150 YEARS OF CELEBRATING THE MAHATMA

Exhibition schedule	Venue
MUMBAI 8th May to 7th July, 2019 10 AM - 6 PM	NEHRU SCIENCE CENTRE Dr E Moses Road, Worli, Mumbai - 400 018 Phone: (022) 24932667 / 24920482 Email: director@nehrusciencecentre.gov.in www.nehrusciencecentre.gov.in
BENGALURU 29th July to 28th Sep., 2019	VISVESVARAYA INDUSTRIAL & TECHNOLOGICAL MUSEUM Kasturba Road, Bengaluru - 560 001 Phone: (080) 2286 4563 Email: vitmuseum@gmail.com www.vismuseum.gov.in
KOLKATA 4th Nov. to 31st Dec., 2019	SCIENCE CITY J B S Haldane Avenue Kolkata - 700 046 Phone: (033) 22854343 / 2607, 23432569 Email: kolkatasciencecity@gmail.com www.sciencecitykolkata.org.in
DELHI 21st Jan. to 20th Mar., 2020	NATIONAL SCIENCE CENTRE Pragati Maidan, Near Gate No.1 Bhairon Road, New Delhi - 110 001 Phone: (011) 23371297 / 1893 Email: info@nscd.gov.in www.nscd.gov.in

Organised by
परमाणु ऊर्जा विभाग Department of Atomic Energy
विज्ञान एवं प्रौद्योगिकी विभाग Department of Science & Technology
राष्ट्रीय विज्ञान संग्रहालय परिषद् National Council of Science Museums

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Designed by
Nehru Science Centre, Mumbai
National Council of Science Museums, Ministry of Culture, Govt. of India

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राष्ट्रीय विज्ञान संग्रहालय परिषद् National Council of Science Museums

VIGYAN SAMAGAM

PUSHING THE FRONTIERS OF SCIENCE

Exhibition

8th May to
7th July 2019

10 AM to 6 PM

Venue
Nehru Science Centre
National Council of Science Museums
Ministry of Culture, Govt. of India
Dr. E. Moses Road, Worli, Mumbai - 400 018
Phone: 91 (22) 2493 2667 / 2492 0482

Contents

Editorial team:
Supriya Das (FAIR) | Purushottam Shrivastava (CERN) | Vivek Datar (INO) | Dilshad Sulaiman (ITER)
Anupreeta More (LIGO) | Debades Bandyopadhyay (SKA) | Prasanna Deshmukh (TMT) | Praveer Asthana, DST

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सत्यमेव जयते

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Government of India
NATIONAL INSTITUTION FOR TRANSFORMING INDIA
NITI Aayog, Parliament Street
New Delhi-110 001

MESSAGE

I congratulate Department of Atomic Energy (DAE) and Department of Science and Technology (DST) for organising the event showcasing India's participation in Mega Science projects - *Vigyan Samagam*. I also congratulate National Council of Science Museums (NCSM), for hosting this exhibition in their venue.

Vigyan Samagam will help in bringing science closer to the society. India's participation in these projects, which are exploring the Universe, from different perspective will help us understand it better. It also allows us to provide exposure to our industries to the cutting edge technologies these projects offer.

I fervently hope that *Vigyan Samagam* would be an ideal science communication platform not only for scientific organisations, academia and industry but also for policy-makers, media along with members of civil society.

I extend my wholesome support for this wonderful initiative and wish the event all success to the Apex Committee responsible for organising the event, with the support of DAE, DST and NCSM.

New Delhi
22.04.2019

(Dr. V.K. Saraswat)

स्वच्छ भारत
एक कदम स्वच्छता की ओर

के. विजयराघवन
भारत सरकार के प्रमुख वैज्ञानिक सलाहकार
K. VijayRaghavan
Principal Scientific Adviser to the Govt. of India

सत्यमेव जयते

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Message

I am delighted to note that Department of Atomic Energy (DAE) and Department of Science and Technology (DST) are jointly organizing this multi-venue Mega-Science exhibition, *Vigyan Samagam*, which is aimed at showcasing India's contribution to international collaborations on fundamental science and research.

India has become member of all of these projects based on its scientific and engineering capabilities. All the major Mega Science projects, working on cutting edge technologies, viz: European Organization for Nuclear Research (CERN); Facility for Antiproton and Ion Research (FAIR); India-based Neutrino Observatory (INO); International Thermonuclear Experimental Reactor (ITER); Laser Interferometer Gravitational-Wave Observatory (LIGO); Square Kilometre Array (SKA); and Thirty Meter Telescope (TMT), are being showcased for the first time in the world, on a single platform.

As we look forward to building a new India, frontiers of science needs to be brought closer to Indian industry, academia and students. *Vigyan Samagam* is aimed at providing a common interactive platform for all these stakeholders and many others involved directly or indirectly.

A first-of-its-kind exhibition, which is being hosted in a caravan mode at four cities starting from Mumbai (8th May – 7th July 2019) followed by Bengaluru, Kolkata and Delhi, will definitely meet its intent and it would pave way for establishing science as a strong career option for the youngsters.

I wish the Apex Committee organizing this event, all the success and want to personally congratulate DAE, DST and the venue partner National Council for Science Museum (NCSM) for their contribution for making it a success.

(K. VijayRaghavan)
22nd April, 2019

के. एन. व्यास
K. N. Vyas

भारत सरकार
Government of India

अध्यक्ष, परमाणु ऊर्जा आयोग
व
सचिव, परमाणु ऊर्जा विभाग
Chairman, Atomic Energy Commission
&
Secretary, Department of Atomic Energy

MESSAGE

It is my pleasure to host the Vigyan Samagam partnering with Department of Science and Technology (DST). Vigyan Samagam being a multi-venue Mega-Science exhibition, will display India's contribution to international collaborations on fundamental science and research. I am happy to state that India has become member of all of these projects based on its scientific and engineering capabilities. All the major Mega Science projects, in which India is participating, are working on high end technologies, and our industries are going to benefit by their participation.

Vigyan Samagam is expected to bring students, academia and Indian industry, who are currently involved in one or the other projects, to look across the other projects and participate in the same. Vigyan Samagam is aimed at providing a common interactive platform for all these stakeholders and many others involved directly or indirectly.

I understand that this would be a first-of-its-kind exhibition in the world, where all the Mega Science projects in which India is participating like European Organization for Nuclear Research (CERN); Facility for Antiproton and Ion Research (FAIR); India-based Neutrino Observatory (INO); International Thermonuclear Experimental Reactor (ITER); Laser Interferometer Gravitational-Wave Observatory (LIGO); Square Kilometre Array (SKA); and Thirty Meter Telescope (TMT), are being showcased on a single platform.

I thank our venue partner National Council for Science Museum (NCSM) for their valuable contribution for making this happen.

The Vigyan Samagan, which is being hosted at four cities starting from Mumbai followed by Bengaluru, Kolkata and Delhi, will surely drive students in choosing basic science as a career option.

I wish the Apex Committee organizing this event, and all the contributors to this exhibition all the success.

(K. N. Vyas)

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सत्यमेव जयते

प्रो. आशुतोष शर्मा
Prof. Ashutosh Sharma

सचिव
भारत सरकार
विज्ञान और प्रौद्योगिकी मंत्रालय
विज्ञान और प्रौद्योगिकी विभाग
Secretary
Government of India
Ministry of Science and Technology
Department of Science and Technology

स्वच्छ भारत
एक कदम स्वच्छता की ओर

25th April, 2019

MESSAGE

I am extremely happy to learn that 'Vigyan Samagam', an eight-month long travelling Mega Science Exhibition at Mumbai, Bangalore, Kolkata and Delhi, is going to start from Mumbai from the 8th of May 2019. This will be the first-of-its-kind exhibition showcasing India's involvement in global and national mega science projects which will enlarge the frontiers of human knowledge and give us better understanding of the Universe, right from elementary constituents of matter and their interactions to galaxies and other large-scale structures, stars, planets and evolution of the Universe and so on. Such questions greatly excite young minds and motivate them to choose research as a career option. Now that India has emerged on the world-scene as an important partner in several such projects, organization of such an event to expose large number of young students and practicing and aspiring researchers to these projects is very timely. I am happy that Vigyan Samagam will give a feel for the totality of India's involvement in these projects, their inter-connectedness and complementarity in looking at various aspects of the structure and evolution of our Universe. I am told that apart from two-day seminars at each of the four locations, every project will organize week-long programmes comprising lectures, quizzes etc. I am also happy to learn that many leading experts from the world would be coming and interacting with the students and visitors as the exhibition advances.

The second aspect that I am very happy about is the attempt to involve Indian industry in this event. India has consistently followed the policy of largely in-kind participation in such collaborations. These projects, though aimed at answering some of the most fundamental questions about our Universe, involve a string of hitherto unknown technologies. These, in fact, push the technology frontiers and many of these technologies have found widespread use, the World Wide Web being the most talked-about example. Indian industry is already involved in all these projects, but the scope and potential are huge and an exposure of Indian industry to the opportunities in such projects is an extremely important goal of Vigyan Samagam.

I am also very happy that the National Council of Science Museums (NCSM) of the Ministry of Culture has joined hands with the Department of Atomic Energy (DAE) and the Department of Science and Technology (DST) and extended its facilities and experience of organizing such events. Their consent to finally host a Mega Science Gallery based on the exhibits developed for this Exhibition in their Delhi Centre is an extremely far-sighted gesture. This will give a longer life to the enormous efforts that are being made to organize Vigyan Samagam.

Finally, I congratulate the officers and staff of DAE and DST for jointly organizing this important event. Our joint efforts in promoting mega science in areas of common interest started in early 1990's and are still going strong. Being an eight-month long travelling exhibition, I am sure, we shall learn and improvise as we go along.

I wish Vigyan Samagam all the best. A positive outcome from this effort may pave way for replication of this concept in other areas of Science and Technology too.

(Ashutosh Sharma)

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Arun Goel, IAS
Secretary

सत्यमेव जयते

150 YEARS OF CELEBRATING THE MAHATMA

भारत सरकार
संस्कृति मंत्रालय
नई दिल्ली–110001
GOVERNMENT OF INDIA
MINISTRY OF CULTURE
NEW DELHI-110 001

MESSAGE

I am delighted to know that the Department of Atomic Energy (DAE), Department of Science and Technology (DST) and National Council of Science Museums (NCSM) have come together to jointly organize a multi-venue mega-science exhibition, Vigyan Samagam on 8th and 9th May, 2019.

It is very heartening to see, through this event, creative and foundational scientific thoughts and approaches will be instilled in the heart of the youth of the country and they will be the future ambassadors across the world, resulting in improved status in Indian science and research studies and creating new ways to the new generations to grow in the technologically advanced environment.

Vigyan Samagam is being hosted in a caravan mode at four major Indian cities; Mumbai, Bengaluru, Kolkata and Delhi where enthusiasts, academic and young students would be able to experience and acquire knowledge on innovations and discoveries made by major scientific institutions in the world.

I extend my support to DAE, DST and NCSM in their nation building initiative and wish the event a grand success.

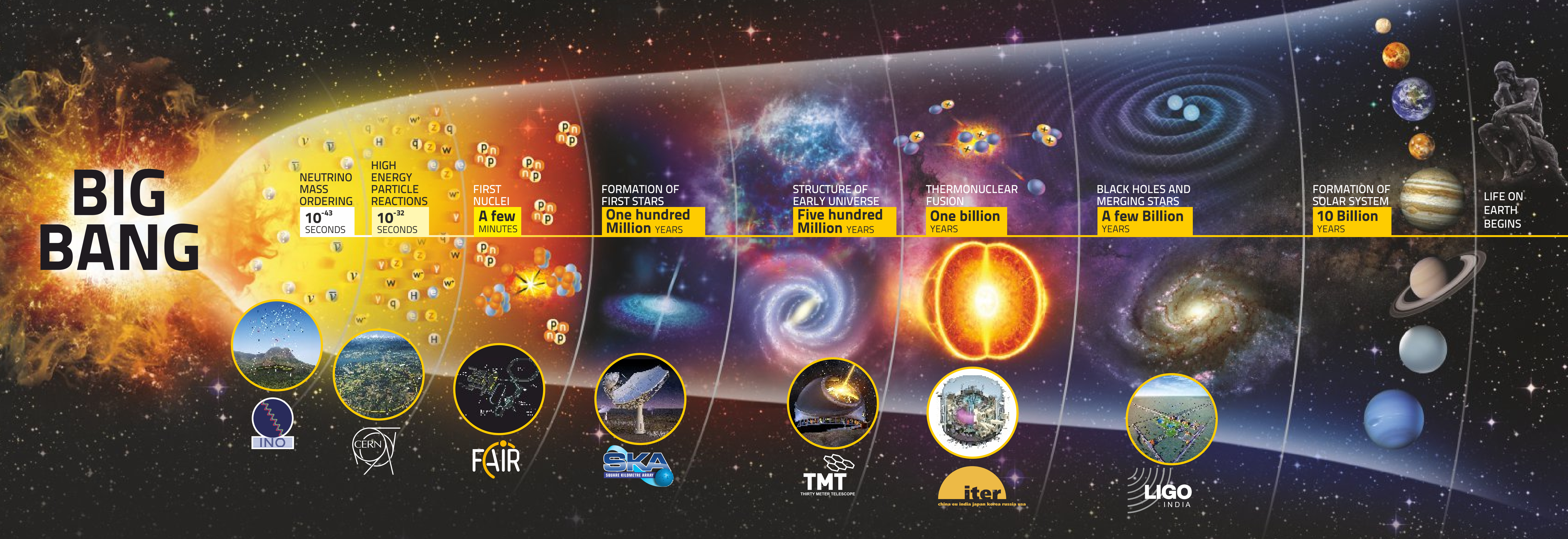
(Arun Goel)

सूचना का अधिकार
Room No. 502, 'C' Wing, Shastri Bhawan, Dr. Rajendra Prasad Road, New Delhi-110 001
Phone : +91-11-23381040, 23386995, E-mail : secy-culture@nic.in, arun.goel62@nic.in

From micro to macro:

Understanding the universe through mega science projects

An artist's impression of the evolution of the universe, showing one key area of science for each project.



Vigyan Samagam

Vigyan Samagam is a multi-venue mega-science exhibition showcasing India's contribution to international collaborations on fundamental science and research. It provides a common platform for all the Mega-Science Projects.

Mega-Science collaborations proposed to be showcased in Vigyan Samagam are:

- European Organization for Nuclear Research (CERN)
- Facility for Antiproton and Ion Research (FAIR)
- India-based Neutrino Observatory (INO)
- International Thermonuclear Experimental Reactor (ITER)
- Laser Interferometer Gravitational-Wave Observatory (LIGO)
- Square Kilometre Array (SKA)
- Thirty Meter Telescope (TMT)

Vigyan Samagam exhibition will showcase India's contribution in fundamental science and research, and provide an interactive platform for all mega-science Projects with students, academia and industry. All these Projects work on cutting-edge technologies which our Indian institutions would be exposed to and will develop industrial capacity. Presence in Mega-Science Projects with multi-national participation keeps us on the same platform as other developed countries. Indian participation in these Projects is based on its scientific and engineering capabilities.

Vigyan Samagam will be a science communication platform for policy-makers, representatives of print and electronic media along with members of civil society. The exhibition will also usher youngsters to strong career options. Such a spectrum of audience is expected to pave the way for a greater interaction between all stakeholders, resulting in cross-fertilisation of ideas.

A first-of-its-kind exhibition, Vigyan Samagam will be hosted in a caravan mode at four cities – Mumbai, Bengaluru, Kolkata and Delhi – from May 2019 to March 2020. At each of the four locations, apart from the themed galleries of posters, models and exhibits, informative audio-visual content and interactive kiosks will be set up. Concurrent with the launch of the event, a 2-day scientific event shall be held at each venue. Weeklong activities consisting of science talks, demos, quiz programmes shall be conducted by all the Projects.

To know more, visit www.vigyansamagam.in or download the mobile app. You can also follow Vigyan Samagam on Facebook, Twitter, Instagram and YouTube.

परमाणु ऊर्जा विभाग
Department of Atomic Energy

Department of Atomic Energy

The Department of Atomic Energy (DAE) has been engaged in the development of nuclear power technology, applications of radiation technologies in the fields of agriculture, medicine, industry and basic research. In 1954, under the farsighted leadership of Dr. Homi Jehangir Bhabha, the Department started its journey with a promise of ushering India to a brighter future. Moving from strength to strength, the Department added several nuclear power plants, R&D centres, healthcare management units, fundamental research and higher education institutions, and industrial services. Environmental stewardship and community development are intrinsic to the programmes of the Department.

DAE proactively collaborates with several national and international institutions engaged in mega-science activities and fundamental research.

The Department of Atomic Energy comprises of six R&D centres, three Industrial Organisations, five Public Sector Undertakings and three Service Organisations. It also has under its aegis two boards for promoting and funding extra-mural research in nuclear & allied fields and mathematics and a national institute. It supports nine institutes of international repute engaged in research in basic sciences, astronomy, astrophysics, cancer research and education. It also has an educational society that provides educational facilities for children of DAE employees stationed across more than 60 locations in the country. It also has a deemed University which helps in in-house career development of its scientists and engineers.

Today India stands tall and proud in the world nuclear community due to deliveries achieved through entirely self-reliant and sustainable strategies of DAE.

To know more, please visit www.dae.gov.in or follow us at www.facebook.com/dae.connect and www.twitter.com/daeindia

विज्ञान एवं प्रौद्योगिकी विभाग
Department of
Science & Technology

सत्यमेव जयते

Department of Science and Technology

The Department of Science and Technology (DST) was established in May 1971 with the objective of promoting new areas of Science & Technology (S&T) and to play the role of a nodal department for organizing, coordinating and promoting S&T activities in the country.

DST, ever since its creation, has led the policy formulation exercise for science and technology at the national level. DST regularly brings out S&T Statistics summarizing the state of S&T in the country.

DST has played the coordination role in the S&T sector quite actively and effectively over the years – with other Central Government Departments/Ministries, State Governments, industry, practising researchers and so on – so that all segments of country's scientific enterprise contribute effectively and make Science, Technology, and Innovation (STI) a key driver of national development. DST is also the nodal department for International S&T Cooperation.

The other hallmark of DST is capacity building and promotion of STI in the country. DST is the single-largest extramural research funding agency and helps sustain the research activities of a very large number of scientists and technologists in the country. It has significantly upgraded the research infrastructure of the higher educational institutions. It has programmes aimed at attracting, nurturing and promoting the study of science and practice of scientific research, right from the school level to practising researchers, including specially designed programmes for women. DST also supports innovation, entrepreneurship, technology development and commercialization covering all stages of the innovation cycle. DST promotes R&D on wide range of topics of scientific, technological and societal relevance without disciplinary and institutional boundaries.

DST has some of country's oldest and finest scientific organizations within its family. DST institutions have formidable research portfolio in areas such as astronomy and astrophysics, materials and nano science and technology and chemistry.

Further details may be found at www.dst.gov.in

राष्ट्रीय विज्ञान संग्रहालय परिषद्
National Council of
Science Museums

National Council of Science Museums

National Council of Science Museums (NCSM), an autonomous scientific society under the Ministry of Culture, Government of India, was formed on April 4, 1978. Today, it administers 25 Science Centres/Museums/Planetariums spread all over India. Science City, Kolkata, Birla Industrial and Technological Museum (BITM), Kolkata, Nehru Science Centre, Mumbai, Visvesvaraya Industrial and Technological Museum (VITM), Bengaluru, National Science Centre, Delhi and Central Research & Training Laboratory (CRTL), Kolkata are National level centres of NCSM. Each of these centres/museums has its Regional Level Centres and District Level Centres called Satellite Units (SUs). CRTL is the Council's central hub for professional training, research and development. NCSM has developed Science Centres/museums for different States and Union Territories of India. It also has developed several centres and galleries for different Government and nongovernmental organisations such as ONGC, BEL, ICAR, and also collaborated internationally for development of Museums/Science Centres or for galleries such as Rajiv Gandhi Science Centre, Mauritius, "India gallery on Buddhism" at International Buddhist Museum, Sri Lanka etc. NCSM also has developed the National Museum of Indian Cinema at Mumbai. NCSM is one of the largest networks of science centres and museums in the world. The Council also collects, documents, restores and preserves important historical objects, which represent landmarks in the development of science, technology and industry. The Council is engaged in imparting scientific temper among the masses in general and students in particular and in enhancing the understanding of science among students. Annually millions of people visit the science centres under NCSM.

Accelerating Science

India, an Associate Member (since 2016) of CERN–the world's largest accelerator laboratory is a proud partner of the Large Hadron Collider (LHC) project from the beginning. Indian scientists and engineers have contributed significantly to both science and technology of LHC. Indians have participated in the construction, commissioning and operation of LHC and of the two large experiments at LHC viz., ALICE (A Large Ion Collider Experiment) and CMS (Compact Muon Solenoid). India has established and is running two tier-2 grid computing centres in the country for LHC data analysis. Indian scientists have significantly contributed towards major discoveries reported from LHC, viz. the discovery of the Higgs boson (that is responsible for mass of elementary particles) in 2012, that led to the awarding of the Nobel Prize in Physics in 2013 and formation of Quark Gluon Pasma (QGP), a deconfined state of quarks and gluons in strongly interacting matter at under extreme temperatures.

LHC, located between Switzerland and France and housed in a tunnel of 27 km circumference, 100 m below the earth's surface is used for colliding protons and lead ions at centre-of-mass energies of 13 TeV and 5.7 TeV respectively creating controlled physical conditions that would have existed soon after the Big Bang. The Raja Ramanna Centre for Advanced Technology (RRCAT), Indore, served as the nodal institute for India's participation in the building of the LHC and the CERN-India collaboration now constitutes a large number of universities and R&D institutes being jointly funded by DAE and DST.

In addition to exploration of science at the LHC, this Collaboration enables (a) participation of Indian industries in advanced technologies; (b) access to several challenging technologies; (c) human resource development by way of training and exposure of our young scientists and engineers at CERN; and (d) capacity building that helps in India's in-house accelerator projects. Prominent examples include four sets of 1MW CW klystrons, 1MW Circulators, wave-guide components and RF hardware for Indian proton accelerators at BARC and RRCAT. Beyond LHC, India has contributed towards design, development, tests and installation of accelerator components for Linac 4 (front-end of new injector for the luminosity upgrade program of LHC) and Compact Linear Collider (CLIC) Test Facility (CTF3).

Contributions to the ALICE detector

Presently, 12 Indian institutes/universities are participating in the ALICE experiment at LHC. Two major detectors, viz., the Photon Multiplicity Detector (PMD) for measurement of photons at forward rapidity and a Cathode Pad Chamber for muon measurements in the ALICE experiment, were fully conceptualized and fabricated by Indian collaborators and are being operated by them. A 16-channel readout ASIC, named MANAS, was developed in India and supplied to CERN for use in ALICE detectors. A state-of-the-art high-speed FPGA based PCIe40 read-out card is being fabricated in India for the ALICE-upgrade. As a part of further upgrade, prototypes of an electromagnetic calorimeter are being built using tungsten as absorber and radiation-hard silicon-pads for readout.

Contributions to the CMS detector

India has made significant contributions towards fabrication, assembly, installation, commissioning as well as operation and upgrade of several components of the CMS detector, notably the Hadron Outer Calorimeter (1100 units), electronics upgrade of the hadronic calorimeter (more than 900 multi-layer and high-end electronics boards and peripherals produced and characterized), mechanical casing of these electronics (100 housings), silicon-strip sensors for the electromagnetic pre-shower detector (more than 1000 units), Resistive Plate Chambers (RPCs) for the muon spectrometer system (50 RPCs and 200 copper-cooling sets for the RPC upgrade). Future hardware participation from India includes several high-technology subsystems of CMS experiment, meant for HL-LHC operation: silicon-based tracker as well as high granularity calorimeter, gas electron multiplier (GEM) detectors and custom-made trigger electronics employing state-of-the-art FPGAs.

Contributions to Worldwide LHC Computing GRID (WLCG)

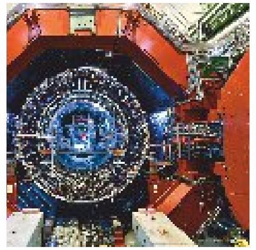
GRID is the natural evolution of the internet technology (World Wide Web was invented at CERN). India has played significant role in the development of GRID technology involving tens of petabytes of data generated every year which involves sharing and monitoring of computing/storage resources worldwide via high-speed (multi-Gbps) internet. India hosts two Tier-2 GRID Computing Centres: at TIFR Mumbai for CMS experiment and at VECC, Kolkata for ALICE experiment.

Collaborating Institutes in India

		Raja Ramanna Centre for Advanced Technology Indore	Bhabha Atomic Research Centre Mumbai	Variable Energy Cyclotron Centre Kolkata
Tata Institute of Fundamental Research, Mumbai	Saha Institute of Nuclear Physics Kolkata	Indian Institute of Technology Bombay Mumbai	NISER Bhubaneswar	Delhi University Delhi
Panjab University Chandigarh	Aligarh Muslim University Aligarh	Rajasthan University Jaipur	Jammu University Jammu	Visva Bharati Santiniketan
Indian Institute of Science Education & Research, Pune	IIT Bhubaneswar	Indian Institute of Technology Madras Chennai	Bose Institute Kolkata	IISc, Bangalore
IIT Indore	University of Hyderabad	Gauhati University Guwahati	Institute of Physics Bhubaneswar	University of Calcutta Kolkata

Technology developed

LHC /Linac 4/CLIC: India contributed significantly towards LHC construction by developing and producing large numbers of a variety of high-technology components with active participation of the Indian industry, such as, high-precision jacks (7080), superconducting corrector magnets (1146MCS + 616MCDO), quench heater power supplies (5500), local protection units (1435) etc. India also contributed towards software development including the JMT-II software, slow control, superconducting dipole magnet measurements (100 man years) and survey systems for LHC. Subsequently for advanced accelerators like Linac-4 and CLIC (CTF3) also, several technologies were developed and supplied. For Linac-4, our contributions included 100kV/20A state-of-the-art solid-state bouncer modulator, development of prototype waveguide components and copper-coated SS power couplers for DTL, CCDTL and commissioning support. For CTF3, our contributions included dipole magnets for TL2, vacuum chambers for TL2, optics design / simulation / analysis and results for TL 2, expert support for commissioning, operation of controls, prototype 12GHz power extraction and transfer structures, 20kW broad-b and solid-state amplifier for sub-harmonic buncher for CLIC linac.



A Large Ion Collider Experiment ALICE Detector

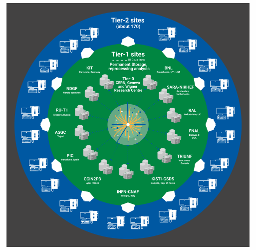
ALICE

Technologies that have been developed/employed by India for the ALICE experiment are briefly mentioned below: (a) large volume gaseous proportional chambers with 220K readout channels employing extended cathode technology; (b) world's largest cathode pad chamber for muon measurement; (c) a 16-channel multiplexed readout ASIC called MANAS with challenging analog signal readout; (d)fabrication of a thick graphite absorber as hadron absorber in the muon detection system; (e) fabrication of Common Readout Unit (CRU), an FPGA-based data segregation system for handling huge data volume coming out of ALICE in higher luminosity operation; and (f) silicon-tungsten calorimeter for detection of electromagnetic particles in the forward region of ALICE.

Compact Muon Solenoid (CMS) Experiment

CMS

Starting with scintillator-based detectors, Indian scientists contributed towards silicon based as well as gas-ionization based detectors. The next phase is marked by production of complex electronics and GEM detectors to match high-data rates at LHC. The challenges of HL-LHC operation will be dealt with silicon based detectors where India will contribute significantly. The development of silicon sensors, as well as custom-made electronics, are some of the other ventures that will enable participation in cutting-edge technologies being used in LHC experiments.



World Wide LHC Computing Grid: WLCG

GRID

Our contributions to the LHC Computing Grid include: Grid View monitoring and visualisation tool; My WLCG, a personalized Grid Monitoring software; Cloudman, a high-level resource management tool to provide a central place to configure resource in a computer centre at an abstract level; Cloud Accounting Project; Distributed Quota Management; Open stack Quota Management; establishment and operation of Tier2 centres for ALICE and CMS experiments that provide the backbones for success of the computing efforts. One of the recent highlights include opportunistic use of cloud computing for CMS experiment from India and development of related middleware.

LHC

Indian industries involved

Electronics Corporation of India Ltd. | Hyderabad; Avasarala, Bangalore | MSME Indo-German Tool Room, Indore | Mann Aluminium, Pithampur, Indore | Semi-Conductor Laboratory (formerly Semiconductor Complex Limited), Chandigarh | Smile Electronics Limited, Bengaluru | Central Tool Room, Ludhiana | Bharat Electronics Limited (BEL), Bengaluru | Hi-Tech Industries, Mumbai | Micropack, Bengaluru | Peninsula Electronics, Bengaluru | Eata Plast Fabrics, Rabale, Mumbai | Alpha Pneumatics, Mumbai | PDR Videotronics, Mumbai | Amit Electronics | HiQ Electronics | Keithley/Tektronix | MPI | Micro-Epsilon India Private Limited, Bangalore | KAF International, New Delhi | Ameliorate Solutions, Bangalore | Nordson-EFD, Bangalore | HDR Holding India Pvt. Ltd, Kolkata

Contact person/Spokesperson

LHC/Accelerators:

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Superconducting corrector magnets for LHC

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ALICE:

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CMS:

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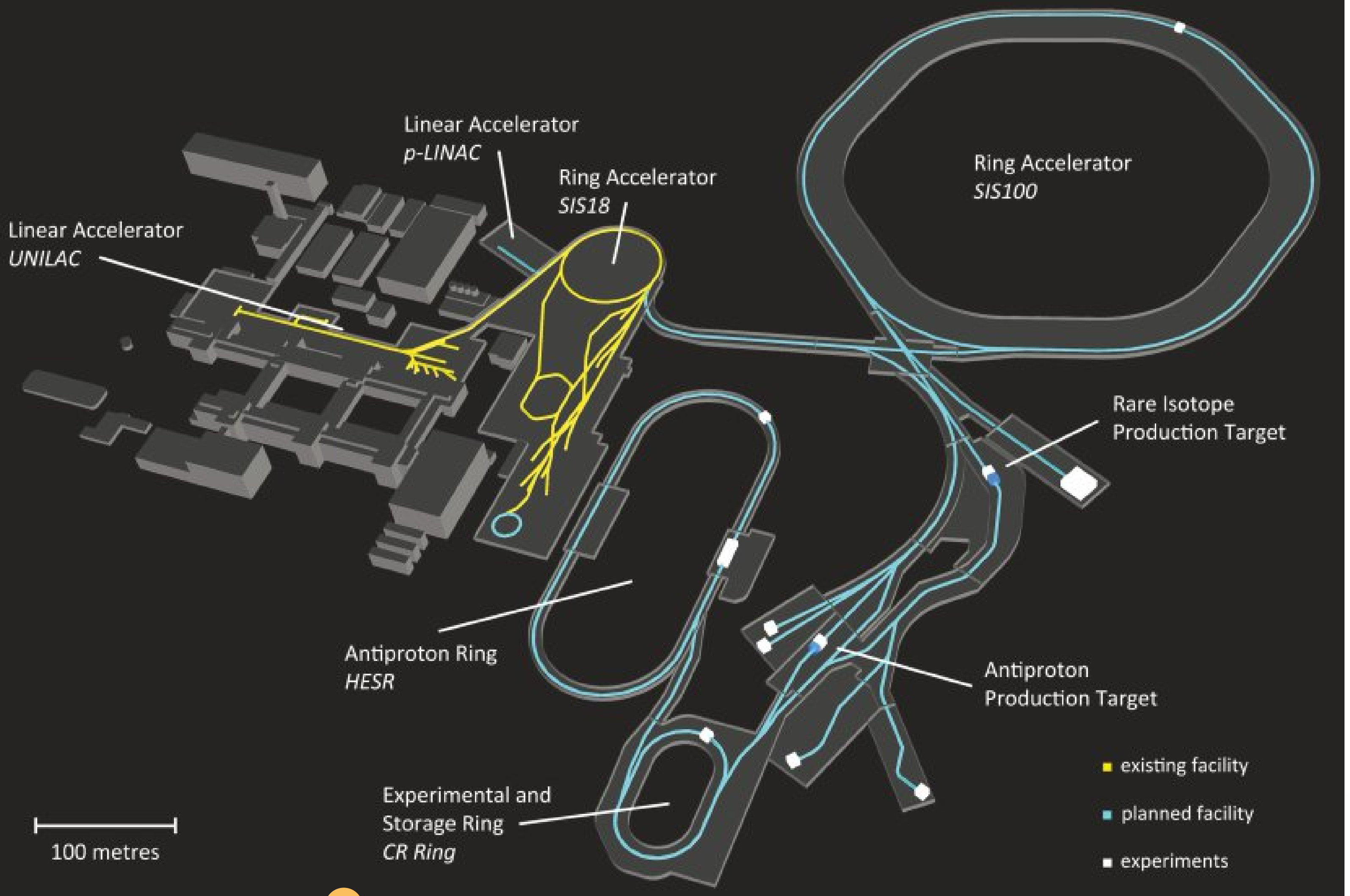
Website

http://www.rrcat.gov.in, http://india.web.cern.ch/india/



FAIR

Facility for Antiproton and Ion Research

The Universe in the Lab

India is a founder country in World's biggest basic science accelerator project in the next decade.

The Facility for Antiproton and Ion Research (FAIR), that will be one of the largest international research facilities in the world, is coming up at Darmstadt, Germany. About 3000 scientists from 50 countires will study the structure of matter and evolution of the Universe from the Big Bang to the present using this facility. All the research activities at FAIR have been subdivided into four experimental programs, namely, Compressed Baryonic Matter (CBM), Nuclear Structure, Astrophysics and Reactions (NUSTAR), Atomic, Plasma Physics and Applications (APPA) and Antiproton Annihilation at Darmstadt (PANDA). The civil construction for the state-of-the-art ring accelerator of 1,100 m circumference as well as the experimental and computational facilities is in full swing on 20 hectares of land. India is the third largest contributor among nine countries (others are Finland, France, Germany, Poland, Romania, Russia, Slovenia and Sweden) that are working as partners to build this facility. India has major responsibilities in building FAIR. Indian companies will design and supply critical items such as ultra-stable power converters, co-axial power cables for powering the magnets, beam stoppers, ultra-high vacuum chambers and superconducting magnets for the FAIR accelerator system. Indian scientists are also working for participation in CBM and NUSTAR experiments. In CBM, the major responsibiliy of Indian scientists is to build a muon detection system based on Gas Electron Multiplier (GEM) technology. In the NUSTAR experiment, Indians are involved in building high resolution gamma-ray spectrometer (DESPEC Germanium Array) and Modular Neutron Spectrometer (MONSTER).

Collaborating Institutes in India

Variable Energy Cyclotron Centre Kolkata	Raja Ramanna Centre for Advanced Technology Indore	CSIR-Central Mechanical Engineering Research Institute Durgapur	Bose Institute Kolkata
Tata Institute of Fundamental Research Mumbai	Inter-University Accelerator Centre New Delhi	Aligarh Muslim University Aligarh	Panjab University Chandigarh
Rajasthan University Jaipur	University of Kashmir Srinagar	University of Calcutta Kolkata	Banaras Hindu University Varanasi
IIT, Indore	Bhabha Atomic Research Centre Mumbai	Saha Institute of Nuclear Physics Kolkata	IIT-Bombay
University of Delhi Delhi	IIT-Guwahati	National Institute of Science Education and Research Bhubaneswar	University of North Bengal Siliguri
IIT-Roorkee	Gauhati University Guwahati	Pune University, Pune	South Gujarat University Surat
National Institute of Technology Jalandhar	MSUniversity Vadodara	Magadh University Bodh Gaya	

GEM prototype fabrication at VECC

Power converter

Technology developed

- Ultra High Vacuum Chambers for housing beam diagnostic equipment at FAIR. The challenges involved are very thin walls and upto seven flanges.
- Superconducting Magnets with very high accuracy: large size magnets (dipoles and multipoles) have been designed by Indian engineers
- Beam stoppers: stop very high intensity Uranium beams in an absorber equipped with proper cooling arrangements. It has been designed in India and will be built by an Indian company.
- Power Converters: These are the devices that energize the superconducting magnets of the accelerator. They need to be ultra stable in voltage and current.
- Gas Electron Multiplier (GEM)-based muon detection system.

Indian industries involved

Electronics Corporation of India Limited (ECIL), Hyderabad

iDesign, Pune

Cadillac Filters Private Limited, Kolkata

Avasarala Industries, Bangalore

Godrej Industries, Mumbai

RPG Industries,Mysore

Vacuum Techniques Pvt. Ltd, Bangalore

Contact person/Spokesperson

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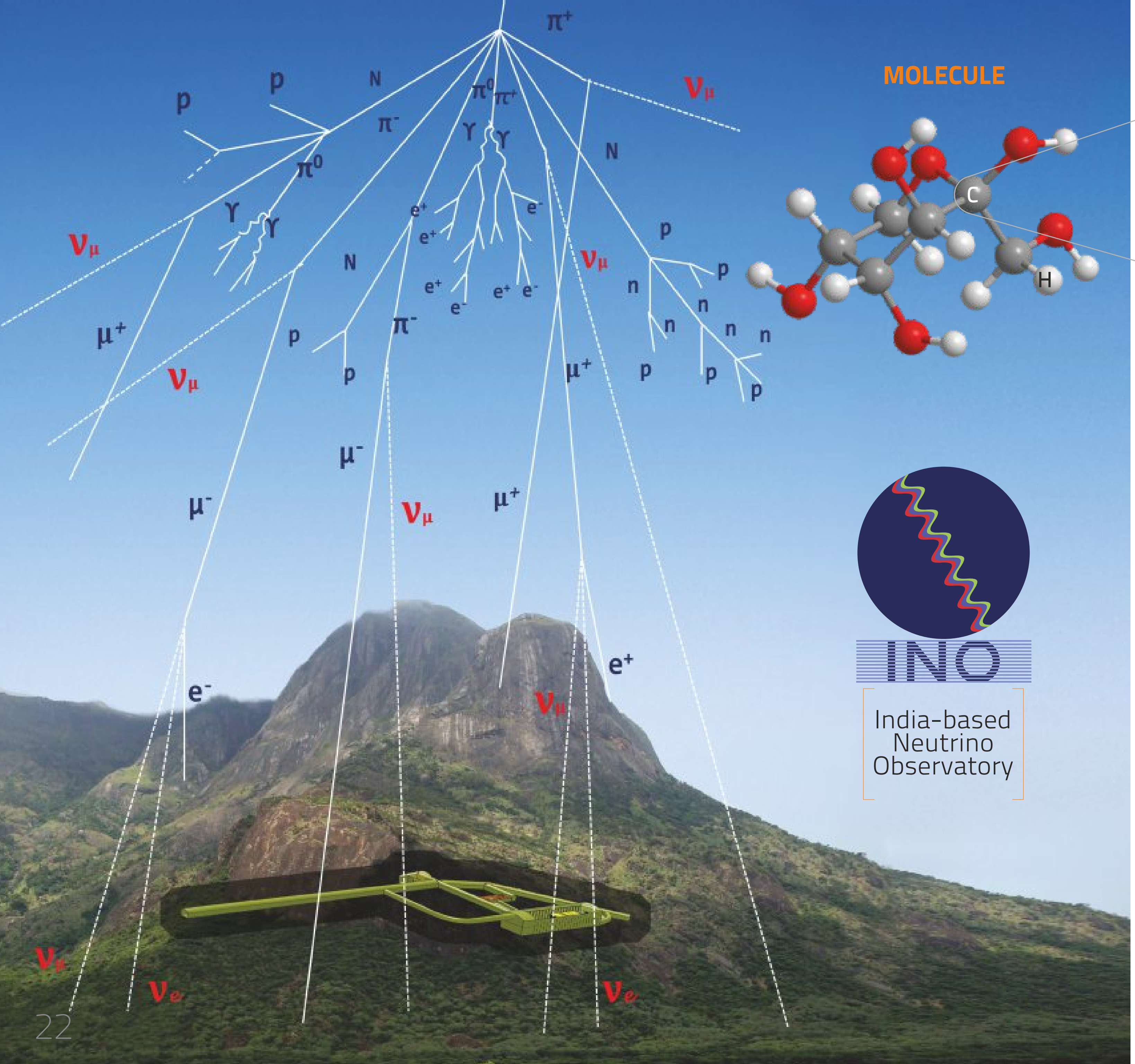

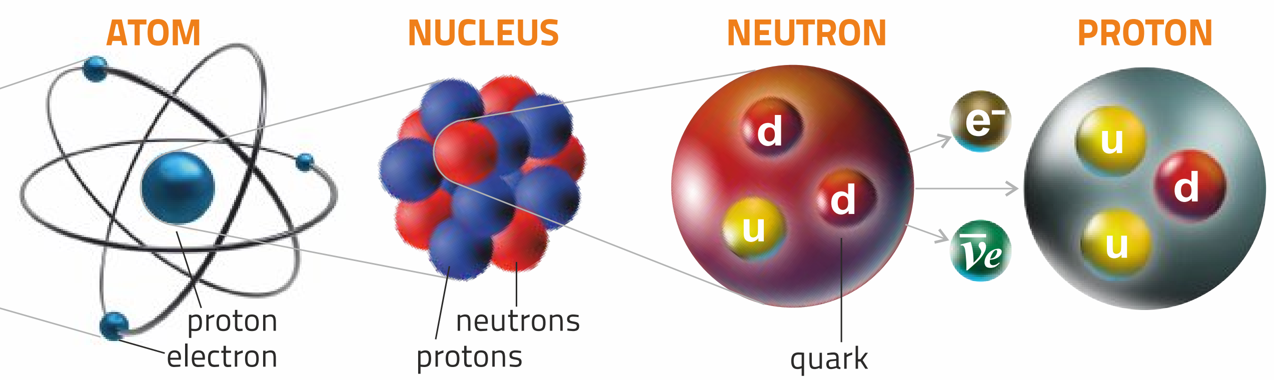

Hunting the elusive neutrino

The India-based Neutrino Observatory (INO) project is an ambitious basic science project aimed at studying the properties and interactions of the elusive elementary particle called neutrino. The Government approved the INO project in January 2015. This included the construction of an underground laboratory at Bodi West Hills (BWH) in Theni district, Tamil Nadu, setting up the flagship Iron Calorimeter (ICAL) detector there and the Inter-Institutional Centre for High Energy Physics (IICHEP) in Madurai. IICHEP would be the nodal centre for Research & Development of the associated detector technology and would run the underground laboratory in Theni. The key advantage of constructing a laboratory in a cavern in a mountain accessed by a 2km tunnel, with an all-round rock cover of about 1000m, is that it offers a low cosmic ray background environment (since the cosmic rays and secondary particles produced in their interaction with the upper atmosphere are filtered by the rock cover above the laboratory cavern). This is necessary for specialised experiments making measurements with neutrinos which interact very rarely with the detector material. In particular, ICAL will detect and measure atmospheric neutrinos to study the neutrino properties, including the mass ordering of the three tiny neutrino masses using matter enhanced neutrino oscillations. The ICAL detector can also be used to search for evidence of long-range interactions between neutrinos and matter, dark matter annihilation occurring in the sun, primordial magnetic monopoles and evidence for or against the anomalous events found by the proton decay detector in Kolar Gold Fields. Finally, the underground laboratory will also provide a conducive environment for other experiments. For example, a collaboration led by a TIFR group is working towards search for neutrinoless double beta decay in tin-124 using a cryogenic bolometer. Similarly, a collaboration led by SINP is planning to set up an experiment to search for Dark Matter using a cryogenic scintillator. The initial background studies have begun in a laboratory at -550m level in the Jaduguda mines.

Collaborating Institutes in India

		Aligarh Muslim University Aligarh	American College Madurai	Banaras Hindu University Varanasi
Bhabha Atomic Research Center Mumbai	Central Univ. of Karnataka Gulbarga	Delhi University Delhi	Harish Chandra Research Institute Allahabad	Indian Institute of Science Education & Research Mohali
Indian Institute of Technology Bombay Mumbai	Indian Institute of Technology Bombay Gandhinagar	Indian Institute of Technology Madras Chennai	Institute of Physics Bhubaneswar	Institute of Mathematical Sciences Chennai
Jammu University Jammu	Jawaharlal Nehru University New Delhi	Lucknow University Lucknow	Panjab University Chandigarh	Physical Research Laboratory Ahmedabad
Saha Institute of Nuclear Physics Kolkata	Tata Institute of Fundamental Research, Mumbai	Tezpur University Tezpur	University of Calcutta Kolkata	University of Calicut, Calicut
Univ. of Hyderabad, Hyderabad	Univ. of Kashmir Srinagar	Univ. of Mysore, Mysore	Utkal University Bhubaneswar	Variable Energy Cyclotron Center Kolkata

Technologies developed

Extruded polycarbonate side spacers and spacer buttons for RPCs; 1m x 1m, 2m x 2m Glass Resistive Plate Chambers with resistive graphite coating; front-end electronics; in-house developed boards for Data Acquisition, Trigger Module and Time Calibration. High-permeability low-carbon soft iron steel for ICAL; Layered Electro-Magnet (85 ton mini-ICAL module); induction heating based copper joint brazing technology; inductive proximity sensor based system for continuous gap measurement between two iron plate layers; magnetic measurements system with multiple search coil pickup loops (for magnetic flux) and arrays of Hall probes based measurements (for B-field strength in inter-plate gaps); closed loop chilled water system for cooling current carrying coils in mini-ICAL and associated DC power supply; RPC trolley (8m high) to place and remove 2m x 2m RPC from ICAL.

Indian industries/agencies involved

Consultancy : Tata Consulting Engineers, Mumbai (ICAL magnet DPR); Tamil Nadu Electricity Board, Chennai (INO DPR); Mitcon Consultancy & Engineering Services Ltd, Pune (MoEF & CC clearance); Pro Designa Consultants, Madurai (Civil works approval for IICHEP, INO site civil construction); Walch and Technology Group, Pune (Project Report for RPC manufacture).

RPC glass gaps : St. Gobain (Sriperumbudur); Asahi-India (Taloja); Cybernetic Instruments (Pune).

Closed loop gas system : Alpha Pneumatics (Mumbai); Shriram Automation (Mumbai).

Resistive coating of graphite paint on glass : Kansai-Nerolac (Mumbai).

Paint booth: Green Glory Technologies, Chennai.

RPC trays and pickup panels : Honeycomb International Inc. (Bengaluru); Nexgen Plastics (Mumbai); S. M. Enterprises (Pune); Fibre Reinforced Industry Ltd. (Pune).

Polycarbonate spacers for glass gaps : Ashwin Plastics (Mumbai); Studio CNC (Mumbai).

Low carbon magnetic grade steel plates : Steel Authority of India Ltd. (Bhilai); Essar Steel (Hazira).

Electronics boards of many types : Rangsons (Bengaluru); Dexcel (Bengaluru); PCB Power Circuit Systems India Ltd. (Gandhinagar).

RPC handling equipment, mini-ICAL assembly : Jalaram Industries (Mumbai); P Chandru Machine Tools (Vellore); Green & Green Engineering Solution (Coimbatore).

Magnet Power Reversal switch and gap measurement system - M/S Integrated systems Pvt. Ltd. (Mumbai).

Magnet coil support G-10 material : Autoelectrical & Mechanical works (Mumbai).

Soft iron plate and SS Spacer-Pin machining : Bhilai Engineering Corporation (Bhilai).

Magnet coil forming and fabrication : Centre for Design & Manufacturing, BARC (Mumbai).

Special Induction based brazing machine : Microtech Industries (Mumbai).

Low conductivity cooling water system: Entech industries (Bengaluru).

Magnetic Measurement Systems : Ferrite India (Pune).

Iron calorimeter (ICAL) prototype

Contact person/Spokesperson

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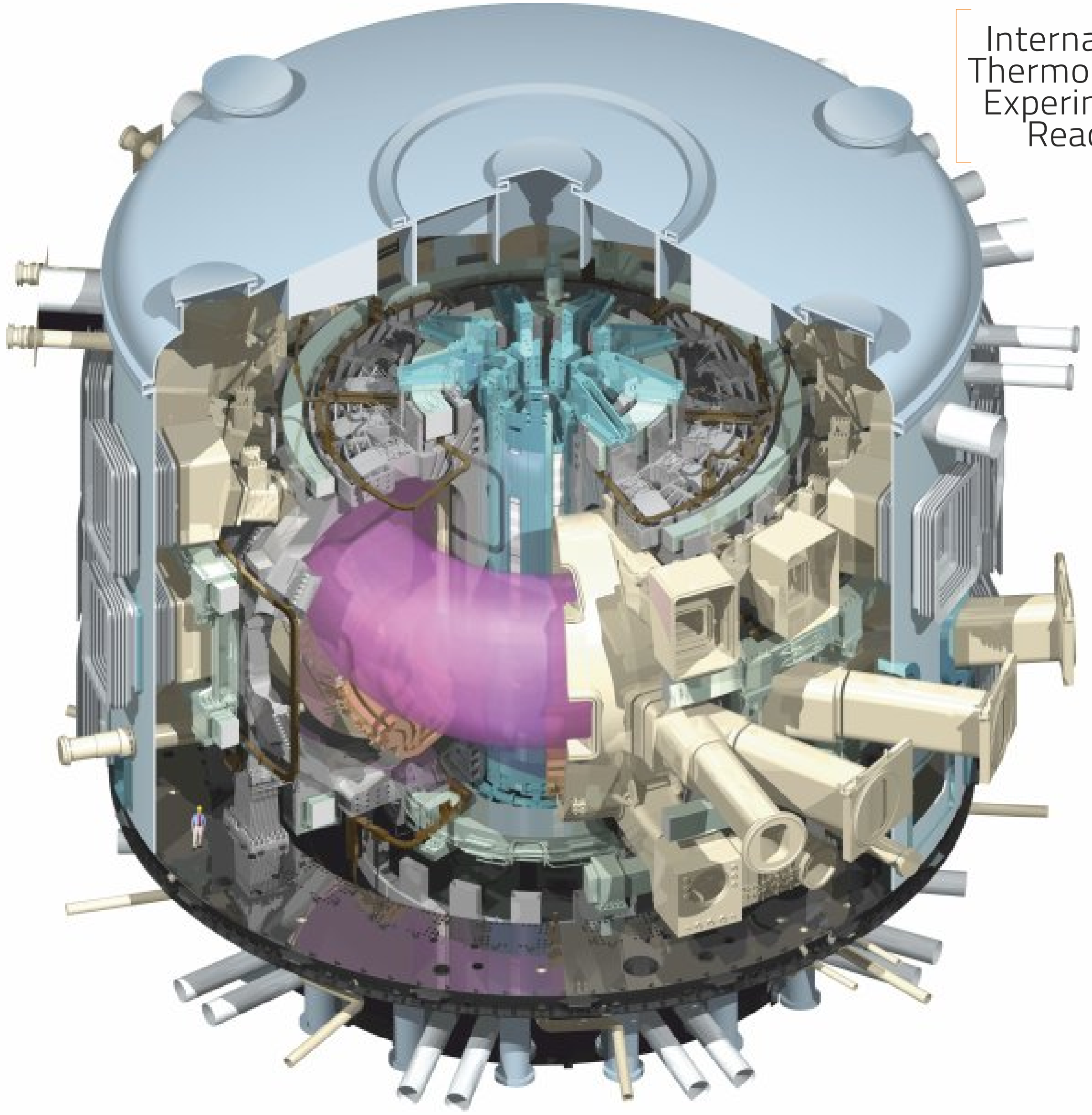
iter

china eu india japan korea russia usa

International Thermonuclear Experimental Reactor



The Way to New Energy

ITER is an experimental fusion reactor facility under construction in Cadarache, in southern part of France to prove the feasibility of nuclear fusion as a future source of energy. ITER will work on the "Tokamak" concept where the reaction of hydrogen isotopes Deuterium and Tritium produce energy by the mass-energy conversion principle, thereby proving to be a source of unlimited energy. ITER partners are the European Union, China, India, Japan, South Korea, Russia and the United States of America. European Union, being the host party, contributes 45% and the other contribute 9% each. Most of these contributions are through 'in-kind' procurement of ITER components. India formally joined the ITER Project in 2005 and the ITER Agreement between the partners was signed in 2006. ITER Organization (IO) is the central team responsible for construction at site and operation, while the ITER partners have created their own domestic agencies to deliver their commitments to ITER. ITER-India is the Indian domestic agency, a specially-empowered project of the Institute for Plasma Research (IPR), an aided organization under the Department of Atomic Energy (DAE). ITER-India is responsible for delivery of the following ITER packages: Cryostat, In-wall Shielding, Cooling Water System, Cryogenic System, Ion-Cyclotron RF Heating System, Electron Cyclotron RF Heating System, Diagnostic Neutral Beam System, Power Supplies and some Diagnostics. Additionally, related R&D and experimental activities are being carried out at the ITER-India laboratory in Gandhinagar, Gujarat.

Collaborating Institutes in India

Institute for Plasma Research (IPR)
Bhat, Gandhinagar

Technologies developed/being developed

Cryostat:

30 m high and 30 m diameter Outer vacuum shell of ITER

Cryolines and cryo distribution system: 4 km cryolines, 7 km warm lines and 7 cryo distribution boxes for ITER cryo-plants of capacities 75 kW at 4.5K, 1 MW at 80K and their supply

In wall shielding: ~80% volume between the two shells of vacuum vessel is filled with borated steel (SS304B4, SS304B7) and ferritic steel for neutron shielding and reducing toroidal field ripple. Requires ~9000 blocks from 70,000 precision cut plates.

ITER – Water Cooling and Heat Rejection System: **10 cells of Cooling Tower:** Avg. 510 MW :Highest heat rejection capacity – Peak ~ 1.2 GW.

14 Plate type Heat Exchanger: **70 MW each:** possibly at the highest range of design.

6 Air-cooled Chillers: **450 kW each:** first, with requirement of seismic qualification for nuclear site.

ICRF source system:

9 RF sources: 2.5 MW at VSWR 2.0/35-65MHz/CW or 3.0 MW at VSWR 1.5/40-55MHz/CW

Power supplies for DNB, ICRF and ECRF systems:

DNB: 10 kV, 140 A Extraction PS

90 kV, 70 A Acceleration PS

ICRH Driver Stage: 8-18 kV, 250 kW, End Stage : 27 kV, 2.8 MW

ECRH : 55 kV, 5.5 MW

ECRH:

2 gyrotron sources: 1 MW power

Diagnostics: Essential to monitor plasma impurities and emission. Ports are needed to house the Diagnostic systems in position and act as shielding from neutrons.

- **X-Ray Crystal Spectroscopy (XRCS):** Set of spectrometers (X-ray crystals, Detectors, Vacuum Chamber).
- **Electron Cyclotron Emission (ECE):** Set of Michelson Interferometers and Radiometers, Polarization Splitter Unit, Transmission lines
- **CXRS:** Optical Fibres, Detectors, Visible Spectrometers, Opto-mechanical components like filters, mounts, I&C.

Special material development

CuCrZr with % compositions controlled to Cr: 0.6 – 0.8%; Zr: 0.07% to 0.15% ; Cd: 0.01%; Co: 0.05% ; total impurities not to exceed 0.1%.

Diagnostic neutral beam system: Detect He ash during D-T phase of ITER plasma and plasma diagnostics using 100 keV 20 A H neutral beam @ 20.7 m from the ion source. This requires extracting and accelerating 100 keV 60 A H- beam from the ion source at an extracted current density of 35 mA/cm2.

Indian industries involved

Larsen & Toubro	Avasarala Technologies Limited	INOXCVA	Kirloskar Group	Kelvion India pvt.Ltd
Ratnamani Metals & Tubes Limited	Gemmo SpA	CARPENTER	Air Liquide Worldwide	PVA TePla
Amtech Electronics India Limited	NFTDC Nonferrous Materials Technology Development Centre	Vacuum Techniques Pvt. Ltd.	SOLCON The Global Experts In Motor Controls	Research Instruments GmbH
Forbes Marshall Pvt. Ltd.		Blue Sky Spectroscopy Inc	Silver Touch Technologies Limited	Industeel
Continental Electronics Corporation	Transformers & Rectifiers(Indian)ltd.	MAN Diesel & Turbo Man Energy Solutions	THALES	Xylem Inc
Veeral Controls P. Ltd	Linde India Limited	CSIR-Central Electronics Engineering Research Institute	Nuclear Power Corporation of India Limited	

Contact person/Spokesperson

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Present aerial view of ITER Construction site

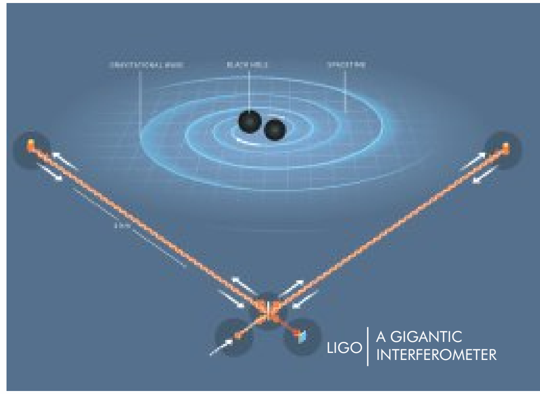
Laser Interferometer Gravitational-wave Observatory

LIGO INDIA

An Indian astronomy mega-science venture in joint collaboration with LIGO Laboratories, USA.

Laser Interferometer Gravitational Wave Observatories (LIGO) are supported by the National Science Foundation, USA and operated by Caltech and MIT

Sensing ripples in Space-Time



LIGO is a world-leading observatory designed to detect gravitational waves from the most violent events in the Universe. LIGO and the associated collaboration, involving 37 researchers from 9 Indian institutions, is known for the first direct detection of Gravitational Waves. This opened a completely new window with which scientists are starting to probe hitherto unexplored phenomena such as the formation of black holes, exploding neutron stars, witnessing the birth of our Universe and so on. This enriches multi-messenger astronomy complementing the conventional means of observing and studying the Universe with telescopes using light. The physical measurements required for gravitational wave detection are arguably the most precise ever made, and they involve cutting-edge technologies that have many day-to-day applications. LIGO-India, an ongoing enterprise to set up a new gravitational wave detector on Indian soil, is a mega-science project jointly funded by the DAE and DST. With this addition to the existing network of detectors globally, we will dramatically increase the sensitivity and positional accuracy with which gravitational events will be detected. India will provide the site, vacuum system and other infrastructure required to house and operate the interferometer and manpower, materials and supplies for installation, commissioning and operations. Presence of such a world-leading facility in India will inspire and attract generations of students to pursue challenging careers in science, technology and innovation.

DAE: Departments of Atomic Energy

DST: Department of Science and Technology

Collaborating Institutes in India

Chennai Mathematical Institute (CMI), Chennai	Directorate of Construction Services & Estate Management Mumbai *	Indian Institute of Science Education & Research Kolkata	Indian Institute of Science Education & Research Pune	Indian Institute of Technology (IIT)- Bombay Mumbai
Indian Institute of Technology (IIT) Gandhinagar	Indian Institute of Technology (IIT) Hyderabad	Indian Institute of Technology (IIT) - Madras Chennai	Institute of Advanced Research (IAR) Gandhinagar	Institute for Plasma Research (IPR) Gandhinagar *
International Centre of Theoretical Sciences (ICTS) Bengaluru	Inter-University Centre of Astronomy & Astrophysics Pune *	Raja Ramanna Centre of Advanced Technology Indore *	Tata Institute of Fundamental Research (TIFR), Mumbai	*Lead institutions responsible for the construction, commissioning and operation of LIGO-India

Technology developed

During its development, LIGO has already spawned innovative technologies in diverse areas as described below

LIGO-India Observatory at the Aundha site. Aerial view as seen from the Corner Station (Artistic rendering by the DCSEM, DAE);

Technology category	Technology advanced or invented by LIGO
High-performance optics and optical metrology	Photo-thermal interferometer
Optical components	Adaptive laser beam shaping
Lasers	Diode-pumped laser
Ultrahigh vacuum components and techniques	Vacuum cable clamp
Sensor technology	Interferometric displacement sensor
Materials engineering	Oxide bonding techniques
Computation and time-series data analysis	Fast chirp transform
Distributed computing	Distributed identity management

Source: Advanced LIGO webpage (https://www.ligo.caltech.edu/page/technology-transfer-case-studies)

A short description of some of the technologies listed above can be found below

Nonlinear optical materials used in the area of high-performance optics and optical metrology require precise measurement of properties such as absorption losses and damage thresholds. One of the most successful approaches developed in Advanced LIGO (aLIGO) to characterize these materials is the Photothermal Common Path Interferometry.

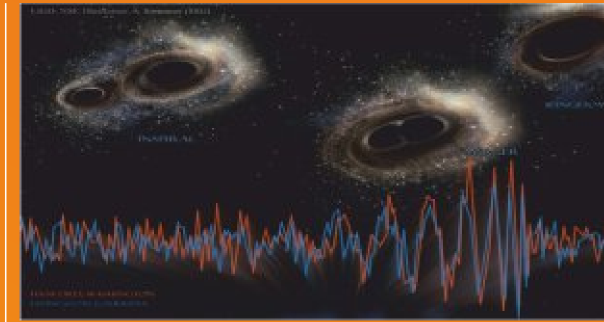
Adaptive beam shaping of the high-power laser beams had to be developed due to the extreme sensitivity to wavefront distortions encountered in LIGO. The thermal compensation system developed for correcting these distortions uses ring-heaters on the outer barrel of the mirrors to correct their radius of curvature and a CO_2 laser to heat a transparent compensation plate.

LIGO uses a variant of "silicate bonding" technique to fabricate the quasi-monolithic fused silica suspensions now being used for Advanced LIGO. This technique was selected for use in ground-based gravitational wave detectors because of its high strength obtained with very thin bonding layers, which results in low mechanical loss and leads to low thermal noise.

LIGO is leading the effort to bring the benefits of federated identity management to large scientific research organizations and projects. This will also give scientists the power to quickly create their own virtual groups and to manage user access to web pages, wikis, email lists, software repositories and other tools needed to support their projects.

Indian industries/companies involved

Indian institutions such as IUCAA, RRCAT, IPR, and DCSEM are in the process of discussing with industries/companies and identifying them which will help in developing the technological capability needed for building detector for LIGO-India.



Gravitational waves were first detected on 14th September 2015 by Laser Interferometer Gravitational-wave Observatory (LIGO) based in Hanford and Livingston. Two black holes of masses 36 and 29 solar masses merged a billion light-years away to form a 62 solar mass black hole and the rest of the mass was released as energy in Gravitational Waves. A simulated picture of the merger event and the signals received in the two LIGO detectors are shown in the above image.

Contact person/Spokesperson

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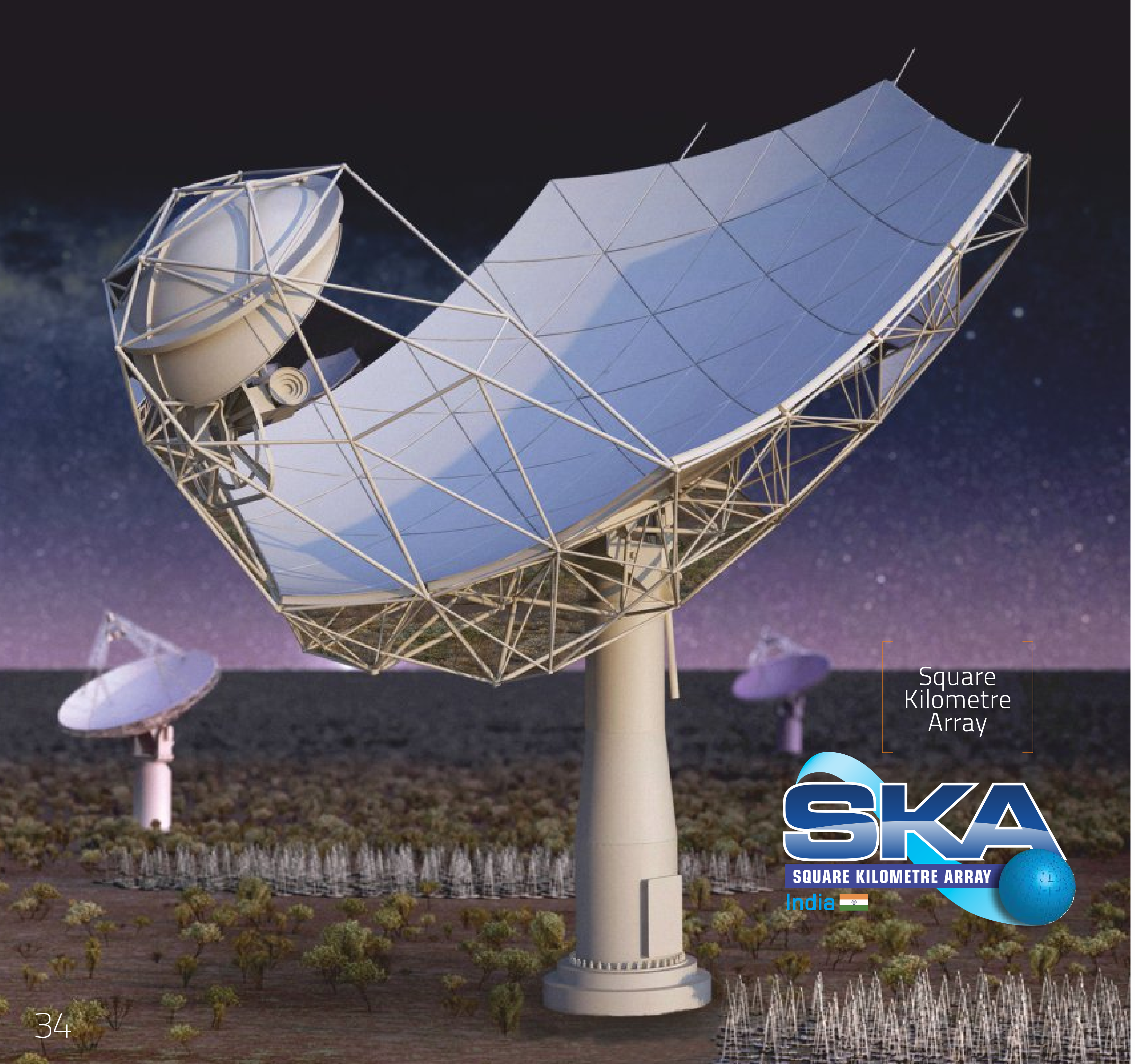

Exploring the Universe with the world's largest radio telescope

The Square Kilometre Array (SKA) will be an array of telescopes, spread over hundreds of kilometres, in two different continents. In the first phase there will be about 200 dishes in South Africa's Karoo region and over 130,000 low frequency antennas in Western Australia's Murchison Shire, that will monitor the sky in unprecedented detail, in a complementary range of radio frequencies. The two sites are chosen for co-hosting the SKA based on the characteristics of the atmosphere above the sites and their radio quietness, which comes from being some of the most remote yet accessible locations on the Earth. The unprecedented sensitivity of the SKA's receivers will allow insights into the formation and evolution of the first stars and galaxies after the Big Bang, the role of cosmic magnetism, the nature of gravity, and possibly even life beyond Earth, not to mention serendipitous discoveries that are expected when something so much more sensitive than any existing facility is built. Indian scientists are involved in many of the SKA's Science Working Groups, and India co-chairs the Solar Physics WG.

The SKA will push several areas of technology to the next level, spanning antenna design, radio frequency electronics and optical fibre technologies, low-power electronics, signal processing, high performance computing, as well as complex system management software. Some of the most challenging innovations will be in the area of software and computing, making it a truly "IT telescope". Whilst 13 countries including India are currently funding the SKA, around 100 organisations in about 20 countries representing over 1,000 scientists and engineers are participating in the design and development of the SKA.

The National Centre for Radio Astrophysics (NCRA) in Pune is leading India's participation in the SKA, which is funded by the Department of Atomic Energy (DAE) and Department of Science and Technology (DST), Government of India. SKA-related initiatives in India are overseen by the SKA-India Consortium (SKAIC) which has almost twenty member organisations from all over the country. India has led the design of the Telescope Manager, which is the brain and nervous system of the entire SKA Observatory, and interacts with all the other elements to run the Observatory. The complex software to be used for the end-to-end management of the entire Observatory has been developed leveraging the expertise of Indian IT industries and utilizing next generation tools and ideas to tackle the complex problem. Indian institutions and industry have also been involved in technology and science with the SKA precursor and pathfinder facilities such as Murchison Widefield Array (MWA) Observatory in Australia and the Giant Metrewave Radio Telescope (GMRT) Observatory in India.

Collaborating Institutes in India

National Centre for Radio Astrophysics Pune	Raman Research Institute (RRI) Bengaluru	Inter-University Centre for Astronomy & Astrophysics Pune	Saha Institute of Nuclear Physics Kolkata	Physical Research Laboratory (PRL) Ahmedabad
IIT Indore	IIT Kanpur	IIT Kharagpur	Indian Institute of Science Education & Research Mohali	Indian Statistical Institute (ISI) Kolkata
Jamia Millia Islamia New Delhi	Presidency University Kolkata	Birla Institute of Technology and Science (BITS), Goa	Tata Institute of Fundamental Research (TIFR), Mumbai	IISc Bengaluru
Indian Institute of Space Science & Technology Thiruvananthapuram	M.G. University Kottayam	St. Thomas College Kozhencherry	Savitribai Phule Pune University	

Technologies developed

1. Telescope Manager: end-to-end observatory management system, with sophisticated algorithms and software, suitable for management of any complex, distributed system. Prototype version being deployed at NCRA's GMRT observatory, which is SKA pathfinder facility.

2. Wideband radio frequency and optical fibre systems: these have been developed by the teams from NCRA as part of the upgrade of the GMRT, a SKA pathfinder facility.

3. High speed digital signal processing modules: these have been developed by RRI for the MWA project – a SKA precursor facility, and also by NCRA for the upgraded GMRT – a SKA pathfinder facility.

Indian industries involved

1. Tata Consultancy Services, Pune
2. Persistent Systems Limited, Pune
3. NVIDIA India, Pune
4. HiQ Electronics, Hosur
5. Smile Electronics, Bengaluru
6. Kamal Electronics, Bengaluru

Contact person / Spokesperson

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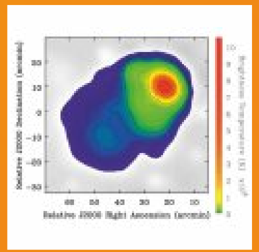
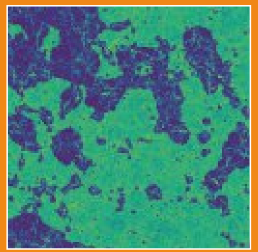
Low frequency antennas

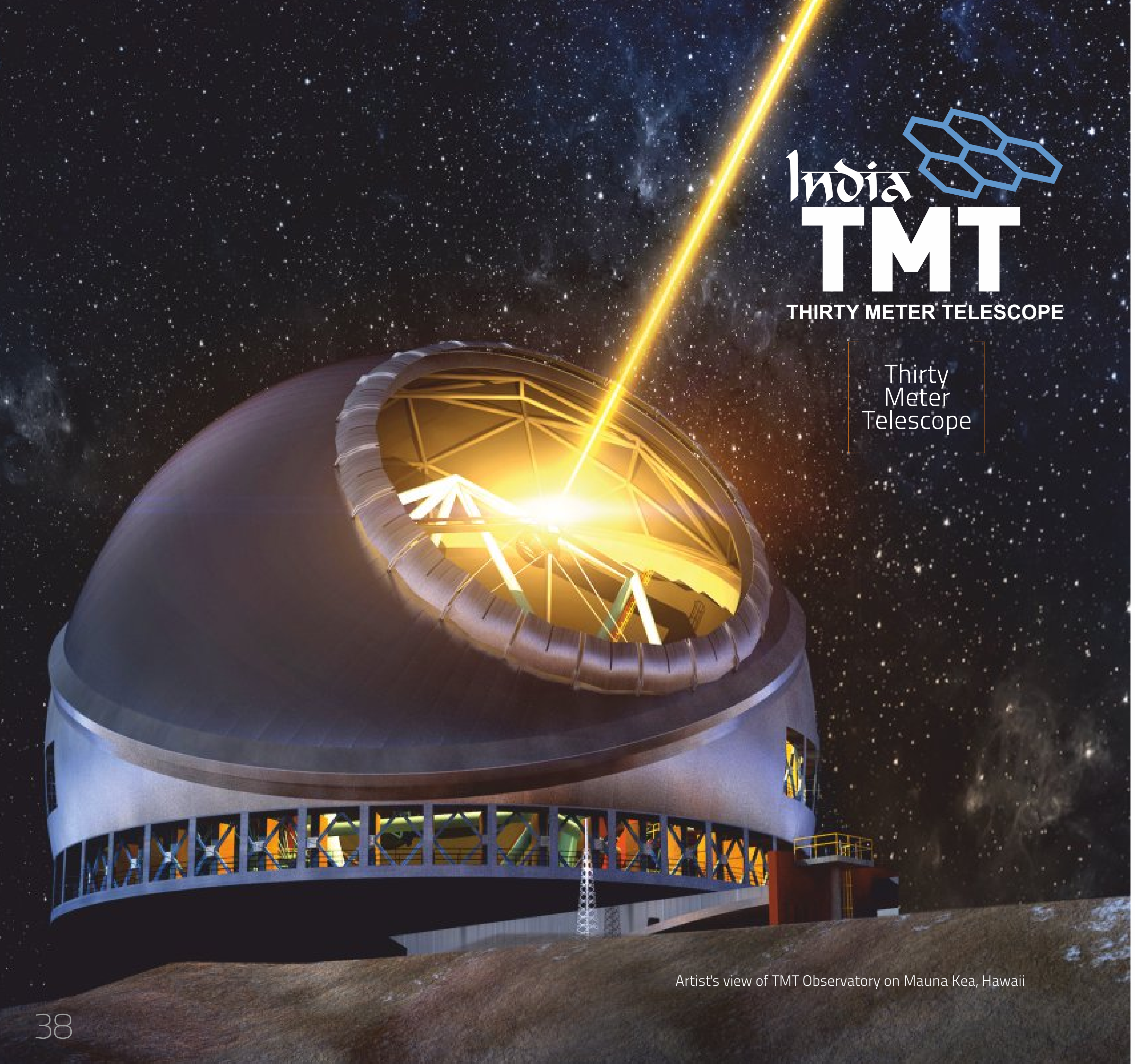
Sample SKA related science activities in India

Indian astronomers are using different SKA precursors and pathfinders to prepare for SKA science. The picture on the left shows an example, viz., a detailed map of a galaxy cluster (Abel521) made using GMRT (a SKA pathfinder facility), revealing interesting new features. Indian astronomers also use the SKA precursors MeerKAT and MWA observatories for cutting-edge science; for example, the picture in the middle shows one of the most detailed images of the Sun ever in radio band made using MWA data. One of the large survey projects at the MeerKAT is being led by astronomers from India. Scientists are also carrying out theoretical simulations which help in interpreting the data, for example, the picture on the right shows simulations of ionized bubbles produced by the first stars in our Universe.

Abell 521 with the uGMRT Band 4 RMS 10^{-5} Jy / beam







Artist's view of TMT Observatory on Mauna Kea, Hawaii

A New Window to the Universe

Our view of the Universe was largely constrained by the unaided vision of our eyes before Galileo Galilei first adapted a telescope to look at the skies over four hundred years ago. Telescopes built till today have led to many fascinating and intriguing discoveries in astronomy, like the discovery of planets around other stars, evidence of accelerating expansion of the Universe, existence of dark matter and dark energy, monitoring of asteroids/comets that could pose a serious threat to the inhabitants of the Earth. The upcoming Thirty Meter Telescope (TMT) will be one of the world's most advanced and capable ground-based optical and infrared telescopes to probe unknown cosmos. An international consortium of scientific institutions and organizations in Canada, China, India, Japan and the USA is building TMT. In India, to efficiently manage India's contributions to TMT, the Department of Science and Technology (DST) and the Department of Atomic Energy (DAE), Government of India have jointly formed an India-TMT Coordination Centre (ITCC) at the Indian Institute of Astrophysics (IIA), Bengaluru. TMT will involve the latest innovations in technology at the heart of the telescope is a segmented mirror, made up of 492 individual hexagonal segments which will work as a single reflective surface of 30m diameter providing unprecedented light gathering capability and an advanced Adaptive Optics (AO) system which will provide superbly high resolution images as if the TMT were in space. India's in-kind contributions to the TMT project include Segment Polishing, Segment Support Assemblies, Actuators, Edge Sensors, Software development for the observatory and design and development of science instruments. TMT, enabled with these technologies will make ground-breaking advances in answering a wide range of fundamental and important scientific questions.

Coordinating Institutes in India

- ARIES ऐरीज — Aryabhatta Research Institute of Observational Sciences (ARIES) Nainital
- Indian Institute of Astrophysics (IIA) Bengaluru
- IUCAA — Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune

International Partners

Caltech California Institute of Technology	University of California	NRC·CNRC National Research Council Canada	NAOJ National Astronomical Observatory of Japan	National Astronomical Observatory of China

Technologies developed

1. Hardware:

Actuators (1526), Edge sensors (3284) and segment support assembly (580) : These are the devices used by the primary mirror control system to precisely position the hexagonal mirror segments to form a 30 metre hyperboloid primary mirror.

2. Optics:

Primary mirrors (84) : Super polished aspheric mirror segments will be produced using stress-mirror polishing technique.

High Resolution Optical Spectrograph (HROS) : A second generation instrument.

3. Software:

Observatory Software (OSW) : This software provides the infrastructure and software architecture support that integrates all TMT software to form one cohesive system.

Telescope Control Software (TCS) : TCS is responsible for the coordination and control of various subsystems that make up the telescope

Indian industries involved

			Accurate Engineering Company Pvt. Ltd. Pune	Amado Tools Bengaluru
Avasarala Technologies Limited Bengaluru	सी डैक CDAC Center for Development of Advanced Computing Bengaluru	cmti Central Manufacturing Technology Institute Bengaluru	CTTC Central Tool Room & Training Centre Bengaluru	EM Elite Metrology Bengaluru
FT Future Tech Engineering Pvt. Ltd. Bengaluru	General Optics (Asia) Limited Pondicherry	Godrej, Mumbai	Honeywell Honeywell Automation India Limited, Pune	IDTR Indo Danish Tool Room Jamshedpur
ipa IPA Private Limited Bengaluru	LTE Lakshmi Tech & Engineering Industries Ltd. Coimbatore	Larsen & Toubro Coimbatore	MAGMA Magma Machining Pvt. Ltd. Ahmedabad	MECHVAC Mechvac India Ltd. Mumbai
NUCON Aerospace Nucon Aerospace Pvt. Ltd. Hyderabad	Optica Optics and Allied Engineering Pvt. Ltd. Bengaluru	PLAN Plan Measuring Services, Bengaluru	SLTL Sahajanand Laser Technology Ltd. Ahmedabad	SGS SGS India Pvt. Ltd. Bengaluru
Silvergrey Engineers Bengaluru	SE Southern Electronics Pvt. Ltd., Bengaluru	Tamboli Engineers Pvt. Ltd., Pune	Techno Tools Precision Engineering Bengaluru	ThoughtWorks® ThoughtWorks Technologies Pune

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