too have worshipped at the shrine of science' – and he was sensitive to the character of scientific knowledge both as a part of human culture and as the base for technological applications. Added to all this was a passion for quality in expression and achievement, an aesthetic sensibility which manifested itself in diverse ways.

To become an institution worthy of such a splendid personality – that is the challenge before the Jawaharlal Nehru Centre for Advanced Scientific Research.

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COMMENTARY

India 2015: A strategic perspective*

K. Sundarji

There are a number of theories that are being projected about the type of world order that is likely to prevail in the 2000s.

The demographic explosion model

This model is based on the prolific black, brown and yellow races exploding inexorably, AIDS and other pestilences notwithstanding. The expectation is that the demographically high-pressure areas of Asia will expand into the low-pressure areas of the Americas, Australasia and Africa, and that genteel actions like amending immigration laws cannot control this type of influx, and the use of force, including weapons of mass destruction (WMD), might be resorted to. This would lead to revolutionary changes in the world order.

The ecology-based model

The ecology-based model, among other things, assumes that demographic explosion would compound ecological disaster. Following from the aftermath of global warming, the ensuing worldwide drought and the submersion of large areas of coastal and island land mass would lead to a shortage of food, water, etc. These, it is expected, will lead to bizarre partnerships among nations and *water wars,* resulting in a drastic rewriting of the rule book.

The powershift model

The powershift model that Alvin Toffler describes in his book *Powershift*[1] is postulated on the outcome of a totally new way in which the world produces wealth and the comprehensive reorganization which would be called for. Toffler compares this with the revolutionary changes that accompanied the shift from the hunting society to the agricultural society, and later to the industrial society.

Model based on a clash of civilizations

The model is based on the clash of civilizations, a theory that Huntington postulates[2]: He says of future conflict, 'My hypothesis is that it will not be primarily ideological nor primarily economic. The great divisions ... will be cultural ... The clash of civilizations will dominate global politics. The fault lines between civilizations will be the battle lines of the future'[2] He looks at civilizations as Western Christianity, Orthodox Christianity, Islam, Confucian and Hindu. He anticipates a tactical accommodation between the Confucian and Islamic civilizations. The Hindu is not so drawn to the Confucian–Islamic, and may be drawn towards the Western Christian.

What models determine international relations during the 21st century is not fully relevant for any short-term forecast We ought to extrapolate from the present, bearing in mind that major changes may occur later. The conclusion drawn by Lind, the Editor of *National Interest*, appears to be the best one to follow. He writes[3], '... the world is not entering an era of harmonious global interdependence and genuinely liberal democracy. While the stakes will be lower, global competition will increase geo-economic competition between the leading economic powers will interact in complex ways with geo-political competition involving them with less prosperous but militarily significant great powers .... In the most advanced industrial nations, the new catalytic state, by its very nature, will encourage the evolution of technocratic elitism. while in the newly marketizing great powers, such as Russia, China and India, authoritarian legacies along with geo-political and developmental imperatives will probably produce variants of plebiscitary or dominant party democracy.'

World order 1995–2015

During the period 1995–2015, the USA would be pre-eminent even in a multipolar world. We will have to assess USA's aims and policies We have to 'guesstimate' the aims and interests of China, Pakistan and India during the period

US aims and policies

The ideal strategy would be under the leadership of the USA:

- The USA and Russia cut back their nuclear arsenal to 10% or less of their original levels.
- Ukraine, Kazakhstan and Belarus are denuclearized.

*Based on a Lecture delivered at the Diamond Jubilee Meeting of the Indian Academy of Sciences on 2 December 1994

- Nuclear arsenals of China, Britain and France are capped
- All the five *legitimates* subject themselves to a universal fissile material cut-off. They accept a non-discriminatory comprehensive test ban treaty, and agree to 'no first use'. They place their nuclear forces under UN control.
- It is ensured that the UN Security Council is not hijacked by a big power or the coterie of a big power to subserve its parochial interests rather than the interests of international justice, by stipulating that military force can be used under UN auspices only if four out of the five veto powers actually vote to do so. Legislation is needed to prevent any single country from commanding any UN force set-up to enforce such intervention The Council should be prevented from being held to ransom by the unreasonable veto of any single country possessing the veto. The veto should be effective only if three out of the five veto powers use it.

These steps would be a big forward movement towards confidence building in the world. It would not place the big powers totally at the mercy of small and perhaps irresponsible powers, nor would it subject totally the powerful minority to the 'tyranny of the majority' of weak nations. Without such an assurance, no agreement would be acceptable to the big powers, and we ought to be considering only the possible and not the utopian for the present.

Lind[3] believes that the world's leading industrial democracies are restructuring themselves as catalytic states, while developing countries and ex-socialist states are abandoning command economics He writes, 'World politics in the 21st century will be complicated not only by the rivalries between catalytic states, but by shifting combinations between catalytic states and those developmental states which remain or become great powers. In this world environment, the United States can attempt to pursue either a 'neo-internationalist' strategy, forestalling geo-economic and geo-political rivalries among North America, Europe and Japan, or a 'neo-nationalist' strategy, which would be more or less openly mercantilist and unilateral'. He goes on to state that because the US lacks the economic resources and political will for the former course, it is almost certain to follow the latter strategy[3].

We cannot be sanguine about the USA adopting a wise and statesman-like policy in setting an example with a drastic nuclear weapon run-down in the short haul, along with a credible promise of working towards universal nuclear disarmament in the future Though the USSR has disappeared, cold war strategic concepts in the USA are likely to take considerable time to change. The University of New Mexico's Institute for Public Policy carried out a study in April 1994 This shows that after the end of the cold war among the general public, 54% believes that there is now an 'increased likelihood' of nuclear war, compared to only 28% who think that this danger has decreased. The perceived risk of nuclear proliferation, as seen by 63%, has also grown[4]. I will, therefore, make the following assumptions regarding the aims and policies of the USA for the period 1995–2015.

- Avoid universal nuclear disarmament for as long as possible.
- Keep the US nuclear stockpile level comfortably high, not only to reassuringly ensure US security, but also for obtaining a domestic consensus.
- Prevent any country other than Russia from obtaining large-scale missile capability of reaching Continental United States (CONUS) with land-based ballistic missiles.
- Keep the numbers and sophistication of Chinese ICBM as low as possible
- Keep the numbers and sophistication of Chinese, French and British nuclear submarines (SSBN) as low as possible Prevent new entrants to the SSBN club.
- Ensure the maintenance and enhancement of USA's technological pre-eminence.
- Prevent proliferation of WMD, local arms races and regional wars.
- Retain the US freedom to use conventional forces to influence regional situations for safeguarding the US interests, without any threat to the forward-deployed US forces from WMD of regional powers This is to be achieved by three means: first, by preventing the emergence of new regional nuclear powers; second, by nuclear deterrence, reinforced by protecting forward-deployed forces from regional nuclear attack by the deployment of Global Protection Against Limited Strikes (GPALS); third, by deterring chemical attacks from regional powers by retaining the right to retaliate with nuclear weapons; the last requirement would demand that the USA should not subscribe to a 'no first strike' doctrine.

I am also working on the assumption that any strategic planning during the next two decades will have to be based on the premise that:

- The UN is unlikely to be strengthened to the extent that it can so credibly, fairly and effectively police the world that nation states can disarm to any appreciable extent.
- Chemical and biological weapons may be banned by all nation states, but may be available to so-called freedom fighters, subversives and terrorists.
- Space would be successfully kept free of deployed weapons.
- Nuclear proliferation, at least to threshold status, would be inevitable in the case of states which have perceived threats to their security and which have the basic capabilities to produce or smuggle the wherewithal.
- Nationalism would still be strong in most parts of the world, with some regional groupings to safeguard their common economic and security interests.
- Ethnic subnationalisms would strive for the formation of new states. Some of these forces, including terrorists, may get access to nuclear weapons or lethal fissile materials.
- Forces, such as religious fundamentalism, empires of narcotics and transnational mega firms that are presently outside the world regulatory bodies like the UN, etc., will need to be brought into the system and regulated or otherwise dealt with.

A New International Economic Order (NIEO) is unlikely to come about without a good deal of resistance and a determined rearguard action from the first world

China's aims

It has been assumed that the following would be China's aims for the period 1995–2015:

- As a large, populous country with an ancient civilization, China wants to be in the major league of world pow-

ers, by right and not by being accepted grudgingly With the voluntary reduction of Russian and US nuclear stockpiles and the accelerating improvement in the Chinese economy, becoming near-coequal in nuclear arsenals generally, if not yet in total military terms, is seen as feasible

- Keep the number of nuclear weapon powers in the world restricted to the present five, but do not make common cause with the USA in this regard, if it thwarts China's ambitions of becoming gradually coequal. The enlargement of the nuclear club might serve China's tactical aims of obtaining better leverage *vis-à-vis* the USA
- As India has explicitly accepted Chinese sovereignty in Tibet, and now that the USSR has disappeared, try and enlist India's support in coping with the USA.

Pakistan's aims

It has been assumed that the following would be Pakistan's aims for the period 1995–2015.

- Maintain a 'non-weaponized' and 'non-deployed' minimum nuclear deterrent to counter India's superior conventional power potential.
- Resist all attempts to force it to sign the NPT, or accept 'capping' and 'roll back' of its nuclear weapon capability. It may claim that it would do so if India also goes along This would be a bargaining ploy.
- Be anti-India, and work for an early pro-Pakistan solution of the Kashmir problem by stepped-up sponsored insurgency and international pressure. Only if after prolonged and frantic efforts they fail in this aim, and it also results in poor economic performance and domestic political turbulence, would a co-operative arrangement with India be considered

India's aims

I have to assume certain national aims for 1995–2015. What does India want to be – a global player, a regional player or an inward-looking isolationist country? Notwithstanding India's high expectations of its future economic performance, I believe that it neither has the wherewithal nor the intention to become a world power by 2015. It will not be isolationist either.

What are India's aims likely to be regarding the so-called North–South problems? Are these merely a hangover from colonialism and the ideological battles of the cold war, having no relevance in today's global village with integrated world trade? If India decides that the developing countries do need to get a better deal from the developed ones, how altruistic is it prepared to be in struggling for it even if it hurts its national self-interest in the process? There may be a major threat to the country during a certain period or there might be none, depending upon how India answers these questions. I rather suspect that regional interests will reign paramount during this period.

The following are India's assumed aims that would have a direct bearing on threat perceptions:

- India does not intend to liberate the areas of its territory that it considers wrongly occupied by China; it will decide to settle the question by a process of 'give and take'.
- India does not intend to liberate the so-called 'Azad Kashmir', currently occupied by Pakistan.
- India does not rule out solutions of the Kashmir problem that accept its independence as part of a South Asian Confederation.
- India believes that a loose South Asian Confederation of at least Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka is a viable entity by 2015.
- India believes that there is no way by which a populous and poor third-world country like China, India or Pakistan can cope with the first world perpetuating the status quo, except by co-operating with each other. It does not mean that co-operation involves ganging up against the first world on principle

Threats to India

The internal threats to India are from poverty, over-population and centrifugal forces. The external threats to India, both nuclear and conventional, from China and Pakistan; do not need to be elaborated upon. However, there is a need to take a look at some of the potential threats that might arise by 2015.

The potential proliferants in West Asia are Iraq and Iran Saudi Arabia has nuclear missiles (sold by China) capable of reaching India, but as yet no officially stated nuclear weapon ambitions or capabilities. In East Asia, the North Korean drive towards nuclear weapons, unless halted, would lead to a nuclearized Korean peninsula This and unbridled vertical proliferation by China might make Japan re-examine its nuclear weapon policy. Any weakening or perceived weakening of USA's extended nuclear deterrence in defence of Japan will almost certainly push Japan towards producing its own nuclear weapons and ballistic missiles. A possible proliferant is Indonesia, it might be driven by vertical proliferation by China, or horizontal proliferation in the Korean peninsula and Japan. If all this were to occur in a worst-case scenario, I am sure India would be generally uneasy, but is still unlikely to feel any big threat geopolitically.

Though looked at clinically, geopolitics may allay a sense of threat, psychological reasons may supervene and colour threat perceptions Indian allergy to fundamental Islam, reinforced by the Chinese sale of missiles to Saudi Arabia, Iran, Pakistan, etc. would play a part It would almost appear that Huntington's prophecy[2] regarding the accommodation between the Confucian and the Islamic worlds is indeed being fulfilled. The maximum threat would appear to be from rabid fundamental regimes, with Iran leading the pack, and at the other extreme a non-fundamental Indonesia posing no threat at all on this count, as of the present The surfacing of fundamentalism in Indonesia in the recent past and the rapid gains that it is making are certainly worrisome.

India's strategy

India's internal strategy would best be served by a strong dose of decentralization of powers from the Centre, not only to the states but also from the state capitals down to villages. Apart from removing a sense of alienation and bringing in people's participation in development, it would be a strong check against all pervasive corruption. The people would feel the ill-effects of it directly as a tangible deprivation and not as something impersonal and aca-

demic, as is the case today. As regards poverty elimination, the best route appears to be economic liberalization with a human face, and a socioeconomic safety net for the underprivileged. If government funding for education is concentrated on primary and vocational education, it would not only help poverty eradication but also population control The population problem, according to some assessments, is no longer a major threat. Gowariker's findings[5] indicate that demographic transition in India has already set in, and is moving swiftly to its final stage He predicts that India will reach the threshold of the net reproduction rate of 1, within a decade from now.

India's external strategy should be on the following lines:

- Adopt an unambiguous doctrine of nuclear minimum deterrence, even if *unweaponized* and *undeployed*, as long as we are capable of executing a second strike within a reasonable period of time, on any adversary who has used nuclear weapons against us.
- Maintain adequate conventional forces, but work towards their mutual reduction *vis-à-vis* both China and Pakistan.
- Even such reduced conventional strengths would be adequate to impose an unacceptably high price for any US attempt to target India like Iraq, provided the Navy is strengthened towards this end. Statistical doubts continue to exist about a leakproof GPALS in the context of forward-deployed US forces and an Indian missile second strike on them.
- Apply relentless diplomatic pressure on the five *authorized* nuclear weapon powers to drastically reduce their nuclear stockpiles and place their nuclear forces under UN control for the time being till universal nuclear disarmament becomes a feasible proposition.

1. Alvin Toffler, *Powershift*, Bantam Books, New York, 1990
2 Huntington, S P., Working Paper No 4, Harvard University, John M Olin Institute for Strategic Studies Project on The Changing Security Environment and American National Interests, January 1993
3 Lind, M , Working Paper No 1, January 1993, pp 45–46
4 Cortright, D , in *Disarmament. The Public Mood, Inforum*, Fall 1994, No 15, Fourth Freedom, Goshen, Indiana
5 Gowariker, V , *Indian Express*, 25 July 1993, p 8

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State of Indian R&D in a competitive world

D. Mukesh and S. Bhaduri

Scientific activity in the world has approximately doubled every fifteen years for the past three centuries[1]. The number of publications emerging from the technological community is awe-inspiring. Every working day, approximately 5000 scientific papers are published and 1000 patents are issued throughout the world. The present score is 11 million papers and 6.4 million patents in the chemical field, as reported by Chemical Abstracts from 1967 and Derwent World Patent Index from 1963, respectively Papers and patents are considered as the tangible output of a science and technological institution.

The ramifications of this avalanche of technical knowledge are enormous and present themselves at every level of research management. At the policy level, it is obvious that the ability of nations to retain a leading economic position is closely tied to their technical and scientific capability. Nations should work for a large productive research enterprise with the potential to continue providing the country with unique advantages in both creation and assimilation of new scientific and technological knowledge. This is largely a product of decades of generous funding by various agencies

Similarly, at the corporate level, with the present open economy and international competition, an Indian company

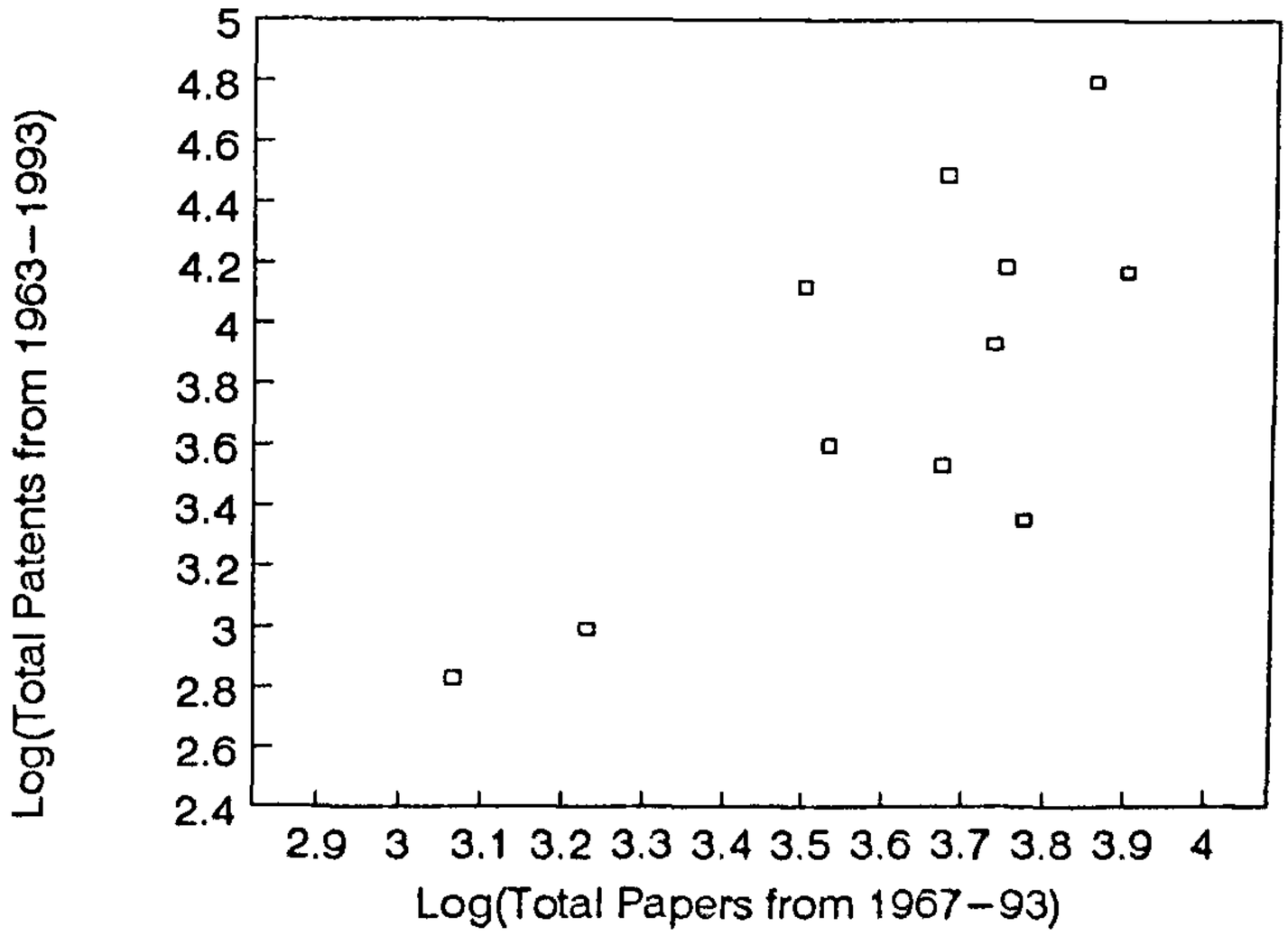

Figure 1. Log–log plot of total patents filed and total papers published by 11 multinational chemical companies.

cannot hope to survive today without a strong base in science and technology. Historically, the practices of Indian industries suited the restrictive industrial policies, protectionism and subsidies. Industries generally operated old and inefficient processes. Also, lenient Indian patent laws and absence of proper protection for intellectual property rights had meant that clever entrepreneurs copied the formulae, technologies and products of others without paying a patent fee. Access to international markets would mean high-quality products and operating efficient, up-to-date and competitive technologies. This will involve a considerable sum of resources for research and development.

The competitiveness of our Indian industries in the international market can be improved only by strengthening the scientific and technological base, and also operating with full awareness of all the research activities progressing around the world. In this paper we discuss the following:

1. The interrelation of science and technology as seen from papers published and patents filed by 11 large multinational chemical companies.
2. The performance of the Indian scientific community in the chemical field over the past decade, and how they compare with the industrialized and emerging countries.
3. Research and development (R&D) expenditure and contribution of the Indian industries towards this expenditure.
4. Lessons we should learn from these findings.

This paper is a detailed investigation of the commentary on science and technology in India, published in *Current Science*[2].

Interrelation of science and technology

A strong science base is essential for achieving technological success and breakthroughs. The latter cannot be accomplished without the former. This is also true in industrial R&D. Figure 1 plots the total number of patents filed as against the total number of papers published between 1967 and 1993 by 11 US, UK, German and Japanese multinational companies (Monsanto, Hoechst, Glaxo, BASF, Ciba-Geigy, Unilever, ICI, Dupont, Union Carbide, Nova and Sumitomo). The data were collected from Chemical Abstracts and Derwent World Patent Index. Surprisingly, the data fall on a smooth upwardly rising curve. An increase in the number of papers published leads to an increase in the number of patents filed, initially in a linear fashion, and beyond a certain value, in a sharply rising manner. Also, there are *no* data points on the top left-hand side of the plot.

Two very important conclusions can be reached from this graph, and they are: (1) a strong science base is essential for generating inventions with true technological potential, hence leading to achieving technological success, and (2) a big jump in the ratio of patents filed to papers published can be achieved only after publishing a large number of papers. These can be achieved only by nurturing a science base over a long period of time.

Pharmaceutical companies in India which may be affected by intellectual property rights (IPR) have suddenly started infusing large sums of funds for R&D to achieve quick breakthroughs in the form of patentable drugs. They have to bear in mind that it may not be possible to compete with multinational drug companies, which have been having a long history of R&D programmes and science bases of substantial capability. Pharmaceutical companies in India should take a long-term view and commit resources to nurture and strengthen selected areas of the science base if they truly intend to maintain a modicum of independence and acquire some measure of competitiveness.

The state of Indian R&D and how it compares with other countries must be viewed with a clear appreciation of the above information, viz. that a strong relationship exists between science and technology and a strong science base is a prerequisite for technological successes.

Table 1. Papers published in the chemical literature (data from *Chemical Abstracts*)

	Percentage share in 1993	Position in 1993	Percentage increase in share from 1983 to 1993
USA	28	1	1.1
Japan	13 3	2	2.7
Germany	7.5	3	0.2
UK	5.7	4	–0.1
Russia	5.4	5	–
France	4.7	6	0.6
China	4.3	7	2 2
India	2.6	9	–0.4

Chemical literature

As reported[3] in Chemical Abstracts, the total number of papers published in the chemical literature increased by 20.8% from 1983 to 1993. Table 1 gives the present position of various countries, their percentage share and how they fared over the past decade. USA is at the top of the list. India ranks 9th, with 11,700 papers. The percentage share has dropped by 0.4% in the past ten years, which should be taken very seriously. India has the distinction of having the fifth largest work-force employed in S&T, but still the output in the chemical field from the universities and industries is poor. China ranks 7th in the list of publications, with a growth of 2.2% during the same period.

Based on papers published between 1988 and 1992 in pure chemistry and multidisciplinary journals like *Science* and *Nature*, USA tops the list for the number of citations per paper, with Israel and Japan holding the second and sixteenth positions, respectively. India does not find a place in the top twenty, which does not translate well for the quality of the papers published.

Chemical patents filed in USA

The total number of patents registered in USA from 1983 to 1993 increased by 5% (Table 2). USA once again tops the list. Emerging Asian economies like Taiwan and S. Korea occupy the 11th and 13th positions, respectively, with an increase of 34% and 42% in the past ten

Table 2. Patents filed in USA

	Percentage share in 1993	Position in 1993	Percentage increase in share from 1983 to 1993
USA	52	1	4
Japan	22	2	9
Germany	8	3	3
France	3.3	4	5
UK	2.9	5	2
Taiwan	0.48	13	34
S. Korea	0.53	11	42
Israel	0.34	15	11
India	0.01	> 20	0

years Israel holds the 15th position, with an increase of 11% in the same period.

The performance of India is miserable and discouraging. Its share of patents filed in USA in 1993 is only 0.01%, with practically no growth in the past decade. The total number of patents of Indian origin filed in USA from 1967 to 1993 is only 62 and, filed internationally is only 290. High cost is given as one of the reasons by the Indian R&D community for not filing an international patent Filing a patent abroad costs from Rs 75,000 for a USA patent to Rs 80,000 for a Japanese patent and Rs 1,70,000 for an European patent.

The total number of patents of Indian origin filed in India is 3457. Indian patent laws allow filing of patents even for process improvements, while the industrialized economies allow only product patents. Both the approaches have several advantages and disadvantages[4]. Interestingly, the number of Indian patents in force in India has fallen to one-third in the past decade, because of the absence of protection of IPR and, hence, little incentive for doing research[5].

R&D expenditure

Table 3 compares the total R&D expenditure as percentage GDP for several countries[6]. Japan heads the list with an expenditure of 2 85% and, India, hardly 0 91% S Korea, one of the emerging eastern economies, spends 1.63% on R&D India has a very large work-force employed in research, which means that the limited resources are spread very thinly Also, 50% of this budget is spent on R&D related to atomic energy, space and defence.

Table 3. Total expenditure on R&D as percentage of GDP (1988 data)

Japan	2.85
USA	2.66
Germany	2.79
France	2.3
Netherlands	2.32
S. Korea	1.63
India	0.91

Table 4. Industries' contribution as percentage of the total expenditure on R&D (1990–1991 data)

Japan	75
USA	72
Canada	50
UK	68
Italy	58
India	23

Contribution by industry

In USA and Japan, more than 70% of the total R&D expenditure is borne by the industries and the remainder by the government[7]. In India we see a reverse picture (Table 4). In spite of 100% tax rebate offered by the government, Indian industries hardly contribute 25% of the total R&D expenditure (another source[8] states that the Indian private sector contributes only about 13% to the total R&D expenditure of the country). Also, American chemical companies spend 3–5% of their sales on R&D and Indian private industries spend less than 0.8%. The record of Indian private sector firms in the introduction of new products and processes that have come out of indigenous research is very poor[5].

Major American chemical industries allocate[9] their R&D funds for basic and applied research, technical services, process and product development in the ratio of 5.20:20.20 35 Indian industries, on the other hand, use their R&D funds primarily for technical services and quality control.

There are several ways available to reduce the R&D budget, such as contracting projects to universities and independent labs, offshore acquisition of technological assets that are cheaper, development of ad hoc alliances with other companies and with other research facilities (especially in the area of environment, safety and energy conversion) and greater interaction with national labs. Indian industries may have to adopt some or all of these methods to improve their R&D base.

Another problem which is ailing the Indian R&D is poor research management. Managing a production or a manufacturing site is much easier than managing research, since the tasks and results of the former operations are well defined. Research management involves an appreciation and understanding of the company's short- and long-term technical plans and developing the research programme accordingly. Poor R&D management does not manifest itself immediately, unlike the former, but causes long-term damage. Hence, incompetence in R&D management goes unpunished.

Conclusions

The most important finding from our study is that a strong and long-term science base is essential for achieving technological successes. This is very clearly detected from the papers published and patents filed by eleven large multinational chemical companies. This figure also warns the Indian companies that they cannot hope to achieve quick R&D successes by suddenly injecting large sums of money.

India has been spending far less on R&D, and, in addition, with a very large work-force, the funds are spread thinly. The poor performance of Indian R&D work-force is reflected from the number of papers published and international patents filed in the chemical field over the past twenty-five years The percentage share of papers published in the chemical literature has dropped by 0.4% in the past decade, while the number of international patents filed is dismal The latter has arisen because of the lenient Indian patent laws and the shelter and protection enjoyed by the Indian indus-

tries Also, the lack of protection to intellectual property has led to blatant copying of processes with impunity, and hence failure to nurture research skills. Multinationals operating in India are also hesitant to bring newer technologies because of these reasons.

In spite of the tax concessions, Indian industries have so far not shared the burden of the R&D expenditure. Poor R&D management and short-term goals have led them to spend less on R&D.

Although this paper covers only the chemical literature, a similar picture may emerge if a corresponding study is carried out on R&D in other branches of science. The watch-dogs of Indian R&D, namely, the Department of Science and Technology and the Department of Scientific and Industrial Research should be carrying out regular studies on the performance of Indian R&D, *vis-à-vis* the international scene, to help the science planners and managers to give better focus to the efforts of the scientific community.

1 *Chem Tech*, (Feb 1993), p 52
2 Bhaduri, S, *Curr Sci*, 1994, **66**, p 14
3 *Chem Eng News*, Aug 22, 1994, p 34.
4 Govindarajulu, V, *Chem Weekly*, Jan 25, 1994, p. 129
5 *Economic Times*, 17th Oct, 1994
6 Shukla, P. R, *Chem. Weekly*, Feb 22, 1994, p 137
7 *Confederation Indian Industries Technology News*, No 1, May 1994
8 Address by Dr P. Rama Rao to the Bombay Chambers' S&T Subcommittee, 15 May, 1993
9 *Chem Eng News*, Jan 24, 1994, p 15

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Decline of blackbuck (*Antilope cervicapra*) in an insular nature reserve: The Guindy National Park, Madras

T. R. Shankar Raman, R. K. G. Menon and R. Sukumar

Based on the equilibrium theory of island biogeography[1], conservation biologists have predicted that insularization of nature reserves would lead to extinction of several species occurring within the reserves[2–4]. Some species are more likely to go extinct than others for a variety of reasons[5]. A classic example of such extinction in insular habitats is that of many bird species on Barro Colorado, which became an island in 1910 during the creation of the Panama Canal[6]. It is generally believed that small, insular reserves will need active management if specific conservation objectives have to be met.

Along with Selvakumar[7], we (RKGM and RS) have been making general ecological observations in Guindy National Park (GNP), Madras, since 1974. A more systematic study was begun in 1991. During this period the park has shrunk in size and enclosed by a wall, the vegetation has undergone qualitative changes, while the population of blackbuck (*Antilope cervicapra*), an endangered antelope endemic to the Indian sub-continent, has declined considerably. While the detailed results of our observations are being reported elsewhere[8], here we highlight briefly the need to take urgent management action if the species is to be saved from its precarious position in the park.

Once covering an area of about 500 ha of one of the last remnants of the tropical dry evergreen forest of the Coromandel coast[9] (now reclassified as the *Albizia amara* Boiv. Community[10]), the GNP was established as a Reserve Forest in 1910. It now occupies an area of only 270 ha, walled off since the late 1980s from the adjacent Raj Bhavan and Indian Institute of Technology (IIT) campus. At least 350 species of flowering plants are found here (C. Livingstone pers. commun. and RS pers. observ.) in addition to about 150 species of birds[11] (V. Santharam, pers. comm.) and several species of lower plants, invertebrates, fishes, amphibians, reptiles and mammals. The park has been regarded in the past as one of the native strongholds of blackbuck, although it is also popular for its sizeable population of chital or spotted deer (*Axis axis*) which was introduced into the park[12] probably less than 50 years ago.

Trends in blackbuck and chital populations

Our studies of the blackbuck and chital populations here during the 1970s were based on total counts[7] and sample counts using belt transects[13, 14] for estimating population sizes, keeping records of population structure (age and sex class of animals) and, in the case of blackbuck, territoriality in males During 1991–92 we used the statistically more robust line transect sampling[15] to obtain estimates of population density and size, in addition to information on population structure, habitat use and territoriality[8]. Classification of animals was based on Schaller[16], Mungall[17] and Selvakumar[7].

During 1975–80, censuses conducted under the auspices of the Forest Department using volunteers and naturalists (including two of us, RKGM and RS) gave an average population of 295 blackbuck (unpublished records) for the combined GNP and Raj Bhavan areas In 1979, a 'total count' gave a figure of 260 blackbuck[7] which can be considered as a minimum number as some animals would have been missed due to poor visibility in denser vegetation. Sample counts during 1981–82 by Menon[14] gave an average figure of 333 blackbuck for this area, which may have been a slight overestimate[13]. These observations indicate that at least 250 blackbuck were present in GNP and Raj Bhavan during 1975–82.

In contrast, the line transect estimate during 1991–92 was 22.9 (±4.1, 95% Confidence Interval) blackbuck/km^2 in