India's techno-economic revolution

Uday Turaga

On the brink of a new national order, CSIR is creating economic reform through science and technology.

India's first prime minister, Jawaharlal Nehru, envisioned the conversion of colonial India to a science-based society. His administration (1947–1964) strongly believed that science and technology were critical prerequisites for a prosperous, industrialized, and self-sufficient society. Nehru was responsible for much of India's scientific edifice, which he described as "temples of modern India" (*1*). Educated at Harrow and Cambridge, Nehru genuinely believed in science, not only for its instrumental and transforming values, but also as a philosophy of life. He often said that "to make friends with science" was necessary for a strong and progressive India (2). Science, however, does not subsist on passion and patronage alone, and the well-intentioned "temples of modern India" soon began to crumble in the planned, socialist economy that India embarked upon.

The protected economy operated through low-quality, high-cost, federally owned companies, collectively referred to as the public sector. This economy allowed no international and little domestic competition. Despite inadequate quality and inefficient service, Indian companies continued to be profitable and had no incentive to innovate or invest in research for corporate survival and growth. Investing in scientific research was an exercise in public relations or was done to milk tax benefits. Scientific institutions were neither respected nor challenged enough to exercise their innovation potential for value and wealth creation. Research in India was pursued not as a commercial activity but for the sake of knowledge. Scientists became accustomed to receiving large federal research funds, which were doled out with minimal fuss and accountability.

Despite these discouraging circumstances, India's scientific community managed to increase agricultural productivity through the Green Revolution, participate in space research, and develop supercomputers. Although these were great achievements, they resulted from technology denial, extensive federal funding, and minimal government intervention. These successes in fact underscored India's failure to achieve scientific excellence in routine circumstances. *The Washington Post* described India's "anger" as being responsible for the country's success in developing its own supercomputers when the United States refused to sell the computers to India (3). Indian science had to be "angry" to demonstrate and achieve its much-touted potential.

Temples of modern India

A new political administration led by Prime Minister P. V. Narasimha Rao took office in June 1991. It brought a sense of economic liberty and revolutionary thinking, which paved the way for the transformation of the Indian Council of Scientific and Industrial Research (CSIR). The laboratories under CSIR are charting a new direction in research priorities. At one time, the laboratories conducted research for its own sake; today, however, the shift in focus is making research more relevant to the needs of economic agents (e.g., productivity, better quality) (4).

CSIR was established in the early 1940s to provide the scientific and technological underpinnings of a nascent industrialized nation. CSIR is India's largest scientific establishment and probably the world's largest chain of publicly funded research laboratories (5). Through its network of 40 research laboratories and institutes, 100 field stations, and 9 technology transfer centers, CSIR is ubiquitous (Figure 1).

Covering a wide spectrum of science and technology, CSIR's research laboratories are classified as discipline- and business sector-specific. The National Chemical Laboratory in Pune and the National Physical Laboratory in Delhi are examples of discipline-specific laboratories, while the Indian Institute of Petroleum in Dehra Dun, the Central Leather Research Institute in Madras, and the Central Drug Research Institute in Lucknow are examples of business-sector–specific laboratories.

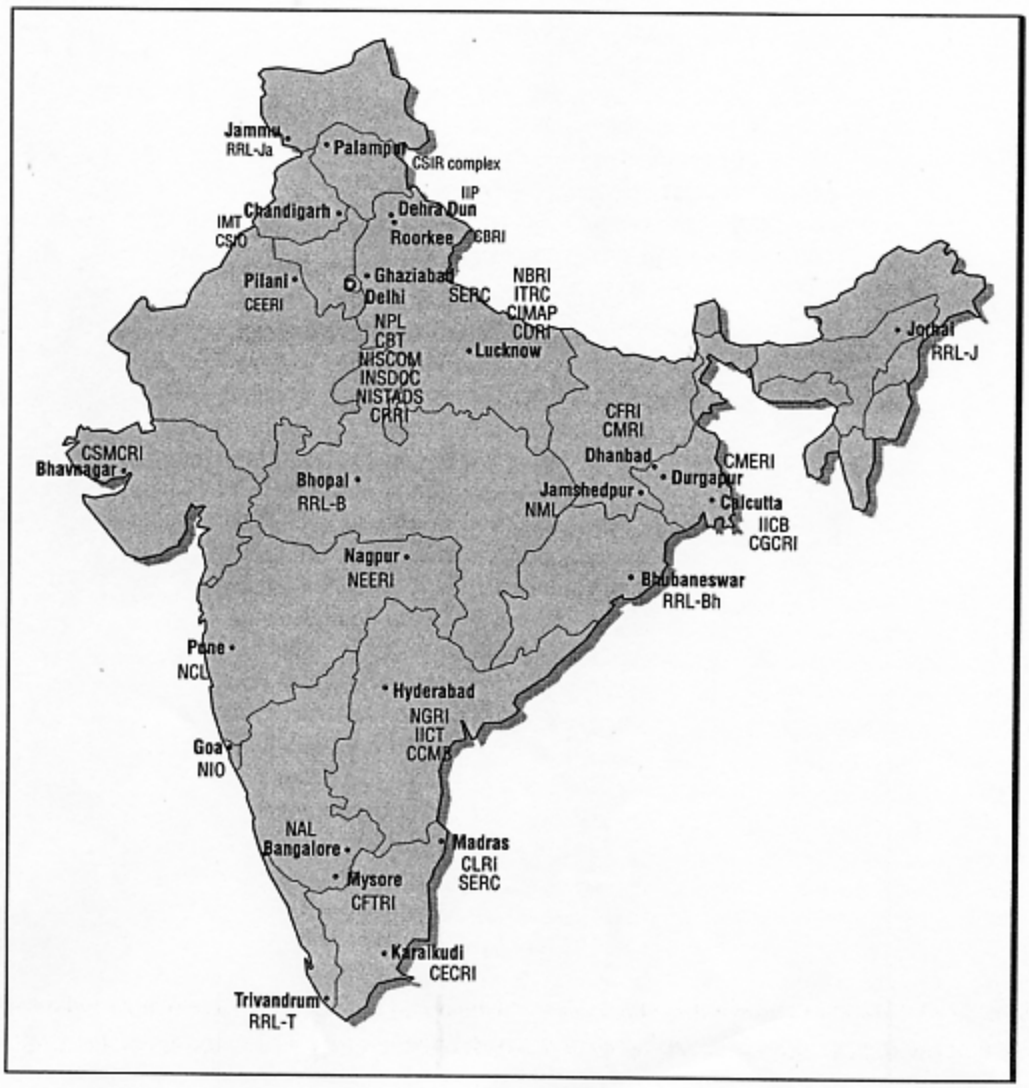

Figure 1

The Indian Council of Scientific and Industrial Research (CSIR). The network includes 40 research laboratories (abbreviated next to the cities on the map), 100 field stations, and 9 technology transfer centers scattered throughout India.

Organization of CSIR

With more than 23,000 employees, CSIR has an elaborate management structure. CSIR is structured as an autonomous and independent organization even though it is federally funded. It reports to and is advised by the Society, a quasi-political wing of the government, which is chaired by India's prime minister and the ministers for science and technology, finance, and human resources development. The chief executive officer of CSIR is designated as director-general, while directors preside over each of the 40 constituent laboratories. The director-general and the directors are almost always practicing scientists and engineers of repute.

The Governing Body and the Advisory Board advise the director-general. The director-general presides over the Governing Body (occupied by members of the government bureaucracy and Indian scientific community and a few CSIR laboratory directors), which approves fiscal, management, and administrative policies. The Advisory Board is composed of eminent scientists, technologists, and business leaders and provides scientific input to the director-general. Directors of the constituent laboratories are assisted by the Management Council in making administrative decisions, while the research philosophy and direction of each laboratory are vetted by the Research Advisory Council, which is usually headed by an eminent scientist in the laboratory's field.

Reinventing CSIR

In the early 1990s, against the backdrop of a new political regime of liberalization and globalization, CSIR began the process of change by appointing a committee composed of directors from its most successful laboratories. The goal was to put together a new strategy for commercializing CSIR's knowledge base (*6*). Headed by R. A. Mashelkar, then director of the National Chemical Laboratory in Pune, this committee (popularly referred to as the Mashelkar Committee) made sweeping and radical recommendations for transforming the staid, old CSIR.

The first change that the Mashelkar Committee implemented was the establishment of independent marketing and financial management divisions for each of CSIR's 40 research laboratories. These new marketing and financial management divisions would have the same autonomy as the R&D divisions. Besides emphasizing the need to staff these divisions with qualified people, the committee recommended that personnel immediately receive formal training in marketing and managing technology.

The most revolutionary recommendations of the Mashelkar Committee, however, pertained to incentives. Aware of CSIR's inability to match private-sector salaries, but determined to jump-start innovative research with strong commercial potential, the committee identified explicit economic incentives for CSIR's scientists. Up to 40% of the intellectual property fee for contract research projects was earmarked for distribution, with the lion's share to go to the principal innovators. For the first time in India's history, the intellectual input of a scientific organization was being recognized in monetary terms.

CSIR 2001

In January 1996, CSIR articulated its aspirations and objectives in a document titled *CSIR 2001: Vision & Strategy* (*7*). The document was not a mere projection of the numbers CSIR could achieve by 2001 on the basis of its past performance. The slim, 17-page document detailed CSIR's aspirations "in relation to what others, the world over," were likely to do in the future. *CSIR 2001* rewrote CSIR's mission statement to reflect a new technology-based economy. Its mission statement is the following:

> To provide scientific industrial research and development that maximizes the economic, environmental, and societal benefit for the people of India.

CSIR's goal for 2001 is to become a self-financing entity based on a global R&D platform poised to provide competitive R&D and high-quality science-based technical services while fulfilling its national obligation as a vital source of science and technology. *CSIR 2001*, however, goes beyond articulating qualitative aspirations to identify the following concrete aims:

- generate external, nonfederal revenue of U.S. $156 million (up from $30 million in 1994), of which at least 50% would be from industrial customers (compared with 15% in 1994);
- derive annual earnings of $40 million from overseas R&D work and services (up from less than $2 million in 1994);
- develop at least 10 exclusive and globally competitive, ready-to-license technologies (compared with none in 1994);
- hold a patent bank of 500 foreign patents (up from 50 in 1994); and
- generate 10% of CSIR's operational expenditure from intellectual property licensing (compared with <1% in 1994). (Note: *CSIR 2001* was written in January 1996, but the comparisons were made with 1994 data because data for 1995 were not yet available.)

CSIR was determined to begin its journey toward true corporate culture. For the first time, an Indian research organization was actually setting realistic goals for revenues, patents, and licensable technologies. CSIR has been relentless and fairly successful at following its roadmap.

Linking research to the marketplace

Historically, CSIR has been perceived as a wastrel—pursuing futile research irrelevant to the needs and aspirations of the marketplace (*8, 9*). Ironically, CSIR has executed high-quality applied research; however, it failed to publicize, let alone commercialize, such research. An important thrust of *CSIR 2001* was to link research to the marketplace.

In an effort to better understand the needs of the scientific community, the finance ministry meets with science and technology leaders before the annual federal budget is presented to Parliament. Over time, the meeting evolved into an exercise in futility, as neither the ministry nor the scientists agreed on any of the issues at hand.

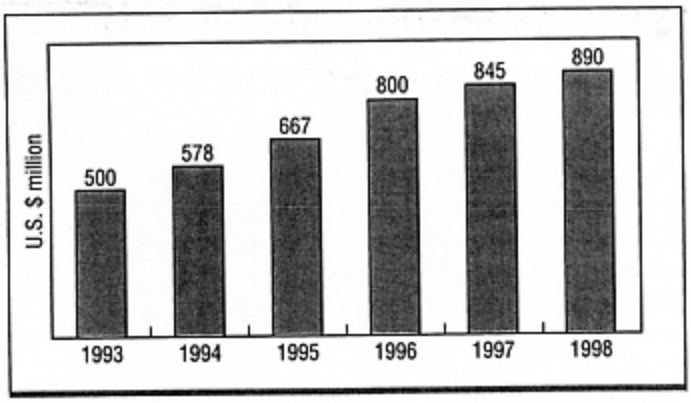

Figure 2 **Net value of products derived from CSIR technologies and services. CSIR has successfully enhanced the value of services and products derived from its knowledge base through several recent initiatives.**

By 1997, it became clear to CSIR that this annual meeting between the finance ministry and scientific leaders was counterproductive to the scientific revolution. CSIR urged the finance ministry to eliminate the irrelevant legislative shackles binding it. For example, CSIR sought the freedom to hold equity in joint ventures with companies willing to commercialize its knowledge base. This turning point explicitly established, in India, the legitimacy of creating wealth from scientific research (*10*).

The Indian Institute of Petroleum (IIP) in Dehra Dun became the first CSIR laboratory to benefit from this partnership. IIP was then advocating a technical–commercial alliance between the Indian Oil Corp., the Gas Authority of India, and Amoco Corp. (now BP Amoco) for the production and use of dimethyl ether as a transportation fuel in India. When the decision to form a joint venture corporation was made, IIP was rewarded with equity and commissioned to provide technological services to the joint venture corporation (*10*).

Today, besides being an important destination for global contractual research, CSIR has alliances and partnerships with several multinational corporations. General Electric has provided most of the foreign exchange earnings of the National Chemical Laboratory in Pune for the past several years, by funding research in polymer chemistry and engineering (*11*). In 1998, General Electric declared this relationship with CSIR as a model for all external R&D alliances (*12*). Novo Nordisk and Boeing are now working with the National Aerospace Laboratories in Bangalore, while Zellco, a major Malaysian construction company, funds research at the Structural Engineering Research Center in Madras (*11*). DuPont and SmithKline Beecham have sponsored pharmaceutical research at the Indian Institute of Chemical Technology in Hyderabad, and the Indian Institute of Petroleum in Dehra Dun has worked with Amoco, Mobil, Stone & Webster, and VOP.

These alliances also included institutions and programs that leveraged strengths indigenous to India. CSIR's New Drug Discovery Program is one such ambitious research project bringing together 500 scientists from more than 20 skill and knowledge centers of CSIR laboratories and alternative medicine schools across India (*11*). Through a multi-institutional alliance, this ambitious program seeks to map the rich, unique, and predominantly unexplored Indian biodiversity and identify at least 20 molecules with the potential to lead to new drugs by 2005. CSIR, whose laboratories have provided 10 of the 13 drugs India has discovered in the past 50 years, intends to go beyond mere capitalization of Indian biodiversity. CSIR hopes to demystify and modernize the practice of Ayurveda and other variants of Indian alternative medicine.

Other initiatives that link science and the marketplace include customer satisfaction evaluation, infrastructure expansion, and organizational re-engineering. From the 1996 data, CSIR was able to document the views and experiences of its customers and clients for the first time since its inception. Professional consultants evaluated these views and developed a program to improve its customer satisfaction profile (*12*). As a result of its knowledge-based initiative, CSIR saw dramatic increases in value generated by its technologies and services (Figure 2). The modest increases after 1996 are attributed to the overall economic slowdown India experienced during that period.

Through grants and World Bank soft loans, CSIR has upgraded its scientific and analytical infrastructure, management information systems, and employee community facilities (e.g., housing for employees, schools for employees' children, and medical facilities). Because structures determine the level of hierarchical bureaucracy and innovation potential in any organization, *CSIR 2001* mandated a complete re-engineering of organizational structure. This mandate was far-reaching and went beyond the mere cosmetic changes that frequently accompany organizational overhauls. CSIR invested greater autonomy and freedom in its management by reducing hierarchy and response time. These measures, part of *CSIR 2001*'s strategic road map, have generated millions of dollars in federal and nonfederal revenues (Figure 3). The *CSIR 2001* initiatives have had a modest impact on nonfederal revenues.

Spurring creative research

Under its new charter, CSIR set out to create an environment that would routinely generate new ideas and harness creativity at all levels. This goal was particularly challenging for an organization of 23,000 people who had never competed for research grants, whose creative urges had been bludgeoned by pervasive mediocrity, and whose sluggishness was legendary.

Research groups of diametrically opposite characters would share space. One group could be a flush-with-funds (often from multinationals) polymer chemistry group efficiently producing research papers, patents, and licensable technologies in a timely manner; and the other could be a

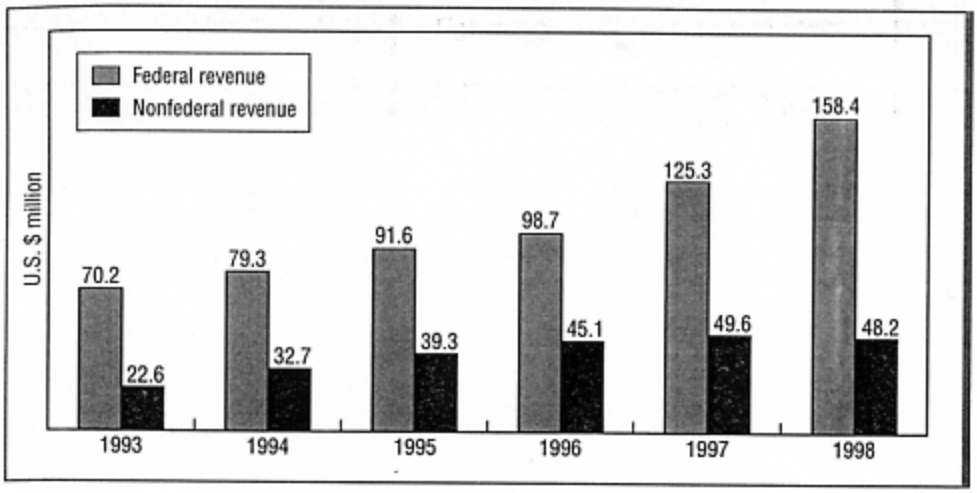

Figure 3

CSIR's earnings. CSIR's leadership has succeeded in increasing federal and nonfederal revenues in the past decade through focused and relentless business development activities.

rundown combustion laboratory that had not seen a client in years and had fossilized over time. The decisive differences between these groups would eventually boil down to their leadership. CSIR's work culture is an impossible mix of contradictions, which, it has often been said, can be leveraged only by leaders, not managers. A hands-on, meticulous researcher who might have acquired his doctorate with an American Nobel laureate and intimately understands managing people in the Indian context could well be leading the polymer chemistry group. The head of the combustion laboratory, on the other hand, could be someone without a Ph.D., arguably the bare minimum to qualify for a career in research. Perhaps he evolved into his position only by marking time, thus, he could be grossly under-equipped to manage, let alone inspire, a group of Ph.D. scientists.

To encourage creativity and ingenuity among scientists at CSIR, the New Idea Fund (NIF) was created in 1996. NIF promotes basic and out-of-the-box-thinking research by funding select ideas. Besides being chosen for their unusual creativity, projects funded by NIF typically have a high potential to result in licensable technologies. Consequently, NIF projects are carefully evaluated and fiercely protected to ensure effective and comprehensive patenting possibilities. NIF is an example of how one intelligent and well thought-out, albeit meagerly funded, program could spur creative research. More often than not, scientists funded by NIF are poster children for CSIR, and many go on to win other research grants.

From "publish or perish" to "patent and prosper"

Compared with other Indian organizations, CSIR has always been the "big fish" in publications and patents (*7*). However, CSIR pales in comparison to other organizations of similar size in other countries. In the mid-1990s, to level the playing field, CSIR embarked on a series of initiatives that included a comprehensive overhaul of its intellectual property policy, organization-wide training of personnel, standardization of research documentation procedures, and management of its patent portfolio as a business activity. Figure 4 (p 48) provides quantitative evidence of the success of managing its patent portfolio as a business activity.

Compliance with World Trade Organization standards was accompanied by widespread xenophobia in sections of Indian society that vast reserves of indigenous knowledge would be lost. To address this problem, CSIR developed comprehensive and far-reaching initiatives. An example is detailed in the box, "The turmeric patent story" (p 48). CSIR has played a critical role in shaping public opinion and policy on patent issues (*12, 13*). The first set of amendments to India's patent law was promulgated in early 1999.

A long road to discovery

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. Indian society, therefore, has reason to be cynical of scientific research. CSIR, however, has been making conscious efforts to ensure its relevance to India's needs.

One example of CSIR's attempt to become more accountable and sensitive to its constituents was *Leather Vision 2010*, written by CSIR's Central Leather Research Institute (CLRI) in Madras (*17*). The proclamation was written in response to a court order mandating the closing of tanneries in southern India because of the growing environmental and ecological risks these tanneries posed. The CLRI rose to the challenge and developed methods of minimizing waste and water pollution from these tanneries. CSIR helped save a $1.6 billion leather exports business but realized no more than a few hundred thousand dollars itself.

CSIR's success in the marketplace is credited to a set of highly motivated leaders. The contributions of two individuals—S. K. Joshi and R. A. Mashelkar—stand out. Joshi navigated CSIR through the nebulous transition India made from a centralized economy to a liberalized one. Mashelkar succeeded Joshi and created a high-profile program of change, building on CSIR's early successes and intrinsic strengths. As in any

The turmeric patent story

In March 1995, the U.S. Patent and Trademark Office (USPTO) granted a patent to the University of Mississippi Medical Center for the use of turmeric powder as a wound-healing agent (*14*). For centuries, turmeric has had many medical uses in India, from treating digestive disorders to healing wounds. Widely recognized and well ingrained in Indian folklore for its medicinal properties, turmeric and other natural products are emotive issues for the Indian people. The turmeric patent became a rallying point for groups opposed to intellectual property rights in India and was projected as a Western attempt to monopolize Indian knowledge reserves (*15*).

In October 1996, CSIR filed a writ with USPTO challenging the award of the patent. CSIR attorneys produced hard scientific evidence that turmeric had long been in the public domain and therefore was unpatentable. USPTO reversed its grant and upheld CSIR's claims. Several Indian newspapers described CSIR as a swashbuckling national hero who had rescued Indian turmeric from Western bio-pirates (*16*).

CSIR, however, projected the victory in an entirely different light. It said that the recognition of scientific evidence and the short time taken for the settlement were the best possible evidence of the integrity, transparency, and objectivity of the international patenting regime. CSIR also reassured India that it had the necessary technical and legal capabilities to handle a complex intellectual property regime to its advantage and interests. The turmeric patent story also sparked potentially far-reaching thinking on the inclusion of traditional knowledge in the realm of intellectual property rights.

successful organization, others in CSIR contributed in equal measure—these lieutenants have their own success stories. The story of T.S.R. Prasada Rao and the Indian Institute of Petroleum is detailed in the box, "Distilling discoveries to dividends". CSIR's organizational reinvention is officially, and correctly, attributed to "Team CSIR" (*12*).

CSIR's successes demonstrate that Indian science is evolving into a global player while maintaining its relevance to its people. The CSIR story is far from complete because not all the dividends from its discoveries have materialized. Nevertheless, a transformation in its collective mind-set is nearing completion, and the potential it provides for scientific excellence in routine, everyday circumstances is a wellspring of hope and opportunity for all those who have been skeptical of India's research investments.

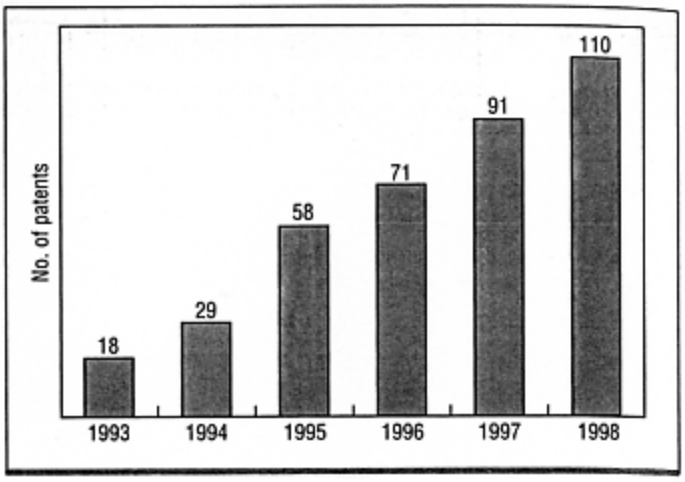

Figure 4 **CSIR's patents. Managing the CSIR patent portfolio as a business activity during the past five years has increased the number of patents applied for and obtained.**

Acknowledgments

I am grateful to R. A. Mashelkar and T.S.R. Prasada Rao—two important protagonists in the struggle to reinvent CSIR—for being so generous with their time and wisdom. Chunshan Song's encouragement was instrumental to this piece and other endeavors of mine. I acknowledge N. S. Bhal, Sumit Dhar, Ajaykumar Gopal, Bharat L. Newalkar, Mohan S. Rana, and John J. Zengel for useful suggestions.

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Distilling discoveries to dividends

In his inaugural address in September 1990, all that T.S.R. Prasada Rao could urge the scientists at the Indian Institute of Petroleum (IIP) to do was "start smiling at work again". Prasada Rao gave up his plush job at an industrial research center to assume directorship of IIP. At that time, IIP had a militant and aggressive labor union, almost no client base, and less than $20,000 in nonfederal earnings. After a 10-year reformation, Prasada Rao has turned IIP into one of CSIR's many success stories.

The success of IIP is due to its talented management and personnel, extensive infrastructure remodeling, and aggressive intellectual property portfolio. Prasada Rao started by creating awareness in the Indian oil industry of IIP's services through technology conferences and aggressive marketing strategies. In addition to marketing already licensable technologies, IIP began working on select projects that had licensing potential. Simultaneously, Prasada Rao sold to the federal government an ambitious vision in which he managed to secure a landmark $2 million for infrastructure development.

Later, IIP received a World Bank soft loan to upgrade and expand its research and analytical infrastructure. Prasada Rao rewrote IIP's personnel management policies and offered incentives to his employees for increased research productivity. IIP enhanced its management structure by creating a new patents division and an efficient project management and review system.

In early 1995, on the heels of its success as a national leader in the Indian petroleum industry, IIP began to develop strategies for expansion into the global marketplace. The plan was to obtain ISO 9001 accreditation for exporting its technologies via contractual research projects with international companies. To produce a single-step catalytic process for the oxidation of cyclohexane to adipic acid, IIP formed its first partnerships with ABB Lummus, Praxair, and Adarsh Chemicals and Fertilizers (an Indian company) (*18, 19*).

IIP's global business strategy primarily included marketing alliances with established refining technology licensors to leverage its limited marketing muscle. IIP used these alliances to become first-to-market on high-risk technologies with potentially lucrative payoffs. In June 1998, IIP and Mobil combined their portfolio of oil lube technologies for joint global marketing (*20*). This partnership proved successful, as the Indian Oil Corp. decided to buy Mobil's isodewaxing lube technology for its Haldia refinery in eastern India (*21*). IIP is now participating in a joint venture between the Indian Oil Corp., the Gas Authority of India, and BP Amoco for the production and use of dimethyl ether as a transportation fuel in India (*10*).

The rise of IIP is a shining example of the transformation that CSIR has undergone. Prasada Rao converted IIP into a successful CSIR laboratory where its scientists could truly smile. IIP's annual earnings as of January 1999 were $3.7 million, $1.9 million of which came from nonfederal sources (*18*). To add to its growing sucess, by 1999, IIP had been awarded with CSIR's highest recognition—the CSIR Technology Award—for the seventh time in eight years.

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