Unleashing science in India

As India heads to the polls this month, **Pallava Bagla** describes how the world's second most populous country is pushing to the forefront of science – from space missions to nuclear technology

With a population of over 1.1 billion people, of whom 714 million are entitled to vote, elections in India are complex affairs. In the next general election, which begins on 16 April, there will be more than 828 000 polling stations, where some 1.3 million electronic voting machines will be used in what will be the world's largest electronic election. The machines themselves were built and designed in India.

Despite the new technology in the polling booths, scientists in India have traditionally been shackled by age-old regulations barring them from holding equity stakes in the private companies that commercialize their inventions. But on 24 February, in a bid to win support from the country's 400 000 government scientists, the Indian science minister, Kapil Sibal, unveiled a new policy that sweeps away these old laws.

Calling it a "historic decision that will unleash the entrepreneurial potential of Indian scientists", Sibal said these measures were part of a much-needed reform process. Equally full of praise was Raghunath A Mashelkar, president of the Pune-based Global Research Alliance and a former president of the Indian National Science Academy, who called it an "absolutely path-breaking achievement". He said it would open the floodgates for wealth generation by embracing the concept of "knowledge as equity".

Big budgets

Today, India spends in excess of $2.5bn on science and technology, with almost three-quarters of this coming from public funding; the country also produces over 5000 PhD students every year. Scientists in India published some 5932 papers in physics journals in 2007 – roughly half the total published by UK scientists and about a sixth of the figure for the US.

Thankfully for scientists, there has been nearly complete bipartisan support for science among the ruling elite. The United Progressive Alliance – a centrist coalition led by the economist Manmohan Singh that has governed India for the last five years – has traditionally been a great supporter of science. So has the right-of-centre opposition – the National Democratic Alliance, led by Lal Krishna Advani.

Pallava Bagla

Blast off
After launching its first mission to the Moon in 2008, India now has plans to send astronauts into space.

In the run-up to the elections, the government announced the creation of eight new institutes of technology, 30 new central universities, five new institutes of science education and research, as well as 20 national institutes of technology. But although the Indian economy has surged forward over the last two decades – it is currently growing at almost 8% per year – not everything is rosy.

In its last budget, the government allocated almost no extra money to science, while the elections themselves have led to some projects stalling. In particular, the Indian Space Research Organisation (ISRO) in Bangalore had hoped to get approval for its proposed manned space activities, which could see two or three astronauts entering low Earth orbit by 2015. These plans, which would cost about $3bn and make India the second country in Asia to send astronauts into space on its own merit using home-grown technology, may now have to wait until after the elections to get approval.

That delay is frustrating, as the ISRO, and indeed the whole nation, is still riding high on the success of its maiden lunar mission: Chandrayaan-1 – a $100m remote-sensing project that blasted off on 22 September last year – which ISRO boss Madhavan Nair calls "path-breaking". The ISRO has, however, approved a second, robotic mission to the Moon to be launched in 2012, for which the government has sanctioned about $125m. The agency also has plans to undertake missions to study the Sun and an asteroid, and to send an unmanned satellite to Mars – all before 2014.

Space is not the only final frontier for India. If all goes to plan, the country could soon have its very own Indian Neutrino Observatory (INO) tucked 2 km below the Deccan Plateau in southern India some 250 km south-east of Bangalore in the Nilgiri hill ranges. When ready in 2012, this will be the single most expensive basic-science research facility ever to be built in India, costing $167m over a seven-year period.

The observatory will be fully funded by India, with the Department of Atomic Energy in Mumbai footing the bulk of the bill. But Anil Kakodkar, chairman of the Indian Atomic Energy Commission, thinks the INO is not "outrageously expensive" for the nation. Vinod Chohan, a physicist at CERN in Geneva, agrees, saying that "India is well off to be able to permit this". When complete – assuming clearance is given by the local forestry department – the INO will have a massive 50 000 tonne detector made from layers of magnetized iron and glass that will be used to detect neutrinos and antineutrinos produced when cosmic rays interact with the Earth's atmosphere.

Global player

Over the last few years, scientists in India have begun to realize the importance of participating in global science projects. The country has already invested $40m in the Large Hadron Collider (LHC) at CERN and has earned the status of "observer state" in this largely European experiment. India's biggest contribution has been to test many of the collider's superconducting magnets and to also build the jacks that support the entire LHC ring. "It is a thriving collabor-

The Indian Institute of Science: a century of success

Founded 100 years ago on 27 May 1909, the Indian Institute of Science (IISc) is perhaps India's leading science and engineering research centre. Located in Bangalore in the south-west of the country, the centre grew to prominence following the arrival of the Nobel-prize-winning physicist Chandrasekhara Venkata Raman as its first Indian-born director in 1933. Other famous alumni include the nuclear physicist Homi Bhabha, who founded India's atomic-energy programme, as well as Vikram Sarabhai and Satish Dhawan – the architects of the Indian space programme.

The centre has made a huge impact on Indian science and technology. The country's aerospace industry can trace its roots back to the centre, while Bangalore's reputation as India's "Silicon Valley" is also based in part on the IISc's early work in computer science and engineering. Moreover, many local firms involved in defence, space science, metallurgy and materials emerged as off-shoots of the institute's activities.

The IISc currently has about 2000 full-time researchers and 2600 PhD students, whose work covers everything from nanoscience and high-energy physics to mathematics and biology, while some 250 new PhD students join the centre each year. It was first conceived in 1896 and proposed to the government in 1898 by the great Indian industrialist Jamsetji Nusserwanji Tata, the founder of what is known as the Tata Group, which produces everything from cars and steel to chemicals and tea. He intended the centre to be a "university of research" established through a family endowment,

but despite this far-sighted philanthropic gesture – at a time when a university education was beyond the reach of most Indians – he declined to have his name associated with the centre. (The famous Tata Institute of Fundamental Research in Mumbai was set up much later, in 1945, by his nephew.)

Sadly Tata did not live to see his centre built as he died in 1904. Indeed, the British government rejected Tata's original idea of including research into the humanities and medicine, which would have given the IISc much more of a university character. Moreover, the donation of 400 acres of land by the Maharaja of Mysore province led to the institute being located in Bangalore, rather than present-day Mumbai, as Tata had intended.

The centre's first director was the British chemist Morris Travers, who started with research in areas that would support the local chemical, food and electrical industries. Initially, all faculty staff were British and, although the students were all Indian, it was not until the late 1920s that Indians began to take up the majority of full-time posts. Modern research only really began to flourish with the arrival of Raman, who was director until 1938 and remained at the IISc until 1948, carrying out work in optics, crystallography and acoustics.

Following its independence from Britain in 1947, India's quest for industrial growth led to the IISc focusing heavily on engineering. Indeed, the 1950s saw many engineers move from the IISc to the newly founded Indian Institutes of Technology (IITs), which themselves grew out of the centre's activities. The IISc later branched out into research into everything from biosciences to aerospace, with many of India's most famous scientists working there.

As for the future, the IISc's current director – the biophysicist Padmanabhan Balaram – says that he intends to create a new interdisciplinary research centre. Two possible fields – energy and materials, and synthetic biology – have already been identified, although the IISc is still waiting for government cash. The institute has also recently set up new centres in Earth science and neuroscience. Balaram even thinks that the IISc might run undergraduate degree courses for the first time. Other plans include the construction of an additional campus elsewhere in Bangalore that would focus on fields such as solar power and sustainable development.

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ation that showed the world that India can participate in giant, multicountry endeavours," says Vinod Chandra Sahni, director of the Raja Ramanna Center for Advanced Technology in Indore, which has co-ordinated India's role in the LHC.

In 2005 India also became the seventh full member of the International Thermonuclear Experimental Reactor (ITER) project currently being constructed in Cadarache, France, which is designed to see if fusion is feasible as a practical energy source. Expected to cost about $20bn, India will contribute more than $2bn over the next decade as part of its National Fusion Research Programme.

"On our own, we would have taken a long time to make an economically functional tokamak; but now, by just contributing 10% of the [development] work, India will have access to 100% of ITER's intellectual property," says Shishir Deshpande, chief of India operations for ITER.

India has also contributed $250m to the $1.5bn Facility for Antiproton and Ion Research (FAIR) at the GSI heavy-ion research lab in Darmstadt, Germany. Some Indian scientists will collaborate on the project, which once completed in 2014 will produce beams for research into nuclear physics, plasmas and nuclear astrophysics.

India's role in the Large Hadron Collider showed the world that it can participate in giant, multicountry endeavours

Nuclear concerns

One controversial scientific issue, which almost forced an early election in the middle of last year, centres on a nuclear deal between the US and India. The deal, which was only permittable after the International Atomic Energy Agency amended its rules last September, will lead to India signing contracts over the next few months worth tens of billions of dollars to import nuclear-reactor technology from France, Russia and the US to provide an extra 30 000 MW of energy. India had previously been barred from importing or exporting nuclear fuel or equipment after it tested a nuclear weapon in 1974.

Notwithstanding these imports, India's domestic atomic-energy programme continues with zeal. India has 17 working nuclear power plants and its futuristic commercial fast-breeder reactor is nearing completion at Kalpakkam on the coast of the Bay of Bengal. When complete in 2010–2011, the $900m reactor will be the world's first to use plutonium in high enough concentrations to produce electricity. "India's energy hopes ride on the success of this technology," says Baldev Raj, director of the Indira Gandhi Center for Atomic Research in Kalpakkam. Work is also likely to start in 2010 on building an advanced heavy-water reactor – a novel reactor design that generates most of its power using thorium (see *Physics World* August 2008 p10).

While Indian scientists try to tackle these hi-tech challenges, several issues relating to the everyday needs of the millions of ordinary Indians are not being forgotten. The India Meteorological Department in New Delhi is in the throes of a $125m modernization plan – an effort being personally piloted by science minister Sibal. He has promised that, if re-elected, he will ensure that India gets what he calls a "world-class weather-forecasting service". Part of the rationale is that two-thirds of the population of India still depend on agriculture for survival, and in order to improve crop yields the physics of the atmosphere needs to be better understood. That is a herculean task, but as Sibal points out, "Indian scientists need to think big and achieve big".