist, Sun Microsystems – epitomizes the intellectual brilliance that created the Silicon Valley, which Joy celebrates as the 'largest legal creation of wealth'. Even so, he is also Silicon Valley's most famous dissident who said that humans could soon become an 'endangered species' because of futuristic technologies such as robotics, genetic engineering and nanotechnology[5].

The first conversation ended on a more optimistic note when the panelists agreed that present-day science and technology and their practitioners had a much higher level of interaction with society compared to the past. Visvanathan urged intensifying this interaction and said that the biggest contribution of the United States was not the Silicon Valley, but instead the 'dissenting movements' of the 1960s such as the publication of Rachel Carson's *Silent Spring*. These dissenting movements altered 'democratic imagination' by provoking independent thought all over the world. Such a climate, in Visvanathan's mind, nourished diversity, protected pluralism, and accommodated cultural differences, all of which enable socially meaningful practice of science and technology.

Whether social discourse had influenced science and technology came up at other instances as well during the conference. Ray Kurzweil, inventor, author and winner of the 1999 US National Medal of Technology, did not buy the argument that the march of science and technology had been influenced by societal interventions. He cited his studies which have only smooth, progressive curves for science and technology, irrespective of cultural upheavals along the path. George Rupp, President, Columbia University, found Kurzweil's claims 'incomprehensible' and asserted that culture did influence science and technology.

What and how good is our control?

In my view, the Genie was a remarkable success because of its ability to meld the philosophical with the tangible. The STS movement is based on deep philosophical questions, while science and technology are about the development of tangible goods and products. For a science practitioner like me, reconciling these apparently contradictory objectives has been the intellectual challenge. To a certain extent, the Genie provided methods to reconcile these contradictions. For example, some conversations sought 'take home' messages that could be implemented (e.g. 'What research should we be doing?'). Other discussions focused on the philosophical portents of science and its relation to society (e.g. information technology 'enhances cultural understanding . . . and informed decision-making' or 'reduces attention spans, erodes communities' and transforms everything into a commodity). A few philosophical ideas from the latter three are presented here.

The second conversation attempted a description of the 'world we are now making' with our science and technology. Richard Rhodes, a Pulitzer Prize-winning author, thought that the world was a much better place thanks to science and technology initiatives such as public health. Alan Lightman provided a defining counterpoint by suggesting that improved human longevity need not necessarily equal improved quality of human life. Lightman, a physicist and a faculty member at the Massachusetts Institute of Technology, set the tone by refusing to equate technology with progress and questioned why the latter should be an 'ordained imperative of our species'.

Thomas Odhiambo, who is an Honorary President of the African Academy of Sciences, forcefully asserted a similar idea. He lamented that science has become too 'rational' and its practice has been reduced to another profession. Such practice of science to achieve the 'good life' as measured by material progress was a gross distortion of the philosophy of original scientists like Charles Darwin who viewed their work as an 'experiment

Odhiambo was concerned that the present approach was divorcing scientists and science from 'the spirit', whose manifestations were peace, love, compassion and tranquility. The 'spirit' or that which cannot be explained by rational science had sustained Africa through its history of '500 dark years'. Odhiambo, however, explicitly asserted that his definition of the spirit had no religious connotations whatsoever. Lightman also sought to explore the spiritual and psychological effects of technology on 'personal, inner lives'. Lightman bemoaned the lack of ace' and wondered how different cultures could 'listen' to each other when there was 'no silence' within individuals. As he exhorted 'slowness' in modern life, he echoed the famous American poet William Henry Davies who wrote in his poem, *Leisure*:

> A poor life this if, full of care,
> We have no time to stand and stare.

Although Odhiambo strongly disapproved of the current practice of science, he did not advocate that it be 'junked' or abandoned. Instead he urged for the development of an alternative pathway that allowed space for 'the spirit' in concurrence with current practices. Lightman thought that such an alternative pathway had to come from the people because only bottom-up solutions could become systemic.

In many ways, Lightman and Odhiambo seemed to be asking what and how good our control experiment or baseline values were. If science and technology and their products were to become universal and absolute indicators of progress and the 'good life', society had a bad control experiment because knowledge of a life where science and technology were less ubiquitous was unknown, thus precluding an objective analysis of the present.

Susan Greenfield, Director of the Royal Institution of Great Britain, refuted that the past was not as romantic as it was often portrayed. Greenfield then mounted a spirited defence of science and its practice as a great achievement that eliminated 'drudgery' and presented mankind with tremendous promise and opportunity for growth in 'individuality'. She spoke with genuine passion for improved scientific literacy and thought that it was necessary for people to know what a gene was 'in a non-hysterical' manner before 'vilifying GM (genetically modified) foods'. She said that the common man was truly curious about science and better ways to whet that appetite must be found. One specific example would be 'science theatres' as popular avenues for entertainment, competing on an equal footing with the movie and concert theatres.

'Some conventions the US should consider ratifying . . .'

The entirely global character of the Genie was the perfect mix for repeated and extended debate on the effects of globalization on science, which is more often than not manifest in the arguments over patents and intellectual property rights. A serious discussion of these issues transcended at least three conversations, while brief references occurred during all.

Mitchell Kapor, founder of Lotus Development Corporation, which popularized computers in the business world through its spreadsheet application, Lotus 1–2–3, said that 'intellectual property' was an 'oxymoron' because property is a tangible object, while most intellectual property relates to the intangible. Kapor highlighted the development and commercial success of Linux, an operating system, as a watershed in the history of intellectual property and the concept of ownership. Linux, unlike most software, has a code that can be freely accessed and modified.

Kapor felt that such a method of ownership was a great leveller and provided affordable access to technology in countries like China and India. He suggested that the voluntary cooperation, which popularized Linux, should be created and encouraged in other fields to enable wider application of the Linux model of ownership. Richard Jefferson, Chief Scientist at the Center for the Application of Molecular Biology to International Agriculture, Australia, was unsure if the Linux ownership model could be readily transferred to other fields because research and innovation in areas like agriculture were costly, while writing software code often requires no more than 'pepperoni pizza, a bottle of Mountain Dew, and some time'.

Nevertheless, Jefferson agreed that the Linux model of ownership could become a great leveller and more. He said that 'almost all core technologies in agriculture' were developed in publicly-funded institutions such as universities and national laboratories but transferred, in some cases on an exclusive basis, to multinational corporations 'because of the lack of strategic oversight'. Because of such exclusive ownership, farmers are being precluded to innovate agricultural technologies to suit their specific needs. Farmers need this 'capacity to innovate' instead of a mere 'capacity to use', because agriculture is 'incredibly culture- and locale-dependent'. The Linux ownership model, if applied to agriculture, could have the potential to provide this 'capacity to innovate'.

Carl-Gustaf Thornström of the Swedish Biodiversity Centre shared Jefferson's position and argued that the idea of patenting 'resources earlier in the public domain', such as agricultural products and practices was 'morally, ethically and even technically questionable'. For example, golden rice was owned through at least 16 patents and 72 instruments of intellectual property[6]. Because of such extensive protection, it took extensive negotiations and efforts before it was made available for licensing at no cost. Instead of patents to ensure property rights in contentious areas like agriculture, Odhiambo exhorted community ownership of biodiversity because such 'co-owning' would prevent the patent office from having to make bioethical decisions and thus, becoming the 'new church', in the words of another panelist.

Kapor recognized that patents, as a form of ownership, were debated even during the US Constitutional Convention in 1787, when private ownership of intellectual property was deemed as the path towards technological development. He, nevertheless, identified the patent system as a major inhibitor for equitable distribution of the products of science and technology. Kapor felt that one way to make the patent system more useful was by reducing the validity of patents from 17 to three years. Three years, in Kapor's view, was sufficient to determine and realize the value of the work's commercial potential, if any, existed.

Thornström suggested a more 'democratic control' of science policy in such issues. When Sarewitz asked of the role of the US in such 'democratic control' mechanisms, especially because over 50% of all public funding of science occurs in the US, Thornström almost coyly responded by saying, 'there are some conventions that the US should consider ratifying!' The US is yet to ratify the Kyoto Protocol, the Convention on Biological Diversity, and the International Treaty on Plant Genetic Resources. Jefferson felt that international governance of such issues needs informed scientists because, in his mind, 'the ignorance of the public on issues like the Trade-Related Aspects of Intellectual Property Rights (TRIPS) was only exceeded by the ignorance of the scientists'.

The 'take home' message

The last conversation asked, 'How should scientific and technological progress be governed in the modern world?' More specifically, Sarewitz began by asking the panel to identify principles that ought to play a central role towards governance of science and technology. Lori Andrews, a Visiting Professor of Law at Princeton University, felt that although science and its direction were governed in some ways by funding (e.g. research budgets), regulatory approval (e.g. for new drugs), and the markets (e.g. how successful a new product or device is), a greater influence must come from values and a democratic and inclusive process. Others referred to Gordon Conway, President of the Rockefeller Foundation, who said that his institution had decided to use six values in their work, namely (a) equity and fairness, (b) diversity, (c) participation and self-governance, (d) knowledge and its usefulness, in particular, Third World relevance, (e) humility and respect, and (f) dignity.

Although Andrews urged the need for values to govern issues such as research funding, she was skeptical of its success because, in her mind, the question was not 'where the money comes from . . . but *who* uses the money'. She was concerned that the band of 'objective scientists' was fast depleting. Andrews was comfortable with scientists advising companies, but dubious of those launching start-up companies based on publicly funded research. In such cases, she thought that society should view itself as a large pharmaceutical company and demand returns on its investment of tax money in publicly funded research.

Similar doubts about the research process were raised at other instances during the conference. Jefferson said that scientists would tend to 'define problems in terms of what they can solve, not what needs to be solved'. Lea Volho, a professor at the University of Campinas in Brazil, said that this led to the increasing irrelevance of her nation's scientific capacity. India too suffers from this problem. After all, 'Indian science produces nuclear weapons, launches satellites and develops number-crunching supercomputers, but it fails in keeping its slums clean, providing clean drinking water to its rural population, and ridding its cities of pollution'[7]. To a certain extent, Volho felt that such irrelevance stemmed from the dependence of scientific advancement on the sole professional metric of publications in reputed Western journals. Jefferson said that scientists tended 'to ignore the development of methods' as opposed to the 'act of gathering knowledge', which was perceived as 'elite' and pure.

One of the last questions asked was, how research funding could be directed based on societal outcomes. John Podesta, a lawyer, who, as Chief of Staff to the US President Bill Clinton, was intimately involved with the highest level of decision-making, said that there are few processes or institutions to guide public R&D funding. Podesta said that it was difficult to expect such direction to come from political institutions because of the complexity and speed of technological research. Research funding in dollars was the only 'metric' guiding decision-making at political institutions.

The results have been discouraging even when the money and infrastructure were available to enable decisions based on outcomes of research programmes. For example, the US National Nanotechnology Initiative began with the explicit commitment to provide resources for the investigation of the societal impacts of nanotechnology. Yet, the funds remain underutilized because institutions that typically pursue nanotechnology do not have the people or culture required to examine societal impacts of a scientific discipline. This is a good example, in Dan Sarewitz's words, of how the 'top down' approach was not enough to stimulate truly meaningful thinking about the impacts of science on society. Podesta agreed and, referring to CSPO, quipped that think-tanks in Washington, DC, asking scientists to reflect about ethical and legal issues, said a lot about scientists!

Personal reflections

Podesta's half-humorous remarks could not have been truer. H. Radford Byerly, who spent years working with scientists as the former Chief of Staff to the House

Committee on Science and Space in the US Congress, was more critical: 'Of course, scientists believe they are serving the public interest, with no curiosity as to what the public interest actually is – an assumption will do just fine. . . . It is very convenient for scientists to assume that doing good science is the whole of their professional responsibility. In my work I saw that scientists were skeptical about everything, except the assumptions and values underlying their work. Believing that good things happen automatically if basic research is funded, they feel free to, and do, chastise anyone who questions this belief. . . . So scientists choose the problems they work on based on scientific interest rather than societal relevance. . . . Scientists justify their requests for Federal funding with the standard argument that doing good science is sufficient . . . Eventually I came to see scientists as a special interest . . . [Science] does not scrutinize itself . . . and objects to others doing so. Yet such scrutiny is sorely needed. . . . [G]ood science . . . has to mean more than scientifically good, it has to mean also socially good, including useful, open, usable, accessible, timely, ethical, accountable: all qualities foreign to science policy'[4].

As an active practitioner of science, much as Byerly's comments prick, I have to agree with them. I chose the discipline I currently practice because it aroused my curiosity and offered me an opportunity to do applied research and not because it satisfied some fundamental value or outcome that I cherished deeply. Of course, scientists do take positions on the social implications of their research, but it is more often than not after a research problem has been chosen.

Indeed, Carol Greider, a professor in the School of Medicine at the Johns Hopkins University, when asked what values led to her research subject, almost hesitantly said, 'Curiosity'. She added that the value of thinking about societal values and outcomes in conducting research was completely foreign to the scientific culture. The interest that she had in STS issues was a 'fluke' that happened after President Clinton appointed her to the National Bioethics Advisory Commission. Furthermore, her STS interests were not even visible, let alone appreciated or encouraged by her peers.

There are, of course, honourable exceptions, two of whom shared space with Greider in the third conversation. Eva Harris and Ignacio Chapela from the University of California at Berkeley chose research because of their strong potential to contribute to values dear to them. Harris works on the dengue virus because very few are investigating it and the two-and-a-half billion at risk live in some of the poorest countries with limited scientific capabilities. Chapela, who works on transgenic crops in Mexico, is motivated by the desire to help marginalized people live better lives. Harris recommended the creation of 'space' where STS issues could be raised by scientists without the fear of being seen as 'suspicious' and urged funding agencies to formulate programmes driven by values instead of 'vested interests'. While Chapela shared Harris's empathy for the marginalized, he also thought that scientists should be allowed to ask questions irrespective of their societal outcomes.

My interest and desire to study and think about the philosophical and societal implications of practising science and technology is, hopefully, evident from this report. As Kurzweil said, science is too important to be left to the scientists alone. All the same, I was surprised to find myself subconsciously cheering Greenfield and Kurzweil, both of whom presented strong and spirited briefs for science. I too shared Kurzweil's fears that STS concepts might be interpreted in the future in an 'overly narrow' manner, creating 'fundamentalist humanists'. After all, today's fundamentalists, e.g. those who terrorize in the name of religion, follow texts 'that were never intended to be

I was surprised, almost taken aback, by my intense and spontaneous support for Greenfield and Kurzweil. Was I just another scientist whom Byerly had chastised so cogently, with my STS interests being only skin-deep and nowhere close to that of a free-minded aficionado? Or, like Vasudha Narayanan of the University of Florida, was 'Pollyanna' my middle name too, in fond hope that science and STS studies could co-exist and complement each other? Although these questions might have, if at all, no quick answers, I comfort myself with the thought that, perhaps, raising these questions by itself constitutes the answer or, at least, a part of the answer.

India has traditionally been much closer to the values articulated at the Genie as critical for meaningful governance of science. For example, both Indian panelists Visvanathan and Narayanan spoke of the country's diversity. Visvanathan spoke about the success Indian agriculture had in retaining 40,000 varieties of rice compared to six from the 160 kinds of apples that the US started with. In writing this report, I have drawn hope from Andrews, who said that developing nations were the most receptive to futuristic designs and plans because, devoid of vested interests, they were fearless to experiment. India, hopefully, will learn from the ambiguous experience with unbridled technological progress of the West and inculcate a strong commitment to ethics and values in its scientific agenda.

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