IIT BOMBAY

update

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Opportunities for the Food Processing Industry in India

- Sanskrit Texts: A Window on Indian Scientific Tradition
- Collaborative Engineering for Product Life Cycle Management
- HR Challenges in the Indian Software Industry

IRCC Notes

Editorial

Globally, India ranks among the first few countries in food production. Both the so-called *green* and *white* revolutions have propelled us to a food-surplus position. Unfortunately, we have not been able to exploit such gains through better distribution, or adoption of new technologies for improved processing, storage and preservation of food. However dimly, images of undernourishment still haunt the nation's consciousness. This issue of UPDATE focuses on the road ahead for our food processing industry, and presents some of the relevant technologies that IITB has developed.

We also feature in-depth reviews of two other areas: *Collaborative Engineering* for advanced manufacturing, and *Human Resource* issues that are proving critical in the IT sector today. The use of collaborative engineering for providing *end-to-end* solutions to design, manufacture, and marketing of products has become popular with many international organizations. Faculty at IITB has been working to establish the concept locally by allying with several large Indian manufacturing companies. We review the essence of the approach and IITB's achievements in the area. Parallely, the high-growth IT sector of the country is having to take recourse to innovative HR strategies in order to perform successfully in the international business arena. The finding of a team from IITB which has researched the issue widely is presented here.

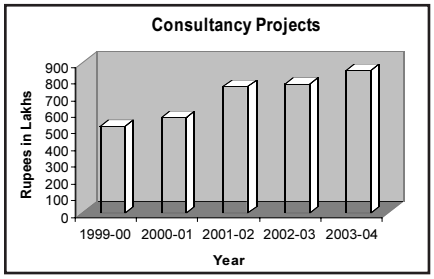
Apart from other features, we review various developments and initiatives underway at the IRCC. As all indications are today, the R&D carried out by our institute is on an upswing and is metamorphosing rapidly through the establishment of newer mechanisms to help move innovations beyond the laboratory into the fabric of the larger society.

Sandip Roy, Editor

Building R&D Partnership with Industry

Being situated in the commercial capital of the country, IIT Bombay has the advantage of being in the midst of the industry hub which can readily absorb the technologies developed at the institute. With a large pool of excellent faculty whose expertise ranges over many areas of science and engineering disciplines, we have persistently promoted effective interaction with industry to address their needs. We have for long provided consultancy for solving short-term problems of the industry, and have also carried out technology development to some extent. However, our current focus is to expand our interactions to a *multidimensional* mode by building strong R&D *partnerships* with the industry.

Along with sponsored research, our industrial consultancy has been growing steadily–both of which have helped create a variety of advanced R&D facilities at the institute. Spurred by this experience, we are now moving into the domain of creative and advanced research for the industry in emerging areas. In such collaborative R&D, IITB provides faculty expertise, infrastructure and advanced facilities, while the partnering industry provides financial support as well as relevant technical support. The aim is to develop technologies of the next generation. With the global outlook becoming highly competitive, and the new IP regime setting in shortly, the route to the nation's economic development may lie dominantly in knowledge-driven, advanced technology inputs.



Over the recent past we have interacted extensively with a large number of companies through workshops and other modes, towards establishing roadmaps for collaborative research. An entire array of organizations has participated in such exercises, including ONGC, Bajaj Auto, GM, HTSL, GE, Cummins India, P&W, Bharat Earth Movers Ltd., Pidilite, NTPC, MTNL, and TCE. We also encourage small and medium enterprises (SMEs) in specific business areas to form an industrial consortium so as to nucleate better R&D interaction with our faculty and students.

IIT Bombay and ONGC have recently signed an MoU to help foster and enhance Institute - Industry R&D partnership. Two sponsored research projects with multi-crore outlay are being supported by ONGC at the initial instance.

Overall, our experience has yielded valuable lessons on the issues that the current regime of globalization has precipitated for both the industry and academia. One of the key concerns of the industry relates to intellectual property generation and ownership. Accordingly, we have initiated various activities relating to IP management. Recently we hosted a national IPR workshop (details provided in another article in this issue) with participation from international experts. Our understanding of the relevant issues has been continually enhanced, which has helped us interact with the industry more effectively.

Adding another new dimension to our efforts, a *Technology Business Incubator* (TBI) is being set up at the Institute with major funding from Department of Science and Technology (Govt. of India). This is expected to help found start-up companies, exploiting IP generated by faculty, students and alumni. Recently, a *Society for Innovation and Entrepreneurship* (SINE) at IIT Bombay has also been registered. It will provide a platform for various entrepreneurial activities: incubation/commercialization of technologies developed at IIT Bombay, bidding for competitive R&D projects, creation of joint ventures and so on. In essence, SINE would provide a framework for multiple modes of interaction between the industry and faculty.

Empowered by all these initiatives, and collaborative mechanisms that are being established, IIT Bombay hopes to be an active partner in assisting the Indian Industry to become globally competitive.

Office of Dean R&D

In Brief

Major New Consultancy Projects

Investigator	Department	Project Title
A Mukherjee	Civil Engg	Seismic Retrofit of a Multistoried Framed Structure
G Kumar	Electrical Engg	Development Contract of S & C Band Printed Antennas
A G Rao	Industrial Design Centre	Establishment of Mini Bamboo Clusters
S Sarawagi	KReSIT	Interactive Data Cleaning using Active Learning
M V Rane	Mechanical Engg	Installation of Diesel Generator Exhaust Heat Recovery
M V Rane	Mechanical Engg	Recuperator for Micro Gas Turbine
U N Gaitonde	Mechanical Engg	CFD Analysis of Dust Ingress in Vehicle
U D Mallya	Mechanical Engg	Development of Resistance Spot Welding Schedules for Steel

Major New Sponsored Projects

Investigator	Department	Project Title
M S Balakrishna	Chemistry	Transition Metal Complexes Containing Phosphorus Based Ligands as Catalysts
N Kishore	Chemistry	Facility for Isothermal Titration Calorimetry in Biological Systems
A K Lala	Chemistry	New Biologically Active Peptides of Natural Origin
V S Raja	Corrosion Science & Engg	Stress Corrosion Cracking Behaviour of Austentic Stainless Steel in Pure Water
K Ramamritham	Computer Science & Engg	Framework for National Entrepreneurs Support Programme for Information Technology
S Chaudhuri	Electrical Engg	Virtual View Generation
S Chaudhuri	Electrical Engg	Advanced Techniques for Remote Sensing Image Processing (Indo-Italian Collaboration)
M U Deshpande	KReSIT	Enhancing Competency of IT teachers and Industry Professionals.
S Vitta	Met Engg & Mat Science	Mirrors for Soft X-rays

Select MOUs

Organization	Date Signed	Scope
Technical University of Munchen Germany	April 2003	Collaboration in Academic and Research Activities
Goa University	December 2003	Academic Exchange and Infrastructure Cooperation in Satellite based Distance Education Programme in Information Technology
Infosys Technologies Limited, Bangalore	January 2004	Research and Development Interaction with Centre for Aerospace Systems Design and Engineering
Friedrich-Alexander Universität Erlangen Germany	February 2004	Collaboration in Education and Research
National Thermal Power Corporation	March 2004	Promotion of Research and Development in Areas of Generation, Renewable Technology and Environment Issues, CFD and Technology Development for Cost Reduction
Oil and Natural Gas Corporation Limited	March 2004	Collaboration relating to the Exploitation of India's Hydrocarbon and Unmineable Coal Reserves

Awards

Prof Sumantra Dutta Roy, Department of Electrical Engineering, selected for the *Indian National Academy of Engineering* Young Engineer Award 2003.

Prof Kartic C Khilar, Department of Chemical Engineering, elected as *Fellow of the Indian National Academy of Engineering*, from the year 2004.

Prof R K Shevgaonkar, Department of Electrical Engineering, elected as *Fellow of the Indian National Academy of Engineering*, from the year 2004.

Prof G Vishnoi, School of Biosciences and Bioengineering, awarded the *AICTE Career Award for Young Teachers* for the year 2003.

Prof S Chaudhuri, Electrical Engineering, has been elected a *Fellow of the National Academy of Sciences*.

Prof Tarun Kant, Department of Civil Engineering, elected as the *Fellow of the Indian Academy of Sciences*.

Prof V G Ukadgaonker, Department of Mechanical Engineering, elected as a *Fellow of the ASME International*.

Prof M S Balakrishna, Chemistry, has been elected as a *Fellow of Royal Society of Chemistry (FRSC)*.

Prof Rinti Banerjee, School of Biosciences & Bioengineering, recipient of the *Young Researcher Grant Award* from the International Foundation for Science, Sweden.

Prof S C Lakkad, Department of Aerospace Engineering, recipient of *Distinguished Alumnus Award* of IISc Bangalore for his outstanding contributions in the area of aerospace activities.

ASAN: The Low Cost ATM

ASAN, a low cost Automated Teller Machine (ATM) was launched on December 5, 2003. Profs V P Bapat and U A Athavankar of the Industrial Design Centre designed it, based on a survey of current and potential users interviewed for their views on existing ATMs. ASAN has several advantageous features over the currently deployed ATMs to suit the Indian customer and settings.

The attractive new design incorporating elements from traditional Indian architecture departs from the current neutral appearance of ATMs. Banks may further customize it to a limited degree. The small size makes it suitable for deployment in places with space constraints. ASAN's ergonomic design suits the typical Indian body dimensions with respect to the height of the keypad and the inclination of the screen. Additionally, the machine has a provision for keeping one's personal belongings, and protruding wings for ensuring privacy during transactions. A multi-coloured card reader status indicator guides users unfamiliar with new technology like smart DIP card readers.

The machine has NCR-intelligent power-saving hardware and software. An integrated pedestal accommodates a UPS, providing maximum availability during outages. The robust engineering design ensures trouble-free operation in hot, humid and dusty environments. Additionally, a unique airflow system allows deployment at non-air conditioned sites. Such features make it suitable for interior locations. Other features include, 40-column graphics thermal receipt printer, secure encrypting PIN pad and a flat panel screen.

Contact: Prof U A Athavankar, IDC, email: uaa@idc.iitb.ac.in

Bio-Char Unit for Charcoal Production

Indian manufacturers still use the highly polluting and inefficient 'pit' method for charcoal production from wood and non-wood waste. Sponsored by the National Mission on Bamboo Applications (NMBA), TIFAC, Dept. of Science and Technology, the biomass research group led by Prof Anuradda Ganesh (Energy Systems Engineering), has developed a simple to operate, non-polluting Bio-char Unit (BCU). Although developed for bamboo waste, the unit can be used for other non-powdery biomass with minor modifications. The uniqueness of BCU lies in using the otherwise polluting gases as a thermal energy source. The gases carry 50% of the energy of the biomass used in charcoal making.

Using BCU, a uniform yield of 25% charcoal from bamboo waste, and about 28% charcoal from other woody biomass is obtained, with a consistent calorific value of 28MJ/kg. A batch of 100kg bamboo waste is converted into 25kg charcoal in two and a half hours. A single person can operate the unit, which costs Rs. 35,000. A bio-char unit was set up at an activated carbon manufacturing plant in Hyderabad, where the suitability of bamboo charcoal as raw material was successfully demonstrated. Another BCU sponsored by KVIC is being put up at a bakery unit at Yusuf Mehrauli Centre, Tara Village, Maharashtra to demonstrate the use of thermal energy from gases for generating charcoal as a by-product. Through NMBA, 15 such units at five different locations in Tripura, Meghalaya, Bastar, Amravati and Pune districts are being deployed for training and further dissemination of the technology. A 10 kg batch unit was also demonstrated at the VII World Bamboo Congress, New Delhi. The BCU is expected to help generate rural employment, and ensure village energy security.

Contact: Prof A Ganesh, Energy Systems Engg, email: aganesh@me.iitb.ac.in

WebROBOT: Internet Based Robotic Assembly Planning System

Globalization has posed many challenges for product design and manufacturing due to shorter product life cycles and frequent design revisions. To realize telemanufacturing, collaborative CAD/CAM solutions are needed to enable seamless integration of distributed physical and knowledge resources so as to provide 'anywhere anytime' access. The Computer Aided Manufacturing (CAM) laboratory at IIT Bombay is actively engaged in designing and developing software solutions in the area of Product Modeling (Palantir), Process Planning (WebCAPP), CNC Machining (WebNC) and Assembly Automation (WebROBOT).

WebROBOT is an Internet based Assembly Planning System for intelligent task level programming of assembly robots. Its Client-Server architecture enables a client to graphically model and synthesize the assembly world. A feature-based CAD modeler enables the user to create and position solid models of parts to be assembled in the virtual world. Unlike the standard robot programming systems that need Teach-in or Joint level information, WebROBOT enables the client to specify tasks at assembly (functional) level in a user-friendly manner. Robust algorithms have been written to 'understand' and process the specified tasks to generate efficient robot control

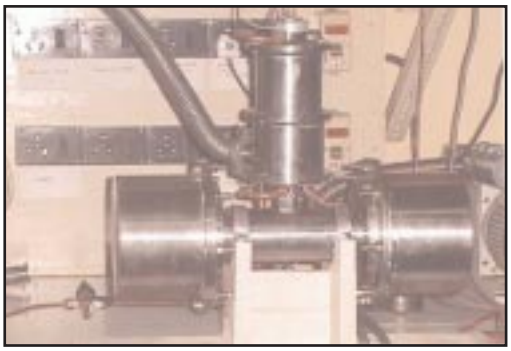
programs. Specific issues addressed include, grasp planning, motion planning, collision avoidance, operation sequencing, and post processing the programs to suit the controller of the robot in shop. Using this technology, robot programs can be automatically transferred by the client to the remote robot site through the server.

WebROBOT implemented in the modular fashion using Object Oriented Programming was linked to the Mitsubishi Movemaster 5 axis robot in the CAM laboratory, and was extensively tested from different locations through the Intranet. Various assembly tasks such as, part placement, single and multipart assemblies, and pattern-based assemblies were tested. WebROBOT was found to provide an efficient web-based solution from client-end virtual assembly modeling to its execution in the real assembly environments. The software can be customized to suit specific robot controllers.

Contact: Prof S S Pande, Mechanical Engg Department, email: sspande@me.iitb.ac.in

Pulse Tube Cryo-cooler

With funding from the Board of Research in Nuclear Sciences (BRNS), Prof K G Narayankhedkar, Department of Mechanical Engineering, has developed a state-of-the-art technology for Stirling type Pulse Tube Cryo-cooler (15 W capacity at 77K). The technology finds applications in re-condensation of nitrogen gas for MRI shield cooling, liquefaction of hydrogen and oxygen for space applications, and helium liquefaction for SQUID.



The cooler has a modular compressor design, and produces cryogenic temperatures without the use of displacers. Hence, it has no displacer seals, moving cold parts, or vibration, leading to greater reliability and longer mean time between maintenance schedules. Additionally, damage to the cold head during operation is eliminated due to the absence of moving parts.

The novel design combines two major technical breakthroughs:

- Dual opposed pistons driven by moving coil type linear motor using flexure bearings, minimiz ing compressor vibrations and acoustic noise.
- Pulse Tube with inheritance tube and reservoir

These features make the Stirling type cryo-cooler more efficient than other cryo-coolers.

Contact: Prof K G Narayankhedkar, Mechanical Engg Department, email: nkhedkar@me.iitb.ac.in

Rapid Prototyping Facility

A state-of-the-art Rapid Prototyping Facility has been recently set up at IIT Bombay with funds from MHRD under the Technology Development Mission. The facility has helped diffuse the technology into the Indian industry. Several companies now employ the technique for their product development.

Rapid Prototyping (RP) makes the manufacture of complex 3D objects as easy and simple as printing a letter, drawing or a picture. In fact, RP machines are also called '3D Printing' or '3D Faxing' machines! This fairly new and fascinating technology has revolutionized the way products are designed and manufactured today. It enables manufacturing of physical objects directly from their CAD models without any human intervention or use of any tools, dies, or fixtures specific to the geometry of the objects being produced. The object is built in an automated layer-by-layer manner, requiring only a definition of its geometry. Rapid Prototyping & Tooling (RP &T) has distinct benefits since the process compresses the product development cycle, and shortens the tool manufacturing cycle enabling organizations to launch new products with short lead times.

Objects as large as 25cm x 25cm x 25cm can be made out of plastics using this facility. Bigger objects can be built in pieces and joined using adhesives, or mechanically, or both. Its major uses include: building concept models in various disciplines of mechanical, aerospace, civil, and bio-medical engineering, and product design directly from CAD files.

Contact: Prof K P Karunakaran, Mechanical Engg Department, email: karuna@me.iitb.ac.in

Design Registrations: Five designs have been registered with the Office of the Controller General of Patents, Designs and Trademarks, India, for *'Key-Lekh'*– a keyboard developed at IIT Bombay for text input in Indian languages (The product was described in the previous issue). Webaddress–http://rnd.ircc.iitb.ac.in/~webadm/update/December03/keyboard.html

Event Highlight

K-Yan: The Compact Media Centre

New generation communication technologies allow creation of novel media products that can serve the community at large. Such products must be robust, and possess simple and universal interfaces. As part of a project from IL&FS (Infrastructure Leasing & Financial Services Ltd.) Educational & Technology Services, Prof Kirti Trivedi of IDC has developed *K-Yan*, such a compact media product for community use. It combines the functions of: a multimedia and internet enabled PC, large format television, DVD/VCD/CD player, CD writer, video-conference device, LCD data projector, and an audio system that facilitates shared viewing and participation by users. Launched in March 2004 at the major event **IT.Com** held in Bangalore, K-Yan has been demonstrated to several Chief Ministers, and senior state and central government officials.

K-Yan is easy to use, has multilingual facilities, and eliminates the need for investing in other media hardware. A single unit can cater to the teaching needs of an entire class, and substantially reduce the cost of computerizing schools. The integration of various functions not only allows students to learn how to use a computer, but also other subjects, and crafts. The product will also be useful in other group learning or information dissemination programs like healthcare, family planning, agricultural practices, and civic awareness drives.

K-Yan is equipped with extra solar energy-based portable power supply to enable use in areas with no electricity. Mounted on a van, it can also function as a mobile communication centre from remote locations. With an internet connection and a web-camera, it would allow low cost web-conferencing from any location–making it useful in disaster management or project progress monitoring. The web-conferencing feature will also be useful in e-governance, as it will facilitate direct communication between various agencies and the administration.

K-Yan has evoked enthusiastic response and is on the way to becoming a major commercial success.

Contact: Prof K Trivedi, Industrial Design Center kirti@idc.iitb.ac.in

Pan-IIT Workshop on 'Management of IP in Academia' at IIT Bombay

In the current global economic scenario, timely and efficient management of Intellectual Property (IP) in premier academic and research institutions has become critical. Apart from producing skilled manpower, institutes such as the IITs are major generators of innovative products and services. Most of the IITs have already initiated institutional IP management activities. For providing a further fillip to such activities, the IPR unit* of IIT Bombay organized a two-day Pan-IIT workshop on 'Management of Intellectual Property in Academia'. Held on the 26th and 27th of February 2004 at IIT Bombay, the idea of hosting such a workshop was originally conceived by Prof. Ashok Misra (Director, IIT Bombay), as a sequel to a Pan-IIT road show conducted in the US about 6 months ago.

L to R: Prof Shishir K Jha, Prof V Kalyanaraman, Judge R Rader, Mr Raghav Saha, Prof Martin Adelman

Targeted at all the IITs and other academic institutions , and the heads of their IPR units, the workshop was unique in the sense that it was made possible by spontaneous and honorary participation of several specialist speakers and professionals. Dr Raj Dave (IIT alumnus, and Patent Attorney, Morrison & Foerster, USA) was instrumental in bringing in a delegation of distinguished American IP experts and industry representatives, who provided an insight into the current status of IPR issues on an international level. The presentations were followed by lively and highly interactive panel discussions, which addressed the deeper issues of IP protection from the standpoint of innovators or creators of IP, and the institution as a whole.

In a succinct speech, the eminent lawyer, Mr. Ram Jethmalani, who was present during the inauguration of the event, acknowledged the superiority and the significance of intellectual property in today's business environment. However, he also put forth a caveat on the importance of exercising global control of what could turn out to be a potentially lethal tool.

The workshop covered a gamut of issues which included the following:

- Managing IPR in academia: national and global experience
- Building Institutional IP Policy for academic institutions: conflicts, critical issues and challenges
- Valuation and protection of IP in a global context.
- IP protection in Technology Transfer: price, royalty stru-c ctures, other terms and conditions.

Event Highlight

- Experimental exemptions in patents/designs dealing with selection of projects, assignment of rights, liabilities, and planning research.
- Case Studies in IPR litigations involving academic institutions
- Entrepreneurship development and IPR
- Copyright issues in academics

Several interesting themes emerged from the deliberations; one of these was the need for evolving a strong institutional IP policy that would clearly address the inherent complexities in the creation and dissemination of knowledge. With the overlap of disciplines and a blurring of boundaries between upstream and downstream research, issues concerning multiple ownerships can be expected to arise–especially in externally funded research projects, and Technology Business Incubation activities. An ideal policy would therefore be one that successfully protects the interests of the innovator (student or faculty), the institute, the sponsor, and the society at large. Such a policy would also help the institute in developing a coherent philosophy, and in achieving its Vision and Mission. As noted by Prof. P Ganguli, "in the present global framework, IPR has come in at the point of idea generation and the challenge lies in managing it from here up to commercial production".

On a national scale, the need of the times is a legislation that will address ownership issues of externally funded projects, similar to the Bayh-Dole Patent and Trademark Law Amendments Act of the US (1980). Institutions such as the IITs can impress upon the government, the need for such legislations.

Next on the Pan-IIT Board's agenda is the organization of a National Workshop on IPR with large participation from the industry. The event would aim to highlight the role of IP in national wealth generation, and inform the industry about the IP management initiatives in the academia. It would also dwell on the need for evolving an organizational R&D strategy in the emerging scenario. The proceedings of the workshop will be shortly brought out by the institute.

List of speakers

- Judge Randall R Rader, Circuit Judge, United States Court of Appeals, USA
- Prof Martin Adelman, Professor of Law, George Washington University Law School, USA
- Dr Raj Dave, Patent Attorney, Morrison & Foerster, USA
- Mr R S Minisandram, Executive Director of IP, Seagate Technology LLC, USA
- Mr David Simon, Director of IP, Intel Corp. USA
- Mr Paul Stone, VP and Chief Patent Counsel, Symyx Technologies Inc.
- Mr Stephen Durant, Partner, Morrison & Foerster, San Francisco.
- Mr Marc Adler, Chief IP Counsel, Rohm & Haas, USA
- Mr Raghav Saha, Advisor, Department of Science and Technology, Govt. of India
- Mr T C James, Deputy Secretary DIPP, Govt. of India
- Mr Manoj Menda , Advocate
- Prof P Ganguli, Advisor, Vision IPR, Mumbai

** The IPR Unit at IITB: Prof Karuna Jain (Co-ordinator) and Prof Shishir Kumar Jha (Shailesh J Mehta School of Management), Prof Prabuddha Ganguli (Advisor, Vision IPR), and Dr Padma Satish (IRCC)*

Techfest 2004: A look back

Zishaan M Hayath*, Department of Civil Engineering

Techfest 2004–Asia's biggest, and IIT Bombay's popular annual technological festival is now seven years old and yet new! Held from the 24 - 26 January with a vivid spectrum of events ranging from competitions to lectures to exhibitions, Techfest attracted the participation of over 15,000 students, faculty, corporate executives and eminent personalities from all over the world. True to its reputation of doing new things every year–be it holding a defense exhibition or showcasing Sony Aibo robots playing football–Techfest 2004 introduced *Cliffhanger*, the international rope-climbing machine design contest, probably the biggest milestone for Techfest yet. About 60 teams out of 400 were short-listed for the event, including three from the 'Rest-of-the-World' category (NTU Singapore, University of Peradeniya Sri Lanka, and Institute of Engineering, Nepal).

Tech-a-tete, the distinguished lecture series of Techfest promises the participants rendezvous with the "who's who", and some of the high-profile achievers of our times. This year, Techfest played hosts to Dr Bharat Balasubramanian, Vice President of 'Engineering Technologies', Daimler Chrysler; Prof Kevin Warwick, Professor of Cybernetics, University of

Students in the Competition Area

Reading, UK; Dr Raghuram Rajan, Chief Economist of the IMF and Director of American Finance Association (over video conference); Prof Yash Pal, India's most popular scientist; Prof Alex Pentland, Founder Director Media Labs Asia; Dr Narendra Bhandari, member of the Moon Mission task force constituted by Indian Space Research Organisation; Prof Urjit

Yajnik (IIT Bombay) and Prof D Narasimha (TIFR, Mumbai).

Competitions have always been Techfest's mainstay. They enable students to construct, destruct, simplify, complicate, understand and battle it out in challenges designed to instill the spirit of 'striving to achieve the best'. Numerous teams participated in over 25 competitions with a total prize of over 6 lakhs. IIT Bombay clinched the overall trophy for the second year in a row. *Yantriki*, the robotics event was a huge success, the other two events in it being *Micromouse* and *Last Man Standing*. For the first time, fully autonomous robots built by the participants solved the maze in Micromouse successfully. IIT Bombay bagged both the first and second positions. *Last Straw* stuck to its philosophy of simple but stimulating design problems. The challenge was to make a Crane and Impact-resisting structure with straws. The participants also made a 21-feet high tower out of drinking straws to register themselves in the 'Limca Book of Records'. *Chemsplash* came back with rejuvenated vigour with *la porsChe* and *High Spirits,* in which models are made using only chemical power. It also included various quizzes and modelling competitions like *Turbulence* and *Dexter's Den*.

Para-jumping by Aakaash Ganga team, IAF

A prominent feature of Techfest is the *Workshops* where the emphasis is not just on 'Learn', but also on 'Do while you learn'. Over the last several years, attractive workshops on Cryptography, Wireless Networking and Forensics have been held; this year's topics included Intellectual Property Rights (IPR), Aeromodelling, Gaming, Car Technology, GPS/GIS and Smart Materials.

A highlight this year was the Indian Naval Exhibition. Inaugurated by Rear Admiral S K K Krishnan, the exhibition showcased technologies used in the Navy. The theme of the exhibition was built upon the basic functions of a warship. The exhibits gave an insight into the complex technologies contributing to making the ship, a cohesive, self-contained fighting unit. Equipment displayed depicted the four essential functions of a warship–to float, to move, to seek, and to destroy.

The last day of the events coincided with Republic Day. To celebrate this occasion, the *Aakaash Ganga* team of the Indian Air Force performed a breath-taking feat of para-jumping on the campus. The event drew a very large body of spectators.

Mr. Ferenc Cako of Cako Studios Hungary (and of Seoul International Cartoon & Animation Festival 'SICAF' fame), performed in India for the first time at Techfest. This very unique and novel show involving figurative painting with sand to the sound of music and projected on a screen, was held in the Open Air Theatre of IIT Bombay before a capacity crowd of 4000! The attractions at *Technoholix* included: the Sci-Tech quiz hosted by renowned quiz master Barry O'Brien, the display of a Formula 3 car (from the stables of Tata Racing team), *Colosseum*–the gaming arcade, and the Dirt Track Racing competition.

In all, Techfest provided an enriching and exhilarating experience, especially to students who had traveled from various parts of the country to participate in the event.

** Overall Co-coordinator, Techfest 2004*

Sanskrit Texts: A Window on Indian Scientific Tradition

Prema Prakash

In the popular perception, India's contribution to the development of science and technology often appears limited to those achieved over the last century or so. However, the wealth of Sanskrit texts provides evidence that such contributions have existed over the millennia–the earliest textual source being the *Rigveda* (believed to pre-date 3100 BC). Yet, an awareness of the precise nature of the contributions has not percolated through our now westernized education system. This is partly due to a lack of wider cultivation of Sanskrit, and access to the ancient texts. Nevertheless, attempts are being made in several academic institutions in India, including IIT Bombay, to bridge this rift with our heritage by archiving, translating, and digitizing manuscripts for easier access.

Indian Science over the Ages

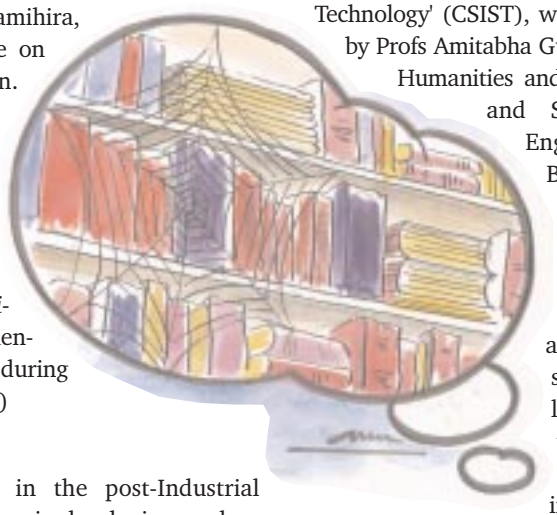
Archaeological evidence shows that the first 'industrial' revolution had begun as far back as the Mohenjo Daro and Harappan civilizations. The *Svetasvatara Upanishad* recounts the earliest conflict between religion and science, which ushered in a new intellectual climate during the Second Urbanization (c.600 BC)–a period that allowed for the first time, the emergence of the 'scientist'. Contrary to the belief that science originated in Europe pioneered by the Greek sage Thales (76 BC), historian D P Chattopadhyaya demonstrated that it was actually Uddalaka Aruni from the Indian subcontinent who possibly was the first in human history to claim the need for arriving at knowledge through experimentation. As is well known today, the rationalist medicine of ancient India was rich in its empirical content. Its founders made use of knowledge not only of anatomy, physiology and pharmacology, but also digressed into other disciplines that later evolved into physics, chemistry, biology, climatology and mineralogy. Also, scholars have acknowledged that Panini's grammar (5th century BC) with its 4000 rules is one of the greatest intellectual achievements of all time. It represents a universal grammatical and computing system, which anticipated the logical framework of modern computing languages.

The period between 4^{th} & 12^{th} centuries AD saw remarkable progress made in the realms of astronomy, mathematics, medicine, metallurgy and architecture. The oldest mathematical works essentially dealing with geometry were the *Sulvasutras*. Mathematics itself developed more as an offshoot of an enduring preoccupation with astronomy. Some of

Manufacturing

the astronomer-mathematicians like Aryabhatta (born 476AD), Brahmagupta (born 598AD), Bhaskaracharya (1114AD), Madhavacharya (c.1340-1425) and Nilakantha Somayaji (c. 1444-1545) had developed methods far ahead of their European contemporaries. Bhaskaracharya was the author of *Siddhanta Shiromani*, a compendium comprising: *Lilavati* on arithmetic, *Bijaganita* on algebra, *Ganitadhyaya*, and *Goladhyaya* on astronomy. His "epicyclic-eccentric" theories of planetary motions were more developed than in the earlier siddhantas. The *Chakravala* (quadratic equations with two unknowns) contained in the Bijaganita gained popularity in 17th century Europe.

The sources for astronomical knowledge are the *Jyotish-Vedanga* (500BC) and the *Panchasiddhantas,* of which, the *Suryasiddhanta* (Varahamihira, 578 AD) has had a major influence on Indian astronomical tradition. Similarly, the postulation of atomism in the *Nyaya-Vaisheshikas*; the extensive treatise on coinage and minting in Kautilya's *Arthashastra*; and the holistic 'science of life' *Ayurveda* with its outstanding texts–the *Charaka, Susruta* and *Ashtanga samhitas*–are examples of the advanced scientific knowledge that was available during the medieval period (c.647 - 1526AD)



This worldly vs. otherworldly

Despite such early achievements, in the post-Industrial Revolution era, India fell behind Europe in developing modern science and technology. Historian, A Rahman has suggested that the reason lay in "a lack of quantification of knowledge and practice, a lack of development of aids to observation, and the failure to evolve a perspective of the future and develop a pattern of knowledge in relation to it". Others have implicated periodic invasions, unfavourable social climate, and the self-seeking policies of the colonial power. The Indian education system was seen to be ritualistic and brahminical, and the subsequent government decree in 1844, which officially recognized only students of the Western education system, led to the decay of traditional Pathshalas. In his well-known book 'Protestant Ethic and the Spirit of Capitalism' the European sociologist Max Weber observed that the capitalist form of economy employed a form of rationality–a "this worldly attitude"–that fostered western scientific thought; unlike the "otherworldly attitude" of withdrawal and renunciation that was supposedly adopted by eastern cultures. In short, the exotic and spiritual aspects of Indian intellectual tradition have been unduly exaggerated over its more rationalistic and analytical elements.

The Sanskrit Cell at IIT Bombay

The usefulness of Sanskrit texts for modern times can be demonstrated by demystifying the basic knowledge in the ancient texts, and by working out new theories and paradigms that can be built on the principles laid down in them. At the suggestion of the Ministry of Human Resource Development, IIT Bombay has set up a 'Cell for Sanskrit in Indian Science and Technology' (CSIST), with an Advisory Committee constituted by Profs Amitabha Gupta (Convener) and P R Bhat (Dept of Humanities and Social Sciences); Profs H Narayanan and S D Agashe (Dept of Electrical Engineering); and Prof Pushpak Bhattacharya (Dept of Computer Science & Engg)

The cell's activities include: initiating teaching and research based on Sanskrit texts, developing a digital archive*, and organizing workshops, seminars and lecture series to highlight and disseminate Indian contribution to science and technology. An elective course has already been introduced at the 4th year level, and the texts currently available at the website are *Suryasiddhanta* and *Bijaganita*. Verses from the former have been juxtaposed with their English translation by Rev Ebenezer Burgess (1861). Prof S M Bhave, Head, CSIST has provided the prefaces to both texts. In the future, the CSIST aims to make more such texts readily accessible and help re-evaluation of ideas dormant in them, and so enhance their utility in the on-going discourse on Indian contributions to the founding of science.

***Acknowledgement**: The author thanks Prof A Gupta and Prof S M Bhave of the Dept of Humanities & Social Sciences for their comments and suggestions.*

**Website: www.csist.hss.iitb.ac.in*

Collaborative Engineering for Product Life Cycle Management

B. Ravi, Department of Mechanical Engineering

To survive and succeed in the global market, manufacturing firms are churning out innovative products with continual improvements in price-, quality- and response- competitiveness. Products now incorporate new features, materials, or technologies with: additional functionality, better user interface, higher efficiency, or smaller size. Price competitiveness relies on manufacturing a product within a target cost given by the target market price, minus desired profit. Quality competitiveness involves designing robust products and production systems to get the quality right–the first time and every time. Response competitiveness implies faster development and introduction of a new product by working proactively with respect to customer expectations.

What is Collaborative Engineering?

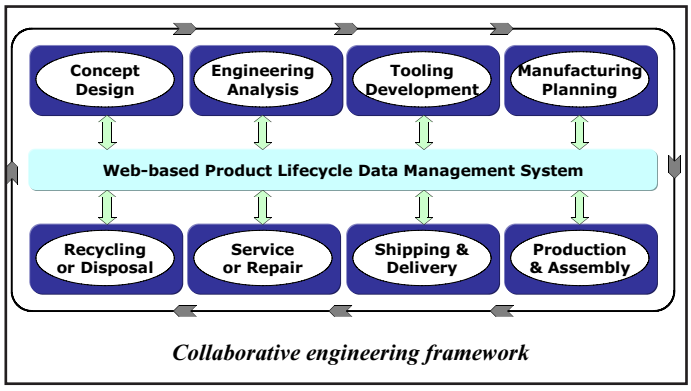
Aggressive innovation by competing firms is leading to more complex products which require specialist teams to handle different activities in product lifecycle, such as: concept design, engineering analysis, tooling development, manufacturing planning, part manufacture, product assembly, delivery, serv-

ice, and disposal. The teams need to work with each other concurrently to optimise the product, and launch it early in the market. Concurrent engineering is, however, difficult to practise when the specialist teams are located in different parts of the world–an increasing trend with globalisation.

The solution lies in connecting the team members through a digital communications network and providing them appropriate software to create, analyse, and modify a virtual model of the product. The model and results are stored in digital form in a central or distributed server, which may be accessed by all team members over a local area network or Internet. This approach to product development is referred to as *Collaborative Engineering*.

Computer-aided Product Development

The virtual product comprises a digital assembly of its part models. The parts are modelled in 3D using computer-aided design (CAD) programs and saved in standard formats (e.g. IGES and STEP) for exchange between different programs. Computer-aided engineering (CAE) programs enable simulating the product mechanism, and optimising the shape of each part under static or dynamic loads by simulating the internal stresses. The part models can be sent to a rapid prototyping system for automatic fabrication of a physical replica for form, fit and function testing. The tooling models (moulds, dies, jigs and fixtures) can be quickly developed by modifying the corresponding part models. Computer-aided manufacturing (CAM) programs enable planning, simulation and optimisation of process parameters. Finally, computer-aided inspection systems enable automatic comparison of virtual and real parts for quality assurance.



Collaborative engineering framework

The 3D product-model is the connecting link between the various computer-aided programs (referred later as CAX-where 'X' could mean design, engineering, manufacturing, or inspection). The programs generate a huge amount of data, which includes the solid models of different iterations and previous versions of products, as well as tooling, materials, process plans, and results of analysis. This necessitates a systematic approach to data storage, verification, and retrieval–achieved by a product data management (PDM) system.

The PDM systems have rapidly evolved over the last decade, and now allow distributed storage and remote access over Internet. They provide better data translation for exchange among various teams. Security is handled by data encryption during exchange, and by facilities for setting limits of access by non-core team members. Also, some useful utilities may be provided for collaboration. For example, comments or suggestions can be attached to product features. Additionally, two or more team members can synchronise their computer displays, point out product features (by an arrow visible to all team members), and discuss improvements using a messaging, or videoconferencing facility.

A complete set of computer-aided programs, PDM system, and collaboration utilities, is now referred to as a-product lifecycle management (PLM) solution. The set may be offered entirely by a single vendor (such as Dassault Systems, France; Electronic Data Systems, USA; or Parametric Technology Corp, USA) or can be put together by integrating the most suitable program for each application (e.g. SolidWorks for CAD, ANSYS for CAE, Delcam for mould design and CAM, MoldFlow for plastic flow simulation and MatrixOne for PDM).

Designing Beyond Functionality

A well-designed product not only satisfies its functional requirements, but also is easier to manufacture, maintain, deliver, and dispose off. Often, even minor modifications to an existing design (such as changing a fillet radius or shifting a boss) may yield significant reduction in costs, defects or lead-time. Such changes are easy and inexpensive for a new product during its *design phase*. The same changes during *manufacturing phase* would entail redoing the tooling and process planning, which is several times more expensive and time-consuming. The costs mount further if the products have already been delivered to customers and have to be recalled to fix a problem that could have been foreseen and prevented by a better design in the first place.

Design for Manufacture (DFM) is influenced by product geometry, material, and process. For example, injection moulded plastic parts need to be designed with a uniform wall thickness to minimise the production cycle time, and avoid sink marks; metal castings must be designed for directional solidification for ease of feeding; forged parts must have generous radii of curvature to facilitate flow of metal; and sheet metal parts made by blanking operations, must be designed for efficient nesting and thereby, stock utilisation.

Similar guidelines are also available for improving a product design for ease of assembly, service, transportation and environment. Design for Assembly (DFA) guidelines include reduction of number of parts, and number of assembly directions. Design for Service guidelines include modular design, and ease of access. Design for Transportation guidelines include provision of suitable hooks and handles for lifting the part. Design for Environment (DFE) guidelines include use of recyclable materials (metals are better than plastics), reduced packaging, and improving the energy efficiency of the product. The guidelines (referred later as DFX–where X could mean manufacture, assembly, service, transportation, or environment) are distilled from practical experience on previous products, and may not be applicable to new materials or processes. They may also conflict with each other, but provide no quantitative feedback to resolve such conflicts. Moreover, most designers have little time, interest or knowledge in handling product lifecycle issues beyond functionality. One way to

overcome these problems is to invite external experts to evaluate the design for various design considerations and suggest suitable improvements. Since the experts are likely to be inaccessible (in terms of time or distance), a web-based PLM system greatly facilitates such collaborations.

The collaborative engineering framework also yields an important by-product: a vast amount of data and information captured in digital form during development of several generations of products. Special data mining tools can be used to process the accumulated data and produce new knowledge. All such information and knowledge can be made accessible over the network, and used in developing future generations of products. Knowledge Management (KM) is in fact, rapidly becoming an important part of Product Lifecycle Management.

The focus of PLM on engineering data and knowledge, contrasts with enterprise resource planning, supply chain management and customer relationship management, which largely handle business process data. There is however, an increasing overlap between the systems and the distinctions are gradually blurring. In future, it is likely that the systems will have seamless connections and data exchanges with each other, and will provide access to any relevant data through a standard (but customisable) user interface.

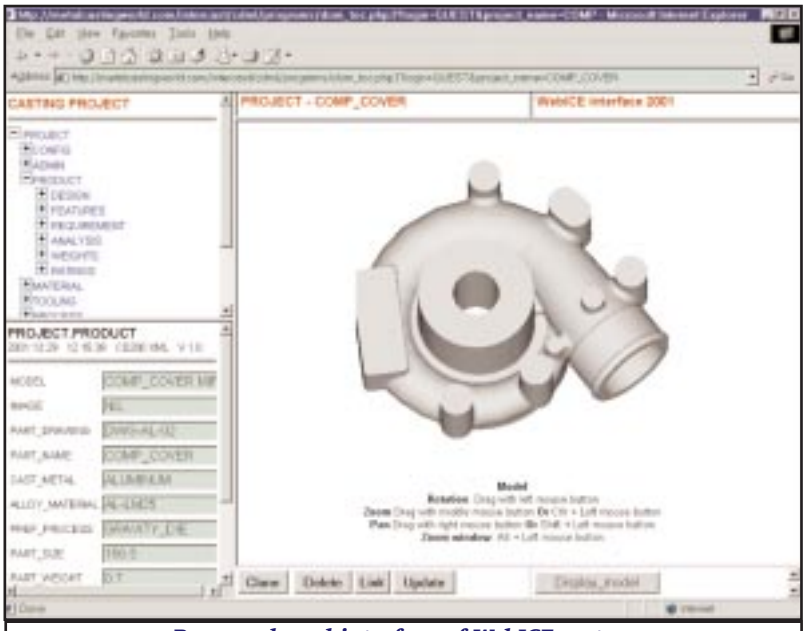
Research Initiatives at IIT Bombay

Our R&D focus is on developing a systematic approach and software tools for collaborative engineering of cast components used in automobile, aerospace, farming, mining, machine tools, electrical, consumer, and other products. Over the last one decade, several elements of a framework code–named WebICE (Web-based Intelligent Collaborative Engineering) have been developed and used for solving industrial problems. The framework allows product, tooling and manufacturing engineers to design, analyse, and improve a casting for lower cost and higher quality assurance using software tools and Internet.

The backbone of the system is an XML-based casting data mark-up language (CDML), which captures over 2000 different items of information about a casting project. The items range from part geometric parameters to material properties, tooling element designs, process plans, and costing details. Other files containing 2D images, 3D models, library options, and knowledge-bits (if-then rules) related to the casting can be linked to different nodes of the CDML tree. The data is stored in a web server, and team members can access and view it using a standard browser. The large size of solid models prevents their real-time exchange over standard network connections. To overcome this problem, a special program has been developed to compress, upload, download, decompress, and display the solid models.

Several programs have been developed to assist the product, tooling, and foundry engineers in their respective tasks, as well as evaluate the product and process. These include: casting alloy selection, process selection, process planning, methoding (feeding and gating design), casting defect prediction, product-process-producer compatibility analysis, shape complexity estimation, tooling process selection, cost estimation, feature recognition and DFX checks. Simpler programs are implemented in PHP/Java and executed at the server itself, whereas computation-intensive programs are implemented in C++ and run at client computers, followed by exchange of results over the network.

The system has been used to troubleshoot and optimise many castings ranging in weight from a few kilograms (e.g. compressor casing and medical equipment housing in aluminium alloys) to several tons (e.g. hydraulic pumps and press tool parts in ferrous metals). Such projects are carried out by active involvement of product, tooling, and manufacturing engineers, and coupled with continuing education programs to impart the necessary theoretical background.



Browser-based interface of WebICE system

Our research focuses strongly on different methodologies and software tools for collaborative engineering, including intelligent CAX, DFX, PLM and KM; these have a direct and immediate impact on the competitiveness of manufacturing firms. Today, many research laboratories in leading universities, and several journals and conferences are dedicated to various aspects of collaborative engineering.

Conclusion

Currently the Indian manufacturing industry is in the global limelight. Just as Japan in 1980s focussed on quality, and China in 1990s established its price competitiveness, India can stake a claim to response competitiveness. This is possible by applying information technology–in which we have already gained world-class experience and reputation–for product lifecycle management and collaborative engineering. Because our industry mainly comprises small and medium size firms, the solutions must be inexpensive and genuinely easy-to-use. This is a challenge that can be addressed only by collaborative R&D between engineering institutes, the IT sector and the manufacturing industry.

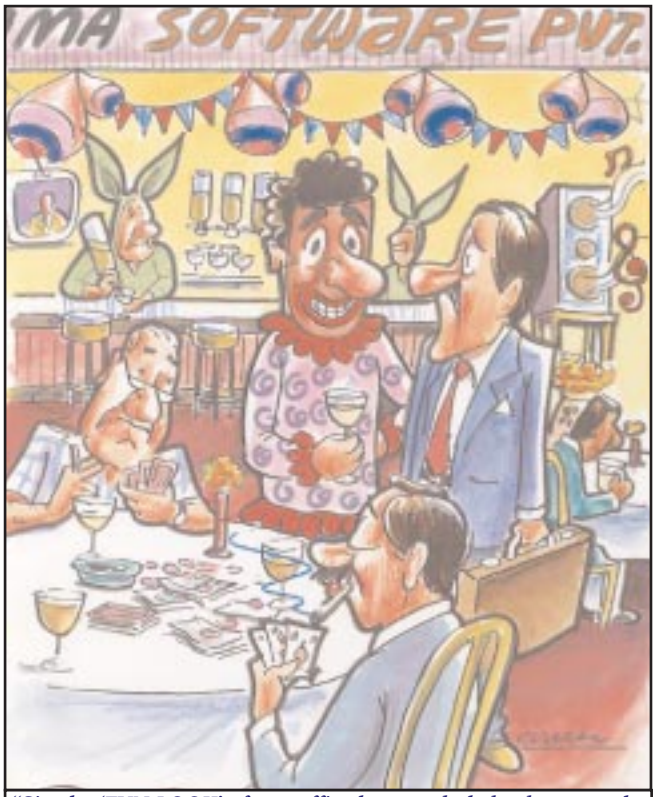
Contact: bravi@me.iitb.ac.in

HR Management

HR Challenges in the Indian Software Industry

Meenakshi Gupta, Department of Humanities and Social Sciences

Software is a wealth and job creating industry, which has in just a few years, grown to US $ 1 trillion, employing millions of professionals worldwide. The Indian software industry has burgeoned, showing a nearly 50% compounded annual growth rate over the recent years. Being a knowledge-based industry, a high intellectual capital lends competitive advantage to a firm. Intellectual capital comprises human capital and intellectual assets–the latter being any created bit of knowledge or expertise. With a global explosion in market-opportunities in the IT sector, the shortage of manpower both in numbers and skills is a prime challenge for HR professionals. The related issues are varied indeed: recruitment of world-class workforce and their retention, compensation and career planning, technological obsolescence and employee turnover. This article presents some of the findings of our recent research on the HR challenges posed by the IT sector.



"Sir, the 'FUN LOOK' of our office has surely helped attract the best brains! Our next challenge is to get them to work!"

Workforce Retention and Motivation

Retention and motivation of personnel are major HR concerns today. *People*–a Gartner group company specializing in management of human capital in IT organizations–has observed that the average tenure for an IT professional is less than three years. Further, the use of new technologies, the support of learning and training, and a challenging environment ranked higher than competitive pay structures as effective retention practices. Our own recent survey of 1028 software professionals from 14 Indian software companies, showed that while the professional gave importance to personal and cultural job-fit, HR managers believed that the key to retention was salary and career satisfaction. Money was a prime motivator for 'starters', but for those into their third or fourth jobs, their value-addition to the organization was more important. Monetarily, offering 'the best salaries in industry' is the minimum every company is doing, apart from performance-based bonuses, long-service awards, and stock options. Many organizations frequently conduct employee satisfaction and organization climate surveys, and are setting up Manpower Allocation Cells (MAC) to assign 'the right project to the right person'. In fact, some are even helping employees with their personal and domestic responsibilities to satisfy & motivate their workforce!

Attracting the Best Talent

In a tight job market, many organizations often experience precipitous and simultaneous demands for the same kinds of professionals. In their quest for manpower, they are cajoling talent around the world. In such a *seller's market*, software companies are striving to understand which organizational, job, and reward factors contribute to attracting the best talent–one having the right blend of technical and person-bound skills. This would mean a knowledge of 'the tools of the trade' combined with conceptualization and communication skills, capacity for analytical and logical thinking, leadership and team building, creativity and innovation. The Indian software industry suffers from a shortage of experienced people such as systems analysts and project managers, and attracting them is a key HR challenge.

Compensation and Reward

Increasing demands of technology coupled with a short supply of professionals (with the requisite expertise) has increased the costs of delivering the technology. This makes incentive compensation a significant feature, with the result that software companies have moved from conventional pay-for-time methods to a combination of pay-for-knowledge and pay-for-performance plans. With the determinants of pay being profit, performance and value-addition, emphasis is now on profit sharing (employee stock option plans) or performance-based pay, keeping in view the long-term organizational objectives rather than short-term production-based bonuses. Skills, competencies, and commitment supercede loyalty, hard work and length of service. This pressurizes HR teams to devise optimized compensation packages, although compensation is not *the* motivator in this industry.

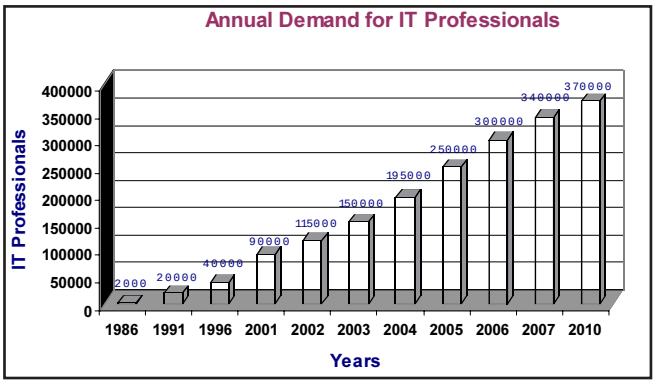
Being 'the best place to work with'

As with any other professional, what really matters to software professionals is selecting 'the best place to work with'–which is what every company is striving to be. The global nature of this industry, and the 'project-environment' (as opposed to 'product environment') has added new cultural dimensions to these firms. In a value-driven culture, values are determined and shared throughout the organization. Typically, areas in which values are expressed are: performance, competence, competitiveness, innovation, teamwork, quality, customer service, and care and consideration for peo-

ple. Flat structure, open and informal culture, authority based on expertise and ability rather than position, and flexi-timings are some of the norms software firms follow. The idea is to make the work place a 'fun place' with the hope of increasing loyalty and commitment.

Coping with the Demand-Supply Gap

Shortage of IT professionals is global in nature and not peculiar to the Indian software industry alone. W. Strigel, founder of Software Productivity Centre Inc. (1999) has projected the shortage of software professionals to be one million by 2006. In fact, a survey reports that 75 per cent of US companies planned to reengineer their applications using newer technologies, but found that 72 per cent of their existing staff lacked the skills needed in these technologies, and 14 per cent were not even re-trainable.



For India, it is predicted that in the year 2004 itself, the IT sector will need 1,95,000 professionals. This trend will continue, and in the year 2010 almost 3,70,000 IT professionals will be required (Strategic Review Reports, NASSCOM 1996-2001). Consequently, recruitment managers are exploring new sources of IT manpower from non-IT professional sectors, as well fresh, trainable science graduates.

Integrating HR strategy with Business Strategy

The strategic HR role focuses on aligning HR practices with business strategy. The HR professional is expected to be a strategic partner contributing to the success of business plans, which to a great extent depend on HR policies pertaining to recruitment, retention, motivation, and reward. The other major areas of concern for HR personnel in this context are, management of change, matching resources to future business requirements, organizational effectiveness, and employee development.

Encouraging Quality and Customer focus

Today's corporate culture needs to actively support quality and customer orientation. With globalization and rapid technological change, quality is of utmost importance for the Indian companies, which earn most of their revenues through exports. Hence, the HR professional as a strategic partner needs to encourage a culture of superior quality to ensure customer satisfaction–the only real measure of quality of a product or service.

To be competitive today, an organization needs to be customer responsive. Responsiveness includes innovation, quick decision-making, leading an industry in price or value, and effectively linking with suppliers and vendors to build a value chain for customers. Employee attitudes correlate highly with customer attitude. The shift to a customer focus redirects attention from the firm to the value chain in which it is embedded. HR practices within a firm should consequently be extended to suppliers and customers outside the firm.

Up-gradation of Skills through Re-training

Rapid and unpredictable technological changes, and the increased emphasis on quality of services are compelling software businesses to recruit adaptable and competent employees. Software professionals themselves expect their employers provide them with all the training they may need in order to perform not only in their current projects, but also in related ones that they may subsequently hold within the organization. As observed by Watts Humphrey, Fellow of the Carnegie Mellon University, "…as software professionals gain competence, they do not necessarily gain motivation. This is because a creative engineer or scientist who has learned how to accomplish something has little interest in doing it again. Once they have satisfied their curiosity, they may abruptly lose interest and seek an immediate change". And when the rate of technological change is high–may be higher than the time required to acquire competence in one area–professionals could undergo psychological turbulence owing to the need to work in a new technology throughout their career. They want to gain new knowledge, which will be utilized by their organization. On the basis of the new learning they want to work in higher segments of software value chain. Therefore, constant up-gradation of employee skills poses yet another challenge for HR personnel.

In Conclusion

With the advent of a work situation where more and more companies are having to concede that their valued employees are leaving them, a new concept of career and human resource management is bound to emerge. The focus of this new paradigm should not only be to attract, motivate and retain key 'knowledge workers', but also on how to reinvent careers when the loyalty of the employees is to their 'brain ware' rather than to the organization.

With lifetime employment in one company not on the agenda of most employees, jobs will become short term. Today's high-tech employees desire a continuous up-gradation of skills, and want work to be exciting and entertaining–a trend that requires designing work systems that fulfill such expectations. As employees gain greater expertise and control over their careers, they would reinvest their gain back into their work.

HR practitioners must also play a proactive role in software industry. As business partners, they need to be aware of business strategies, and the opportunities and threats facing the organization. As strategists, HR professionals require to achieve integration and fit to an organization's business strategy. As interventionists, they need to adopt an all-embracing approach to understanding organizational issues, and their effect on people. Finally, as innovators, they should introduce new processes and procedures, which they believe will increase organizational effectiveness.

Some of the information in this article is based on the work of Dr N S Rathi, Asst. Placement Officer, IIT Bombay.

Contact: meena@hss.iitb.ac.in

Opportunities for the Food Processing Industry in India

Narendra Shah, CTARA* & K V Venkatesh, Department of Chemical Engineering

In India agricultural and dairy sectors have achieved remarkable successes over the last three and a half decades. Besides being one of the world's largest producers of food-grains, India ranks second in the world in the production of fruits and vegetables, and first in milk production–providing much needed food security to the nation.

The accomplishments of the green and white revolutions have, however, not been matched by concurrent developments in supply chain management, and in new technologies for better processing, preservation, and storage of food. Pockets of shortages and near starvation, substantial wastages due to spoilage, quality deficiencies, and inadequate returns to the farmer are still very much in evidence.

Increased urbanization, improved standards of living, and the convenience needs of dual income families point to major market potentialities in the food processing and marketing sectors. This is also evident from the presence of several global foods giants and leading Indian industrial enterprises in the country's food processing sector, such as: Nestle India Ltd, Cadbury's India Ltd, Kelloggs India, Hindustan Lever Ltd, ITC-Agro, Godrej Foods and MTR Foods Ltd Besides, in the current globalized milieu, our surplus food production, as well as the increasing preference for Indian foods (in several regions of the world) need to be leveraged to achieve economic, and strategic objectives through exports. The Food and Agriculture Integrated Development Action (FAIDA) report (1997) prepared by McKinsey has estimated that, driven by changing consumer preferences, the annual consumption of 'value-added' foods alone would grow to Rs.225, 000 crores by 2007–larger than the entire manufacturing sector! A more recent report has stated an absolute revenue increase of Rs. 900 billion in food manufacturing between 1993 and 2000. This is in contrast with Rs. 150 billion and Rs. 300 billion in the pharmaceutical and IT industries, respectively. Overall, the value of the Indian food industry has increased from Rs. 3.09 trillion in 1993-94 to Rs. 3.99 trillion in 2000-01. The segments with the largest growth potential have been identified as dairy, wheat, fruits and vegetables, and poultry. This report has also identified some of the major challenges for the emerging food industry in India (see box).

Major Challenges for the Indian Food Industry

- Consumer education that processed foods can be more nutritious
- Low price-elasticity for processed food products
- Need for distribution network and cold chain
- Backward-forward integration from farm to consumers
- Development of marketing channels
- Development of linkages between industry, government and institutions
- Taxation in line with other nations
- Streamlining of food laws

Challenges in Food Processing

Unprocessed foods are susceptible to spoilage by biochemical processes, microbial attack and infestation. The right post harvest practices such as good processing techniques, and proper packaging, transportation and storage (of even processed foods) can play a significant role in reducing spoilage and extending shelf life. The challenges in processing lie in retaining the nutritional value, flavour, aroma, and texture of foods, and presenting them in near natural form with added conveniences. However, such qualities cannot be readily quantified and correlated with physico-chemical parameters, sensory evaluations providing the only means of benchmarking. Besides, processed foods need to be offered to the consumer in hygienic and attractive packaging, and at low incremental costs.

The challenges for the food preservation, distribution and processing sectors are diverse and demanding, and need to be addressed on several fronts to derive maximum market benefits. Presently, the organizations addressing the educational and R & D requirements are too few, and there is a pressing need for supplementing their efforts. In the emerging scenario, the Food Engineering professional needs to develop sufficient awareness and appreciation of the relevant principles of life sciences, and physical sciences, as well as of a wide variety of other topics including: nutrition, preservation and storage techniques, processing unit operations, bio-processing, waste management, distribution and supply chain management, food laws and regulations and so on. Besides, the professional needs to develop an appreciation of R&D and innovation in critical technology areas such as: newer or novel process development in preservation and storage techniques, rheology, colloids and dispersal systems, packaging-polymers and composites, sensors for detection and process control, bioprocess engineering, and so on.

Food Process Engineering Mission Projects at IITB

IIT Bombay has developed an appreciation of the challenges, as well as opportunities in this area over the last decade, and has played a leading role in conceptualizing a Technology Development Mission Project (funded by MHRD, Govt. of India) on Food Process Engineering with IIT Kharagpur, IISc, Bangalore, and several industry partners. The projects addressed four major areas described below:

Supercritical Fluid Extraction (SCFE) process[1]

SCFE process can help the Indian industry to compete in a fast growing international market for value-added natural products. Presently, the high cost of imported SCFE equipment deters economically viable use of SCFE technology. Our objective has been to develop viable, world-class SCFE technology through indigenous design and manufacture of components. The SCFE prototype plant designed and installed at IIT Bombay has state-of-the-art safety and process control features of commercial SCFE plants. It is used for technology demonstration, scale-up studies, test sample (extract) generation, and process optimization. Products extracted using this technology have the advantages of purity, high concentrations

and extended shelf life. The process allows flexible operating conditions for multiple product extraction, and simultaneous fractionation of extract. It also eliminates toxic residues due to the use of supercritical CO_2 as solvent. The technology has been licensed, and SCFE plants based on this technology have been sold to industries in India and abroad. *More details at www.iitbombay.com*

Controlled Atmosphere (CA) Technology for Long term Storage of food grains [2]

CA storage consists of reduction of oxygen by elevating nitrogen and/or carbon dioxide concentrations in storage units, so as to enable preservation of the quality of food products during storage. The technique of chemical fumigation that is widely used for storage, although effective to an extent, is not environment friendly. As an alternative, a Pressure Swing Adsorption N_2 generator was designed and established at IIT Bombay. This aids the creation of nitrogen and/or carbon dioxide-rich, and oxygen-depleted atmosphere in a storage unit. Bag-stacked items such as, cereal grains, seeds and black tea have been successfully stored without any infestation, moisture pick-up, and with superior quality maintenance in terms of taste, color, lustre and aroma. The choice of plastic films used as covering material for the stored grains was based on their gas permeability and water vapour transmission rates. The work has culminated in the transfer of the CA technology. More recently another project on black-tea storage has been executed, and the resulting technology transferred after filing an international patent jointly with the industrial partner.


CA Storage for palletized stacks of food grains

Engine exhaust-fired Truck Refrigeration System (TRS) [3]

Proper refrigeration is critical to the transport of perishable items. A novel technology developed at IIT Bombay, which utilizes engine exhaust has shown encouraging results with both prototype testing and full demonstration. The engine exhaust-fired TRS can replace the conventional dedicated engine-driven vapour compression truck refrigeration system (DEDVCRS) used for transporting fresh fruits, flowers and vegetables, frozen vegetables, fish, meat and ice cream. The TRS can be slightly modified for use in milk transport trucks. The salient features of the system are: rugged and reliable design due to few moving parts, low life-cycle costs due to lower initial and operating costs, and the use of environment friendly ammonia as refrigerant.

A similar 'Shipboard Chilling System' for small fishing trawlers is being transferred to an Indian client for commercialization. Using these systems, the cost of co-generating power for hot and cold utilities can be 15 to 50% lower than current methods, where a significant amount of heat is lost to the atmosphere from the engine cooling water and exhaust gases. Successful implementation of these technologies will help reduce fuel consumption, and also save valuable foreign exchange in importing the DEDVCRS, or its components.

Liquid nitrogen based Individual Quick Freezing (IQF) technology for seafood [4]


IQF Tunnel for presevation of Sea Food

India has excellent potential for development of the seafood industry, which has emerged as an important foreign exchange earner. The industry has recognized the need for IQF technology, which is far superior to the conventional processes in terms of quicker freezing time, better flavour and shape retention etc. Compared with the IQF process using mechanical refrigeration (currently being used in India), the cyrogenic process developed at IIT Bombay uses liquid nitrogen as the freezant. The seafood is frozen individually by direct contact with nitrogen vapours and liquid nitrogen spray. This offers greater convenience to the consumers and adds value to the products.

IIT Bombay has indigenously designed and developed a cryogenic tunnel which possesses the following advantageous features:

- low initial investment.
- compact unit–allowing mechanization and automation of the production process
- rapid freezing–ensuring retention of original texture, flavour, and a good marketable appearance.
- prevention of oxidation of the product due to presence of nitrogen gas during packing.

To summarize, the projects pursued at IIT Bombay have led to notable contributions. Besides sensitization to the critical aspects of food processing and preservation, they have helped develop a strong knowledge base, expertise, and important facilities in these areas. The Institute has initiated a continuing education programme series, including courses on 'Engineering Concepts for Food Industry.' The Ministry of Food Processing Industry (MFPI) has provided first-phase support for the development of a modern Food-Process Engineering laboratory at IIT Bombay. The Institute is now well equipped to launch a five-year Dual Degree programme in Food and Bioprocess Engineering (with Chemical Engineering as the core discipline), by employing the institutional strengths in a wide range of related disciplines such as: Biotechnology and Bioprocess Engineering, Chemical, Mechanical and Post Harvest Engineering, Information Technology and Technology Management.

Contact:

[1]*Prof M Mukhopadhyay (Chemical Engg.) mm@che.iitb.ac.in*

[2]*Prof N Shah (*Centre for Technology Alternatives for Rural Areas) nshah@iitb.ac.in,; Prof K V Venkatesh (Chemical Engg.) venks@che.iitb.ac.in*

[3]*Prof M V Rane (Mechanical Engg.) ranemv@me.iitb.ac.in*

[4]*Prof K G Narayankhedkar (Mechanical Engg.) nkhedkar@me.iitb.ac.in*

Address for Correspondence:
Dean R&D, Industrial Research & Consultancy Centre (IRCC)
IIT Bombay, Powai, Mumbai 400076
Tel : +91 22 2576 7039 Fax: 2572 3702 / 3480
E-mail: update@ircc.iitb.ac.in
The Web Edition of this Newsletter, available at: http://www.ircc.iitb.ac.in/update
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