R & D Highlights 2016

Indian Institute of Technology Bombay

Foreword

Prof Devang V Khakhar
Director, IIT Bombay

I am pleased to share with you that the institute continues to be ranked as one of the top universities of the country and among the best in the world. IIT Bombay attracts the brightest students from the Country for its Bachelor's, Master's and Doctoral programmes, and in the 57 years of its existence, more than 48,000 students have graduated from IIT Bombay.

IIT Bombay is in the midst of rapid and exciting change with three big trends: firstly there has been very rapid growth in student numbers (from 5,300 students in 2009 to more than 10,000), secondly, the institute has rapidly grown its postgraduate programmes and R&D activity (funds received have grown from almost 5 fold since 2009) and thirdly, there is a huge student interest in entrepreneurship with a vibrant startup ecosystem developing around the campus. The Institute continues to strive for excellence in its core activities of teaching and research in this milieu of change.

Research is an increasing focus of activity of the Institute coupled with strong efforts to see that the fruits of the research are translated into commerce through licensing or through startups. The Institute has been able to attract outstanding faculty members from not just India but other parts of the globe. Research and development are an increasing focus of activity at IIT Bombay. The Institute has set up several large multidisciplinary research centers to address complex problems in a holistic way involving faculty members and students from different departments. We have also been able to further our links with international and national peer universities, enabling us to enhance research and educational programmes at the Institute.

The goal is to promote Research that makes a difference - a difference to society, to industry and to the profession itself.

Excerpts from Director's report at IIT Bombay's 53rd Convocation

IITB wins the National Intellectual Property Award 2015

IITB wins the Thomson Reuters India Innovation Award 2014

IIT Bombay at a Glance

Research and Development (R&D) at IIT Bombay has evolved and flourished over the decades since the Institute's inception in 1958. The synergy of academics and research has catapulted the Institute into the illustrious circle of world-class institutions. Apart from offering sound science and technology solutions to various government sectors, industry and to society, IIT Bombay pursues basic research leading to knowledge generation that lays the foundation for empowering India as a nation to be technologically confident and self-reliant.

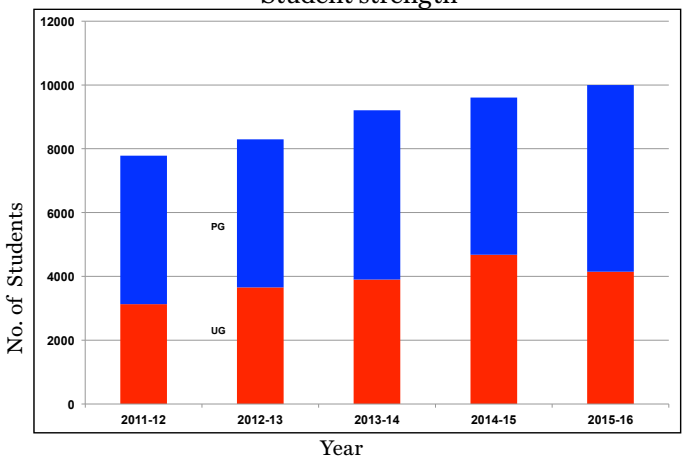
- Academic units: 26
- Research Centres: 18
- Faculty: 600^{+} full time + 100^{+} part time (adjunct & visiting)
- Students: ~ 10,000 (2899 PhD)
- Postdoctoral fellows: ~ 130
- Degrees awarded in 2015: 2389
- PhD degrees awarded in 2015: 266
- Research project staff: 1358
- R&D funding for FY 2015-16: ₹ 251.8 Crores
- Research publications (since inception upto 6.7.2016): ~ 21,400
- Research publications (2015): ~ 1650
- Citations for all publications (since inception upto 6.7.2016): ~ 2,31,600
- h-index (as on 6.7.2016) : 136
- Patents filed (as on 1.7.2016): 43
- Technology transfers / deployment so far: > 140
- Total companies incubated: 82

Prof V Ramgopal Rao wins Infosys Prize 2013

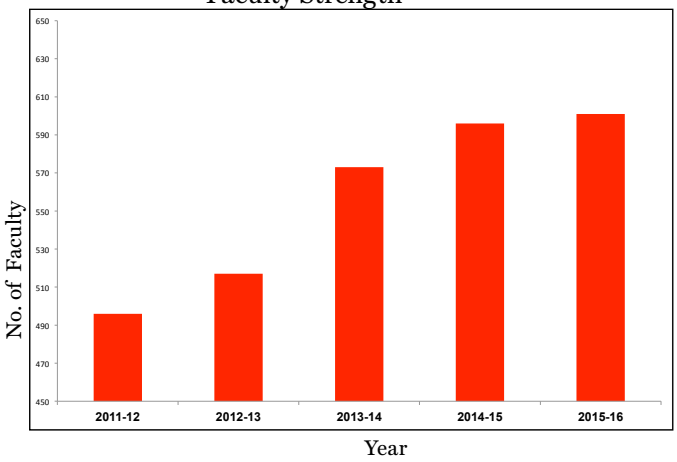
Prof D B Phatak – recipient of Padma Shri Award 2012

Faculty and Students

Student strength

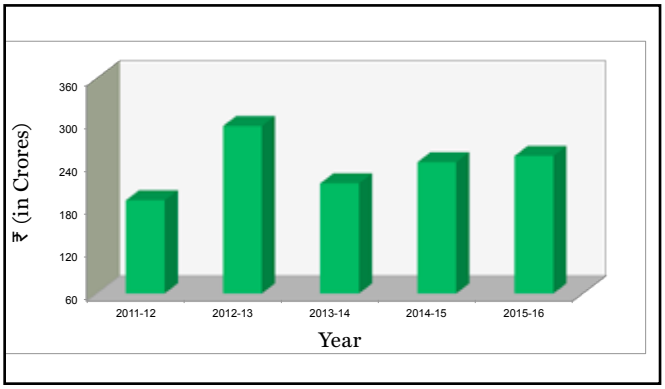


Faculty Strength



R & D Funding

New R&D projects are initiated every year in all the areas of science, engineering, management and social sciences, typically ranging from two to five years duration. These include short term consulting projects and longer term sponsored research projects. Funding received for R&D activity in 2015-16 was ₹ 251.8 Crores. This includes grants received in the year for the new projects sanctioned and the ongoing projects.

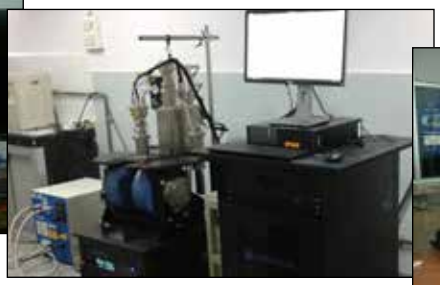


Financial year	Research Funding (₹ in Crores)		
	National Organisation	International Organisation	Total Receipts
2011-12	181	8.9	189.9
2012-13	277.8	15.7	293.5
2013-14	199	14.6	213.6
2014-15	227.3	15.7	243.1
2015-16	**236.1**	**15.7**	**251.8**

Research Facilities

The Institute provides high end infrastructure facilities and laboratories to support research activities. Facilities are augmented and upgraded regularly.

Laser Scanner Microscope Facility

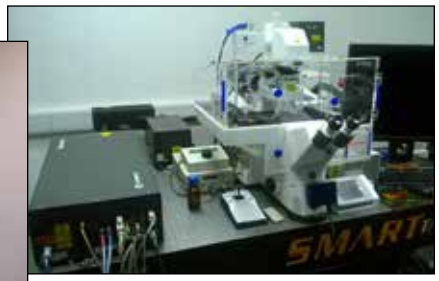


Hall Measurement System

Image based Spray Diagnostic Systems

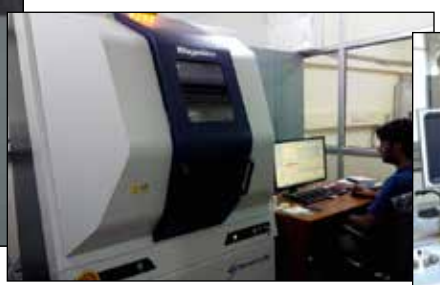
Protein Crystallography Facility

Laser Doppler Vibrometer



Spinning Disc Confocal Facility

High Resolution Mass Spectrometer



High Resolution X-Ray Diffractometer

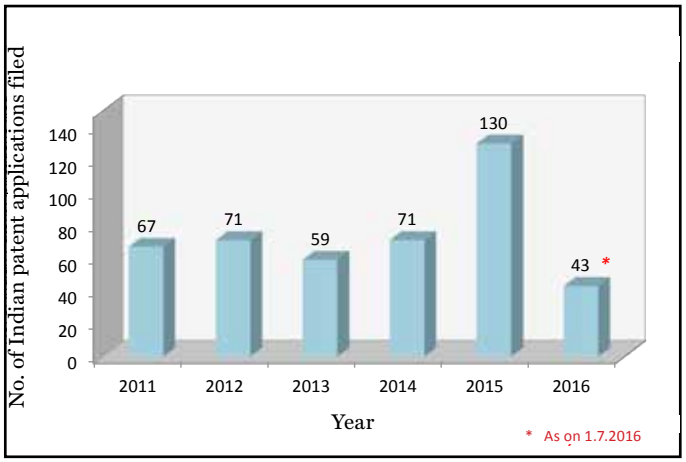
Cryo FEG Scanning Electron Microscope

750 MHz NMR Spectrometer

Orientation Imaging Microscope Facility

Sudarshan: The National Geotechnical Centrifuge Facility

Patents and Publications



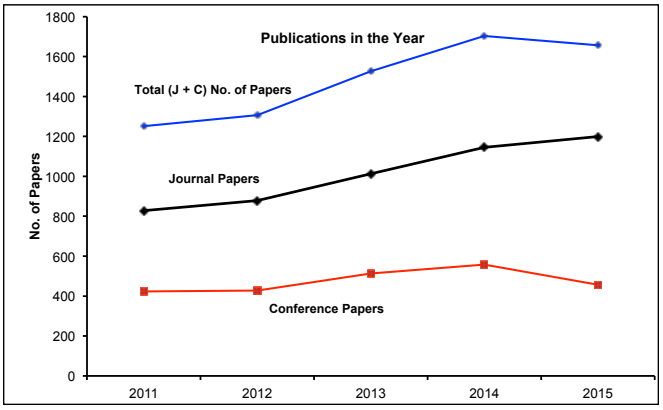
Patent applications filed during 2015

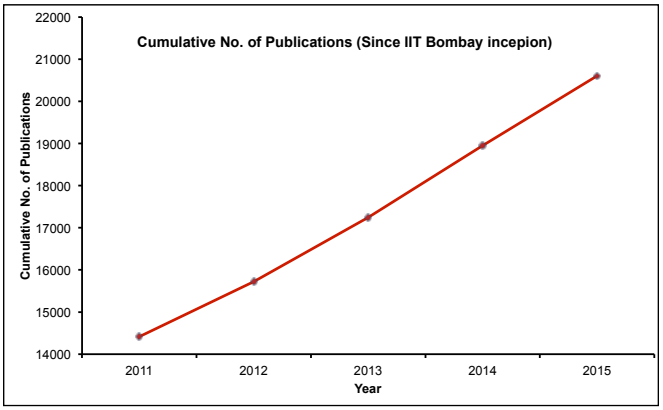
Indian	130
PCT	6
US	5
EU	1
Trademarks (Indian)	5
Copyrights (Indian)	1
Design	1

Period 1.1.97 to 1.7.2016

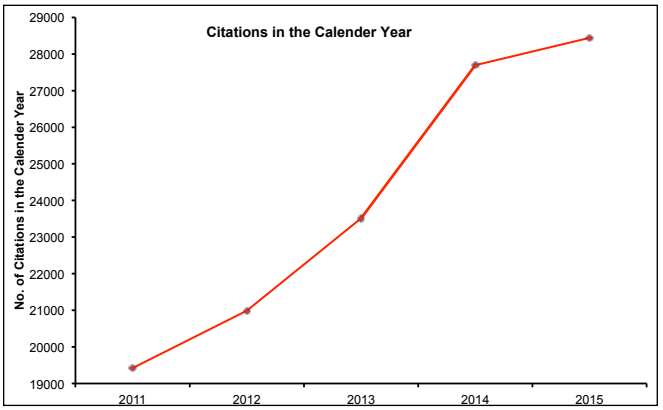
- Indian Patent Applications: 620
- Foreign patent applications: 115
  (US, EU, Japan, Canada, Taiwan, Hong Kong, Brazil, Gulf)
- PCT applications: 94
- Patents granted (Indian + Foreign): 115 + 52

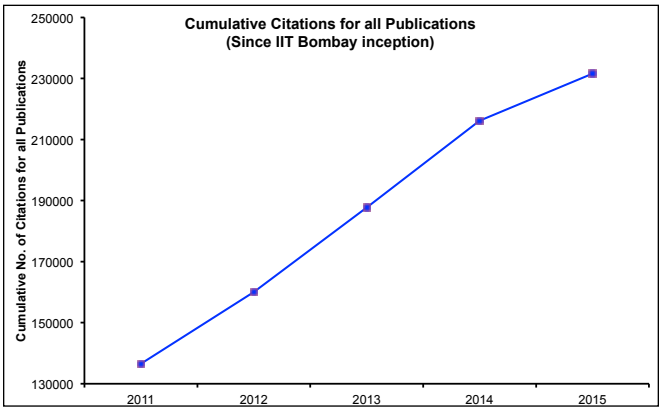
Publications





Citations





(Source: Scopus)

Technologies transferred / licensed

Direct licensing

- Board games design
- Electro Slag Refining Technology
- Ethernet switch routers
- GRAM++ software
- Hybrid cooling system technology
- Multi-utility heat pump technology
- Soil biotechnology for waste management
- Software for bid matching in day-ahead spot electricity market
- Tube-tube heat exchanger technology
- V-trough concentrated module

Licensing through collaborative development

- Amplified fluorescence polymers as sensors
- Asymmetric device applications in advanced CMOS technologies
- Design of ATM enclosure – ASAN
- Fuel additives for improving efficiency
- Inorganic – Organic hybrid coatings
- Modular FRP toilet units for railways
- Laminated Object Manufacturing - rapid prototyping process
- Short term load forecasting
- Silicon locket for cardiac monitoring
- Steer-by-wire system for vehicles
- Technology for better packaging of construction materials

Vestibulator for cerebral palsy

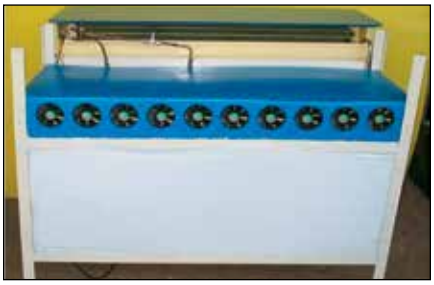
Unibody electric 3 wheeler

Zero Sum: an educational game based on mathematics

Fuel additives

Ethernet switch router

Sewage treatment plant set up at BMC, Mumbai



Modular hybrid air conditioner

Modular Toilet Unit for Indian Railways

Non-tracking solar collectors for indoor cooking

Technology Business Incubation

Society for Innovation and Entrepreneurship (SINE) is the technology business incubator at IITB set up in 2004. SINE supports technology startups founded by IITB community or that are based on IITB technologies, and extends the role of the institute by facilitating conversion of R&D into entrepreneurial ventures. SINE has an infrastructure spread over 10,000 sq.ft, and can incubate 15-17 companies at a time. Incubated companies cover a diverse spectrum of technology areas including healthcare, big data analysis, mobile apps, fintech, nanotech, biotech, clean-tech, social media, etc. Visit www.sineiitb.org/

Companies graduated	39
Companies currently incubated	28
Jobs created through entrepreneurship / start-ups	2000+

Research Park

Applied Materials joins as Anchor Client

The IIT Bombay Research Park Foundation is a not-for-profit arm of IIT Bombay registered as a Section 8 company. It was established in 2014 with financial support from the Ministry of Human Resource Development, Government of India. This Foundation aims to provide an ecosystem wherein researchers from IIT Bombay and Industry work in close collaboration with each other for product innovation, addressing technology challenges and in research areas of mutual interest.

Through this Foundation, IIT Bombay aims to collaborate with large, medium and small enterprises, technology startups and accelerators. This Foundation provides a mechanism for technology-focused companies to co-locate R&D personnel at IIT Bombay and seamless access to laboratories, research infrastructure and other research services. Industry R&D personnel can have close interaction with IIT Bombay faculty and student researchers.

R&D Overview

IIT Bombay has made concerted efforts to align its R&D focus with the national goal of achieving technological self-reliance. Students and faculty member conduct research projects in all areas of science and engineering. The institute has ongoing academic and research collaborations with many national and international universities, government institutions, PSUs and private industries. These interactions aim to keep pace with expanding frontiers of knowledge and global developments and also continually work towards national needs. Its pre-eminent position at the cutting-edge of research is reflected in its impressive list of research projects and their outcome.

Make in India Activities

Make in India is an initiative of the Govt. of India to encourage multinational and domestic companies to manufacture products in India. IIT Bombay has been working towards developing indigenous technologies and know-how with a focus on economy and efficiency. IIT Bombay has stepped up to impart R&D solutions to various sectors.

In-house fabricated solar cells

1MWe solar thermal power plant at Gurgaon

Cantilever based e-Nose

- **The National Solar Thermal Power Testing, Research and Simulation Facility:** a grid-connected 1 MWe solar thermal power plant designed, installed and commissioned at Gurgaon, New Delhi; a solar thermal simulator developed that solves energy and mass balance equations for user defined plant configurations. http://www.ese.iitb.ac.in/~NSTPP/

- **The National Centre for Photovoltaic Research and Education (NCPRE):** part of the Jawaharlal Nehru National Solar Mission of the Govt. of India and supported by the Ministry of New & Renewable Energy (MNRE) to promote photovoltaics R&D. http://www.ncpre.iitb.ac.in/

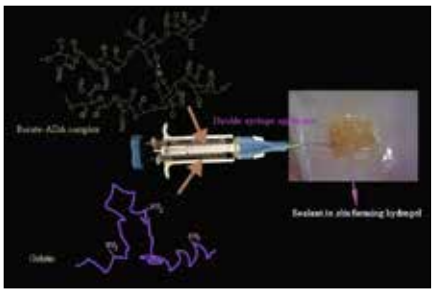
- **The National Centre for Aerospace Innovation and Research (NCAIR):** a joint initiative of IIT Bombay, Boeing and Department of Science and Technology, Govt. of India; aims to provide economically viable and sustainable solutions to Indian aerospace manufacturers. http://www.ncair.in/

- **Cryocooler technologies:** having applications in defence, space, surgical techniques, medical imaging and MagLev trains

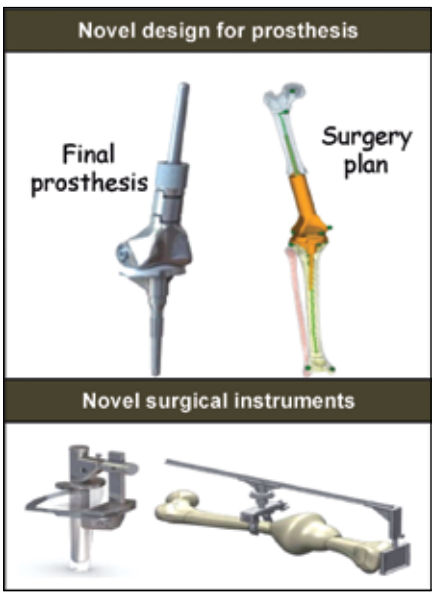
- **Cantilever based e-Nose for explosive detection:** low cost, sensitive device; detects RDX and TNT in parts per billion; has integrated wireless transmission capability

RoVer

SüChek



Minimally invasive cartilage regeneration technique



- **RoVer:** a remotely operated vehicle for handling and disposing Improvised Explosive Devices (IEDs)
- **SüChek:** a low cost diabetes testing kit
- **Carbogen gas inhaling apparatus:** for stress relief for people working in high-noise environments
- **Minimally invasive cartilage regeneration technique:** can be used as a painless, inexpensive, and non-toxic method to cure osteoarthritis. http://www.iitb.ac.in/en/research-highlight/injectables-osteoarthritis
- **Biomedical Engineering and Technology (incubation) Centre (BETiC):** a centre established by Govt. of Maharashtra and DST; has integrated facilities for design, analysis, prototyping and testing and facilitates clinical trials, IPR and technology transfers in collaboration with medical and industrial partners. http://betic.in/
- **X-ray to 3D:** computationally efficient modeling algorithm developed to convert 2D Xray images of a bone from a patient into a 3D model. This work won the 'Gandhian Young Technological Innovation Award in 2014'.
- Low cost, high quality knee mega-prosthesis to circumvent amputations in bone tumor cases
- **Centre of Excellence in Steel Technology (CoEST):** sponsored by Ministry of Steel, Govt. of India has a vision to see India as a world leader in steel production and technology. The focus includes R&D in steel technology and creation of high quality manpower for the steel industry.
- **The ISRO - IITB Space Technology Cell:** promotes advanced research related to space technology. http://www.csre.iitb.ac.in/isro_cell/

Digital India Activities

Work related to communications, network and security, and IT has been one of the major focus. These include R&D towards the Digital India initiative.

Inauguration of ECR 1000 Series Router

TICET – Unlicensed Band Radio

- Low cost, power-efficient high speed ethernet switch routers deployed at different sites by the Mahanagar Telephone Nigam Ltd, Mumbai, RailTel and National Knowledge Networks.

- **TTSL-IIT Bombay Centre of Excellence in Telecommunication (TICET):** a joint initiative of IIT Bombay, Tata Teleservices Ltd & the Department of Telecommunication, Govt. of India for capacity building, design and fabrication, and offering advisory support to the telecom sector; various technologies developed including cost optimization tool to reduce fuel consumption at telecom towers; supports entrepreneurship. http://ticet.iitb.ac.in/ticet/home.html

Extensive funding from **Department of Electronics & Information Technology (DeitY)**, Govt. of India allows in various research areas to bring about a transformative impact:

State-of-the-art nanofabrication facility

- **Centre of Excellence in Nanoelectronics (CEN)**, established in 2006, is a collaborative project with Indian Institute of Science (IISc), Bangalore.
  - State-of-the-art nanofabrication facilities
  - Research projects with social relevance leading to prototype development
  - Indian Nanoelectronics Users Program (INUP): provides hand on training, sharing of expertise in Nanoelectronics to researchers across the country.

http://www.cen.iitb.ac.in/ and http://www.inup.iitb.ac.in/

Night vision - Long range surveillance

- **National Centre of Excellence in Technology for Internal Security (NCETIS):** Activities are targeted towards developing indigenous technology and self sufficiency in areas of Electronics System Design Manufacturing for the strategic sector of internal security. http://www.ncetis.iitb.ac.in/

- R&D in the area of perception engineering has enabled the development and improvement of the performance of hearing aids and speech communication devices based on techniques related to noise suppression, distortion-free dynamic range compression and, improvement of consonant-to-vowel ratio.

Ministry of Human Resource Development (MHRD), Govt. of India has supported a series of programs on knowledge dissemination to various colleges/institutions across India.

NME-ICT: Empowerment through synchronous & asynchronous instruction

NME-ICT (National Mission on Education through Information and Communications Technology):
This project envisions empowerment of teachers, through workshops conducted for thousands of teachers at one go, using a unique blend of technology and an innovative pedagogy. Thousands have experienced the effectiveness of this approach, and of the resulting open source contents.
http://www.it.iitb.ac.in/nmeict/home

- **Teach 10,000 Teachers (T10kT) programme:** 15 Short Term Training Programmes (STTP) have been conducted. These STTPs envisage a collaborative development of digital teaching / learning contents incorporating specific needs of teachers and students.
http://www.it.iitb.ac.in/nmeict/About_T10kT.html

- **FOSSEE (Free and Open Source Software for Education):** works on the adaptation and deployment of open source simulation packages equivalent to proprietary software like Scilab, Python, eSim, DWSIM, OpenFOAM, Osdag, OpenModelica, OR Tools, Sandhi and OpenPLC.

Video based Teachers' Training Program

- **Massive Open Online Courses (MOOCs):** to enhance learning experience, MOOCs was launched from IITBombayX (the extended online educational service of IIT Bombay). The platform was built to cater to specific needs for Indian learners, such as multi-lingual facility, T10KT programs and blended MOOCs. This is developed on open source codebase of open-edX, and contains several enhancements. Various courses have been initiated using this platform.

- Quality improvement of classroom teaching through Video based Teachers' Training Program (VbT2P)

E-Yantra

- **E-Yantra:** initiative to provide hands-on learning to engineering students who have limited access to labs and mentors. The objective is to create the next generation of Embedded Systems engineers in India with a practical outlook to take on challenging problems and provide solutions.

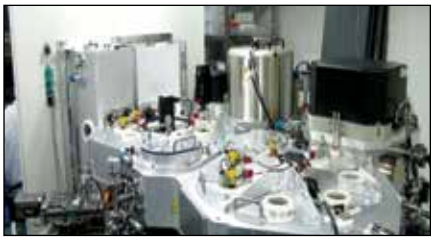
- **Sandhan:** a search engine for Indian languages developed in consortium with many institutions; intended for the tourism domain.
http://clia.iitb.ac.in:8080/sandhan

IIT Bombay - Industry Collaborations

From its inception, IIT Bombay has benefited from being located in one of the most industry-intensive hubs in the country. The overall external R&D orientation of the institute has been very much aligned by this situation. The institute houses several advanced R&D facilities, including sophisticated state-of-the-art laboratories funded/donated by industry.

Benefits of collaboration

- Access to fresh ideas, innovation and talented student base
- Partner in knowledge creation, technology development and human resource development
- Complementary skills and capabilities upgradation
- Access to new technologies
- Access to high end equipment and other resources
- Multidisciplinary research pool
- Facilitating processes and systems for collaboration
- Leverage public funding
- Access to qualified personnel for recruitment



Endura equipment for PVD

Yahoo! Hadoop Cluster Laboratory inauguration

Cummins Engine research facility

Examples

- **Applied Materials Manufacturing Laboratory:** to promote research in nanoelectronics, nano-manufacturing and solar photovoltaic technology

- **PowerAnser Lab:** an IIT Bombay, Tata Consultancy Services (TCS) and Tata Consulting Engineers (TCE) partnership to bring the benefits of IT to the power sector; deployed webSTLF technology and webNETUSE to stakeholders

- **Yahoo! Hadoop Cluster Lab:** to help conduct research on search based technologies

- **TCS-IITB Research Cell:** for long term collaboration with TCS in major areas of research like Software Engineering, Machine Learning, Intelligent Infrastructure, Scheduling and Planning, VLSI, Power Network Analytics and Steel Technology

- **Cummins Engine Research Facility:** Integration of new engine and renewable fuels technologies to support sustainable development and to improve lives, especially in rural villages. Successful technology demonstration - Rural electrification of a village in Odisha.

Modes of Interaction

R & D Projects:

Chair Professorship / Endowment:

Continuing Education Programme:

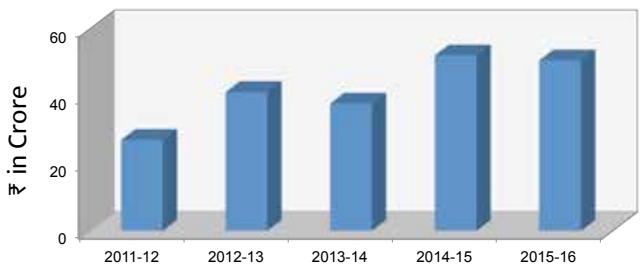
Labs & Facilities:

Licensing:

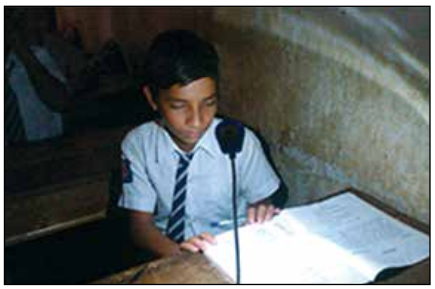
Consortia:

Student & Post Doc Fellowship Sponsorship:

Industry Funding



Other glimpses of R&D

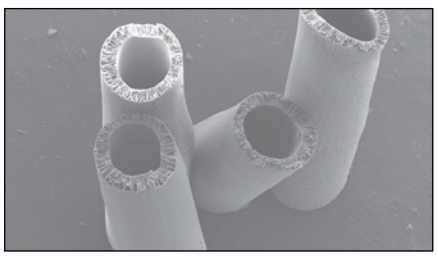


Solar Urja Lamp

Folic acid enriched cosmetics

UV Mask

Team Drishti



Hollow Fibre

Energy

- 1 Million Solar Urja Lamps (SoUL) have been provided to students in 7903 remote rural villages in Maharashtra, Madhaya Pradesh, Rajasthan and Odisha through support by the National Clean Energy Fund, Ministry New and Renewable Energy (MNRE), Govt. of India. Further activities of deployment across India have been initiated.
  http://www.millionsoul.iitb.ac.in/

Healthcare

- **Nutrient enriched cosmetics:** a cheap drug delivery system has been developed to deliver nutrient supplements through skin, pregnant women, with an aim to reduce infant mortality.

- **Silicon locket for cardiac monitoring and diagnosis:** allows continuous monitoring of various heart parameters; Arrhythmia occurrence automatically transmitted through SMS, to central server using mobile phone interface; undergoing field trials.

- **Drishti:** auto-tunable lens for universal eye glasses; winner in product design category in Samsung Innovation Awards 2012

- **Healthcare Research Consortium:** has multiple partners including leading hospitals, cancer research centres, medical technology companies and NGOs.

Urban Development

- Centre for Urban Science and Engineering (C-USE): an interdisciplinary centre working to improve the quality of urban life; member of the New York based international consortium, Centre for Urban Science and Progress (CUSP).
  http://cuse.iitb.ac.in/

Climate Studies

- The interdisciplinary programme in Climate Studies was initiated in 2012, to undertake interdisciplinary research and education to develop a scientific understanding of regional climate change and connect it to impacts (environment, resources, socio-economic) and effective response (technology and adaptation). It also aims to build systems and tools (integrated measurement systems, modelling platforms, assessment tools) for the study of climate change.

Desai Sethi Centre for Entrepreneurship

- The Centre aims to foster entrepreneurship and technology innovation through new programmes for education and research, multi-disciplinary courses, research laboratories and partnerships. Students in the programme will receive instruction and mentorship from internal and external faculty to enable them to become the next generation of business leaders. http://www.iitb.ac.in/dsce/

Social Responsibility

Recognising the importance of contributing to the society in a meaningful way, IIT Bombay focuses on work in both urban and rural communities, providing technology-based solutions and utilizing the power of the internet and communications technology. Tools and technologies for the village industry and craft sector, educational and communication aids, products for alleviating problems of those with disabilities, devices for extending benefits of computer technologies to rural communities, and other useful innovations are some of the areas where IIT Bombay has been actively involved. The Indian Rupee symbol was designed by IIT Bombay which is now the official Indian currency sign used globally.

Dry sanitation system

Bore recharge system

Bund at Bhojpada Village, Thane

Currency symbol for Indian Rupee

Dhoop stick making machine

Water supply in Parbhani city

Water storage tanks constructed using natural fibers

ASAN: ATM enclosure

K-Yan: the compact media centre

aAQUA web portal for Indian farmers

Efficient smokeless chulah

Floating fish cage in Dimbhe dam

Liquid jaggery machine

Herbal oil extraction unit

Low cost check dams

Rain water collection at rural communes

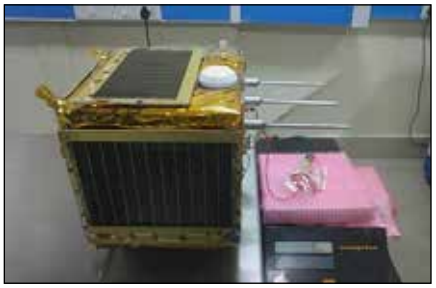
Mumbai Rail Map

Reducing drudgery for women

Student Initiatives

Matsya

Solar powered house



Pratham

Rakshak

ORCA: Latest edition of car with team

- **Matsya:** a multidisciplinary platform to pursue research interests in underwater robotics. In the last four years, IITB has developed four vehicles under the series of Autonomous Underwater Vehicles (AUV), each one more advanced and more capable than its predecessor, Matsya 4.0 being the newest member of the series. Matsya 3.0 represented IITB at the International RoboSub competition at San Diego, USA, in August 2014. http://www.auv-iitb.org/

- **Solar Decathlon:** Students of IITB and the Rachna Academy of Architecture, Mumbai designed and constructed a 700 sq.m house powered entirely by solar energy and participated in the Solar Decathlon competetion held at Versailles, France, July 2014. http://teamshunya.in/

- **Mars Rover:** a six wheel mobility system on which various subsystems are integrated; consists of rocker-bogie suspension system and four wheel steering system. The steering system allows for sharper and easier turns on tough terrains and also enables on the spot rotation for the rover. The team participated in the Arkaroola Mars Robot Challenge 2014, and was one amongst the 23 student teams that made it to the Finals of the University Rover Challenge 2015 held at the Mars Desert Research Station in southern Utah, USA.
http://urc.marssociety.org/home

- **Pratham:** design of a satellite to orbit at an altitude of 500-600 km with four months mission life; two downlinks and weight of 9.8 kgs; more than 40 students from various departments involved. http://www.aero.iitb.ac.in/pratham/

- **Rakshak:** robust Unmanned Aerial Vehicles (UAV) - a fixed wing aircraft developed for civilian applications, to counter problems like search and rescue missions and military surveillance; participated in the event 'SAE Aero Design Collegiate 2015 (Advanced class)'; stood 7th out of 15 international teams; overall ranking at 12th position in the competition.

- **Intelligent Ground Vehicle Competition:** The student team competed in the 24th edition of Intelligent Ground Vehicle Competition in Oakland University, Michigan, USA during 3rd to 6th June, 2016. Team stood fourth in the *Basic Auto-Nav Challenge* category and qualified as one of the five teams to appear in Advance Auto-Nav Challenge. The team also geared up for Mahindra RISE Driverless Car Challenge and has cleared three out of five stages of the challenge.

- **IIT Bombay Racing:** the team competed in three international competitions in the design and engineering of amateur high performance race cars; endurance run completion at Formula Student UK'14; judged as one of the best in design documentation. http://www.iitbracing.org

Centres of Excellence / Consortia

- Biomedical Engineering and Technology Incubation Centre
- Centre for Aerospace System Design & Engineering
- Centre for Formal Design and Verification of Software
- Centre of Excellence in Nanoelectronics
- Centre of Excellence in Steel Technology
- Centre of Propulsion Technology
- Geospatial Information Science and Engineering
- Healthcare Research Consortium
- National Centre for Aerospace Innovation and Research
- National Centre for Mathematics
- National Centre for Photovoltaic Research and Education
- National Centre of Excellence in Technology for Internal Security
- National Mission on Education through ICT
- National Solar Thermal Research, Testing and Simulation Facility
- Power Anser Laboratory
- Tata Center for Technology Development
- Tata Teleservices -IIT Bombay Centre of Excellence in Telecommunication
- Wadhwani Research Center for Bioengineering

Important Awards and Fellowships

Awards

- Padma Shri award: 2
- Shanti Swarup Bhatnagar Prize for Science and Technology: 13
- Infosys prize: 1
- Swarnajayanti Fellowship award: 12
- J C Bose National Fellowship: 12
- DAE-SRC Outstanding Research Investigator award: 4
- C N R Rao National Prize for Chemical Research: 2
- Chemical Research Society of India, Silver medal: 3
- Chemical Research Society of India, Bronze medal: 13

Fellowships

- Fellow, Indian National Science Academy, New Delhi: 13
- Fellow, Indian Academy of Sciences, Bangalore: 21
- Fellow, Indian National Academy of Engineering, New Delhi: 29
- Fellow, The National Academy of Sciences, India (Allahabad): 28
- Fellow, Institute of Electrical and Electronics Engineers: 5

The Industrial Research and Consultancy Centre (IRCC)

IRCC was established in 1975 as the nodal unit responsible for managing and coordinating all activities related to research and development at the Institute, including facilitating interactions with external agencies, setting up simplified processes for financial, manpower and intellectual property management, licensing activities and schemes for incentivising and supporting researchers.

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