CONNECT

WITH THE INDIAN INSTITUTE OF SCIENCE

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Dealing with Dementia
Understanding neurodegeneration

Aerospace Research in India
How IISc helped launch it

Science Pedagogy
Facilitating student learning

INDIAN INSTITUTE OF SCIENCE
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IN THIS ISSUE

EDITORIAL

"We are far, far ahead and there is no one who can catch up with us, at least in the near future, and that's the sad part, because we *want* competition – to drive us to do better, to go higher," said S Gopalakrishnan, the Chairperson of the Department of Aerospace Engineering, in an interview to *Connect*. He was referring to where the Department stands in comparison to its counterparts in the country.

Gopalakrishnan talked to *Connect* (you will find the interview on our website) as the Department gets ready to celebrate 75 years of its existence. Known as the Department of Aeronautical Engineering until 1982, it was established in 1942 following a resolution passed by the Court of IISc, presided over by Sir M Visvesvaraya. In the interview, Gopalakrishnan also discussed how the focus of the Department has changed over the years and laid out his vision for its future.

To mark the occasion, this issue of *Connect* features stories about aerospace engineering at IISc and about people who were part of this illustrious Department, including Satish Dhawan. His former student Roddam Narasimha talks about Dhawan as a mentor, scientist and institution builder, and his daughter Jyotsna Dhawan reveals what Dhawan was like as a father, away from the public glare. Other stories about aerospace engineering include how IISc helped in seeding other science and technology institutes like NAL and ISRO, the role of the distinguished aerospace scientist Hans Liepmann in influencing the careers of both Dhawan and Narasimha, a history of the old aerospace engineering building, profiles of the wind tunnel complexes, and an interview with fluid dynamicist Rama Govindarajan, an alumnus of the Aerospace Engineering Department.

And there's more; this issue also provides a glimpse into important research on the malaises of hepatitis C – a communicable viral disease – and dementia – a neurodegenerative disorder, a discussion on science pedagogy, an essay on what makes graphene special, a first-hand account of rural innovation in Odisha, and a peek into day care facilities on campus.

Published by the Archives and Publications Cell (APC) at the Indian Institute of Science (IISc), *Connect* is a quarterly magazine that seeks to bring together the IISc community and engage with the outside world – through stories about life in the Institute, its research, and rich heritage.

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Photo courtesy: APC, IISc

The Department of Aeronautical Engineering on 15 August 1947. VM Ghatage sits fourth from left. RG Harris, the Head of the Department, sits fourth from right

HOW IISc LAUNCHED AEROSPACE RESEARCH IN INDIA

Deepika S

And how its alumni shaped it in the years that followed

IISc set up its Department of Aeronautical Engineering in 1942 – bang in the middle of World War II. It was the year that the Nazis were to begin acting on their horrific plan for a "Final Solution", and that the Japanese military strengthened its grip over Asia and inched closer to mainland India, invading Burma and the Andaman Islands, and attacking Sri Lanka. It was also the year that the 'Manhattan Project' to develop nuclear weapons solidified, and that the British began bombing German civilians and industrial workers "without restriction", leading to devastating air raids like Operation Millenium and Operation Gomorrah that would go on until the end of the war.

World War II didn't reach the Indian mainland until 1943, when Japanese planes bombed its southern coast and in 1944 attacked Kohima and Imphal. But as a British colony, India had to contribute manpower and resources to the war, and back in 1942, IISc had to direct much of its efforts toward the war too, including training "skilled artisans" such as electricians, machinists and carpenters. Although the war wasn't the stated focus of the Department of Aeronautical Engineering, it was involved in it straight away: it was set up with laboratories and a wind tunnel in which Hindustan Aircraft Limited (HAL, renamed Hindustan Aeronautics Limited in 1961) aircraft models were tested, and practical lessons were imparted in collaboration with HAL and British Royal Air Force (RAF) personnel. Classes began formally in the Department on 1 January 1943 with a compact one-year course populated with 15 graduate students and just two members of faculty: a lecturer and an assistant professor.

That assistant professor was Vishnu Madhav Ghatage, a promising engineer in his early thirties who had trained at the University of Göttingen in Germany under Ludwig Prandtl, a pioneer in the field of aerodynamics (who also taught Theodore von Kármán, another important scientist who would go on to found the Jet Propulsion Laboratory at Caltech). Ghatage had completed his doctoral research in Nazi Germany and left for India in 1936 to teach at university in Pune and Mumbai for a few years before joining HAL, which was set up in Bangalore in 1940.

Ghatage, who joined IISc's Aerospace Department in October 1942 (the year HAL was nationalised), was to leave the Department and rejoin HAL in 1948, and eventually rise to be its General Manager and Managing Director until he retired in 1970. HAL went from overhauling and repairing British and American aeroplanes during the war to making indigenous aircraft, and its close relationship with IISc is one that continues to this day. But IISc's early ties to HAL were the first of several important links that would ensure the Department's continued role in influencing the field of aerospace engineering. And it certainly wasn't the last time that World War II would have something to do with bringing to IISc enormously talented scientists who would go on to build India's aerospace programme.

Burgeoning in Bangalore

According to IISc records, in April 1946, a Mission from the Ministry of Aircraft Production visited the Department and realised that the Institute could contribute to the aircraft industry, both in terms of research and personnel training. "They [the Mission] have since reported in favour of the location of the industry in Bangalore, partly in view of the existence of this Department," says IISc's annual report for that year.

Photo courtesy: Roddam Narasimha

Roddam Narasimha (centre) with Satish Dhawan (in checked jacket) at the Asian Congress of Fluid Mechanics

Bangalore would go on to play a significant role in the industry's expansion. In 1960, the National Aeronautical Laboratory (NAL, renamed National Aerospace Laboratories in 1993) relocated from Delhi, where it was set up the year before under the Council of Scientific & Industrial Research (CSIR), to premises in Bangalore. Today, even private aerospace companies like TeamIndus have set up in or moved to Bangalore to benefit from the local industry and its ancillary fields.

The year NAL moved to Bangalore, IISc's Aerospace Department began helping them design and set up a large transonic/supersonic wind tunnel, which could be used to test models of vehicles that could travel close to or faster than the speed of sound. P Nilakantan was NAL's Director from its inception to his untimely death in 1964. He was an IISc alumnus who studied under CV Raman (and was dubbed pleasant but "as stubborn as his teacher" by physicist WH Zacheriasen in a letter to the theoretical physicist Max Born). Having then graduated from Caltech with an MS in 1942, he had also served as a lecturer in the Aerospace Department at IISc from 1944 to 1945, and went on to work for the Civil Aviation Department and the Ministry of Defence before joining NAL.

'The troika'

Srinivas Bhogle, who worked at NAL for over two decades, writes that a report authored by Nilakantan in 1956 recommending R&D in aeronautical engineering may have driven the very establishment of NAL (as well as the Defence Research and Development Organisation's – DRDO – Aeronautical Development Establishment – ADE, set up in Bangalore in 1959, and where APJ Abdul Kalam would begin his career). And according to Bhogle, Nilakantan "sincerely believed that he was India's man of destiny in aeronautics. His passion for this role was all-consuming; he saw himself as the grand architect and mastermind of Indian aeronautics."

Irrespective of what Nilkantan may have believed, he wasn't the sole driving force of Indian aeronautics: Bhogle writes of "the troika of P Nilakantan, VM Ghatage, and Satish Dhawan which worked together on dozens of national aeronautical committees, and virtually wrote the country's aeronautical R&D agenda for the future." Ghatage, Dhawan – who was Head of IISc's Aerospace Department and later, Director of the Institute – and Vikram Sarabhai – also an IISc alumnus and the Indian Space Research Organisation's (ISRO) founder – were on NAL's Executive Council.

SR Valluri and Roddam Narasimha, both alumni of IISc and Caltech, would follow Nilakantan as directors of NAL. Valluri, only 41 when he took charge, would oversee NAL for nearly two decades, through exciting moments as well as a lull that Dhawan reportedly described as being like "a beautiful bride, all decked up, but with nowhere to go." (Incidentally, Valluri and Dhawan were related by marriage – Valluri married Shyamala Manel, a cousin of Nalini Nirody, who married Dhawan.) By the time he retired in 1984, Valluri had procured approval for the Light Combat Aircraft (LCA) programme and was appointed Director-General of the Aeronautical Development Agency (ADA), the apex body set up in Bangalore that year to manage the programme. Narasimha, a student and then member of faculty at the IISc's Aerospace Department for several years, would carry forward the LCA programme at NAL, and initiate several new successes like the FloSolver, a parallel computer for Computational Fluid Dynamics. He was also on HAL's board of directors and was the longest-serving member on the Space Commission, and remains associated with IISc to this day.

The criss-crossing trajectories of the Aerospace Department's faculty and alumni have helped build what its current Chairperson, S Gopalakrishnan, describes as an "ecosystem". From training programs for DRDO scientists to providing IITs with faculty members, Gopalakrishnan says the Department's footprint has been ubiquitous. HAL, NAL, and ISRO are its close relatives.

However, considering the comparatively large role that ISRO plays in the public imagination and the strong connection it would come to have to the Aerospace Department, it is perhaps ironic that the Department had little to do with ISRO's earliest years. There, the seed appears to be World War II: without it, perhaps there may never have been a direct link at all.

Jab Sarabhai met Bhabha

Circling back to World War II and 1942 brings us to Vikram Sarabhai, a young student from an influential Ahmedabad family, who came to IISc. The war had interrupted his studies at Cambridge, where he had just completed an undergraduate degree in physics and maths, and he had been given permission to continue working towards his PhD while back in India on the condition that it would be supervised by CV Raman. That year, he published the results of his study titled 'Time Distribution of Cosmic Rays'. Amrita Shah, in her book *Vikram Sarabhai: A Life*, points out that his chosen subject of cosmic rays was not a popular one at the time, and suggests that it may have been Raman's influence that set him on that line of inquiry.

The same year, it was at IISc that Sarabhai met Homi J Bhabha, whom Shah describes as "the man who was to found India's atomic energy programme and loom like a Colossus over Indian science until his death in the mid-1960s."

Photo courtesy: ISRO

APJ Abdul Kalam (left) and Vikram Sarabhai at ISRO

Bhabha had been made Professor at the newly set-up Cosmic Ray Research Unit in 1942. Shah emphasises that while Bhabha was interested in cosmic rays for the atomic particles they revealed, Sarabhai would come to see them as tools to study outer space. The friendship between the "two princes of Indian science", as she describes them, was forged over science as well as their shared elite backgrounds and "taste for the good life". This bond would mean a great deal to Sarabhai's career further down the line.

When the war ended in 1945, Sarabhai returned to Cambridge to submit his PhD thesis. It was in 1947 that he travelled back to India, and set up the Physical Research Laboratory (PRL) in Ahmedabad. As research at PRL continued alongside Sarabhai's numerous other commitments and interests, he had begun to speak to his colleagues there about beginning a space programme. The Cold War, which began soon after World War II ended, was pushing this new technology forward, and although Sarabhai was not interested in developing weapons, he was keen on developing a rocket programme for research and satellite technology for communications.

Sarabhai the stargazer

Shah writes that Sarabhai was "very clearly persuaded of an almost paternal role for himself with regard not just to his family but all the people he interacted with, the nation and then humanity as a whole." He dreamed of using space technology for long-range weather forecasting, "applications in agriculture, forestry, oceanography, geology, mineral prospecting and cartography", with a "strict focus on peaceful ends". At a time when no developing country could have hoped for a space programme, Sarabhai, gutsy, ambitious and far-sighted, worked towards making it a reality.

In 1961, with Bhabha's influence, PRL was recognised as a centre for R&D in space sciences, and Sarabhai became a board member of the Atomic Energy Commission (Bhabha was its Chairman, and in 1966, Sarabhai would succeed him). In 1962, Sarabhai was appointed Chairman of the Indian National Committee for Space Research (INCOSPAR) and began looking for a suitable location for their sounding rocket experiments: they settled on Thumba, a fishing village in Kerala named after a flower. In November 1963, the first sounding rocket was launched from India. Six years later, INCOSPAR grew into ISRO. When Sarabhai died suddenly in 1971 at the age of 52, ISRO, peopled with young and passionate scientists but lacking in a formal structure that would ensure its continuity, would have to change drastically.

Dhawan's 'new direction'

When Sarabhai passed away in 1971, Dhawan was contacted by Indira Gandhi, who was Prime Minister at the time, and asked to run ISRO. Dhawan happened to be on sabbatical at Caltech, and agreed to the job on two conditions: that he continue as IISc's Director simultaneously, and that ISRO be shifted to Bangalore. Gandhi agreed.

Dhawan was an engineer who had interned at HAL and was mesmerised by aircraft. He received a scholarship in 1945 to study aeronautics in the US and graduated from Caltech. On his return, he joined IISc's Aerospace Department as faculty in 1951, and was made Head of the Department in 1956. He took over as the youngest Director of IISc in January 1963, and by the time he was made ISRO's Head, he had already achieved considerable stature.

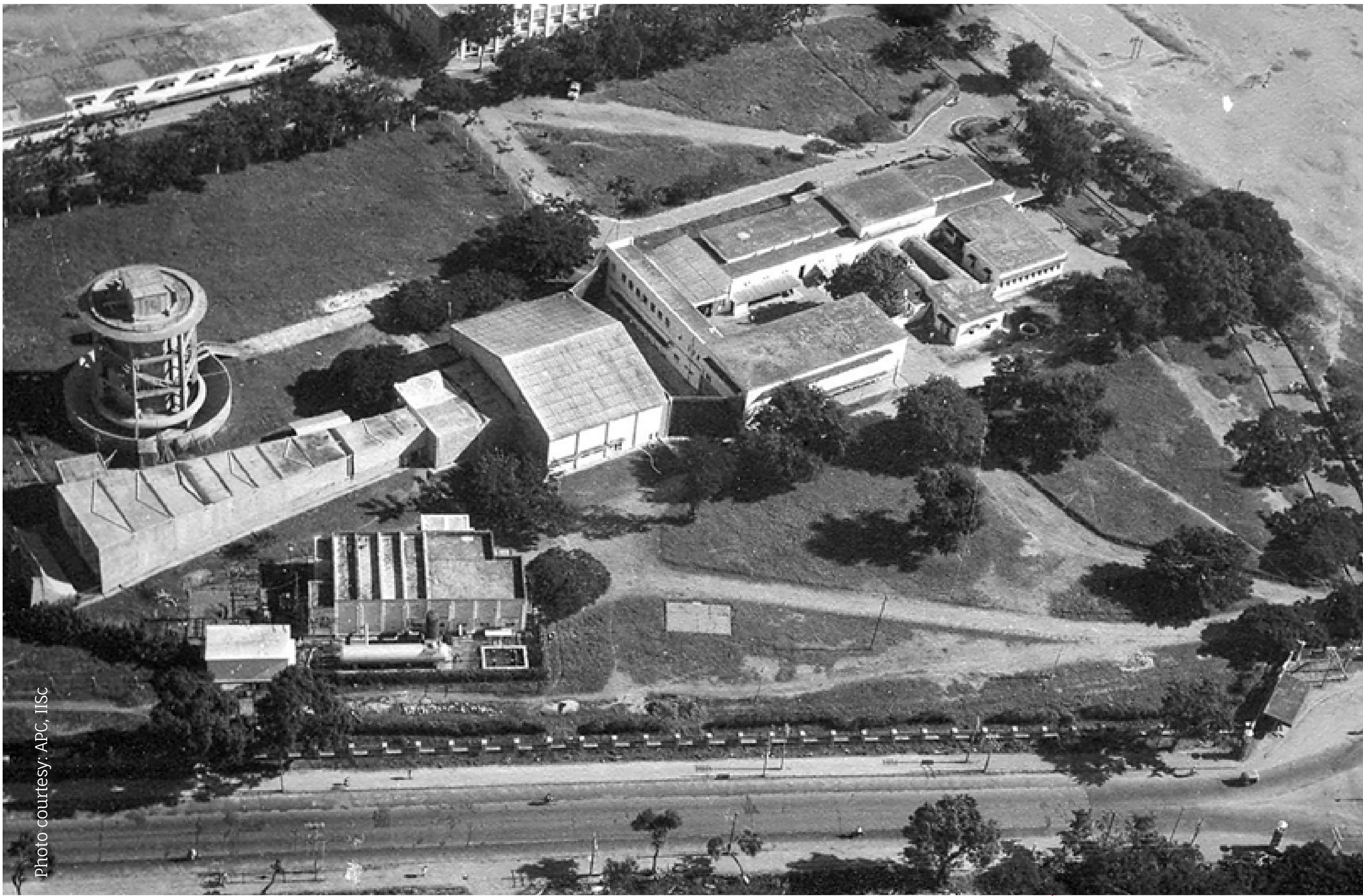
In his memoir, *ISRO: A Personal History*, scientist R Aravamudan writes about the day Dhawan first arrived at ISRO in Thumba, and was annoyed by the elaborate reception – it was to signify a huge change in culture: "We were accustomed to Sarabhai's visits which often resembled some kind of endless durbar." Aravamudan goes on to write, "Sarabhai's management style was that of a patriarch dealing with a small well-knit family. [...] There were no formal systems in place, with parallel technical teams operating. Sometimes they would work on the same system without any coordination." Dhawan, who Aravamudan describes as "businesslike", with a "systematic approach" and "no-nonsense style", inherited both Sarabhai's extraordinary vision and successes as well the fledgling organisation's internal mess: "widely dispersed teams" and employee agitations that were to continue for several years, some even turning violent. He brought to ISRO the tight structure it needed to handle the growth that was expected of it.


Photo courtesy: ISRO

Satish Dhawan at ISRO in 1982

Dhawan also brought IISc's Aerospace Department directly into the picture. Aravamudan writes that he was "very particular that local industry and academia should be associated with the programmes. He felt there should be a two-way dissemination and absorption of expertise. So he inducted organisations like HAL, HMT and BEL and institutions like IISc and government research laboratories to partner ISRO." Aerospace Department alumni like PS Nair, who worked on India's first satellite mission, would go on to leave their mark at ISRO.

K Kasturirangan, ISRO's former Chairperson, said in a talk at the International Centre for Theoretical Sciences (ICTS) earlier this year that Dhawan "transformed every institution he got involved with" and "strengthened and gave new direction to the Indian space program." And in the process, Dhawan appears to have placed the Aerospace Department in the forefront of Indian space technology.



The old Aerospace Engineering Building

THE AEROSPACE ENGINEERING DEPARTMENT'S FIRST HOME

Akhila Thomas

The old building at IISc, designed by German architect Otto Koenigsberger, represents an architectural style that blends minimalism and functionality

IISc is over 100 years old with many stories to be told. And not just about its people. There are also tales of its buildings waiting to be recounted. Hidden amidst the lush canopy of the Institute is one such building which until a few years ago was the home of the Department of Aerospace Engineering – called the Department of Aeronautical Engineering until 1982. The building oozes vintage charm: it has a classic entrance with the wide wooden doors, pastel tones on its walls, and a striking wing-shaped overhang sloping over the main entrance. It was designed by Otto Koenigsberger, a German refugee living in Bangalore.

During the 1930s, thousands of Jews fled Germany after the Nazis came to power. One of them was Koenigsberger

The building oozes vintage charm: it has a classic entrance with the wide wooden doors, pastel tones on its walls, and a striking wing-shaped overhang sloping over the main entrance

who first moved to Egypt when he lost his job in his homeland. After spending a few years studying the architecture of ancient Egyptian temples, he arrived in India to become the Chief Architect of the State of Mysore, a position he held from 1939 to 1948. He constructed many structures during this period in Bangalore: the City Bus Terminal at Kalasipalayam, the Krishna Rao Pavilion in Basavanagudi, the Bathing Ghat in Chickpet, the Tuberculosis Sanatorium on the grounds of NIMHANS, and the Victory Hall (now the Jawahar Bal Bhavan) in Cubbon Park. Koenigsberger was also a town planner. He went on to plan cities like Jamshedpur, Faridabad, Bhubaneswar and Sindri. In 1948, Prime Minister Jawaharlal Nehru appointed Koenigsberger as India's first Housing Director to build temporary houses for people from across the border who had become refugees as a result of India's partition.

Photo courtesy: Rachel Lee

Otto Koenigsberger at his desk

When Koenigsberger was in Bangalore, he became good friends with Homi J Bhabha who was then at IISc. And through Bhabha, he came into contact with the Tatas. They hit it off immediately. This was mainly because they shared an appreciation of the importance of using science in architecture and town planning.

Koenigsberger's association with the Tatas resulted in him leaving behind an impressive architectural footprint in IISc. Besides the Aeronautical Engineering building, he was responsible for the Metallurgy (later renamed Materials Engineering) building, a hydrogen gas plant (now housing commercial establishments including Prakruthi restaurant), and a dining hall and auditorium (currently serving as the Hostel Office).

Trained as a modern architect, he believed in what he referred to as scientific architecture. He saw no contradiction in combining local wisdom with his philosophy of modern architecture. He is described by Rachel Lee, a historian who has studied his work, as an "experimenter". This brought him into conflict with his boss Sir Mirza Ismail, the Dewan of Mysore State, who favoured a more colonial architectural approach. But Koenigsberger persisted with his efforts to incorporate scientific principles into his designs, though he often gave in to the demands of Ismail who insisted on porticos and clock towers. However, he had more freedom to express himself in the buildings he designed as a private architect, including those at IISc. The first of these was the Department of Aeronautical Engineering.

Koenigsberger designed and constructed the building in quick time. He also designed India's first wind tunnel, which is embedded in the building (the tunnel still exists, but has not been used for many years). In 1959, an open-circuit wind tunnel was constructed, one that continues to be used to this day.

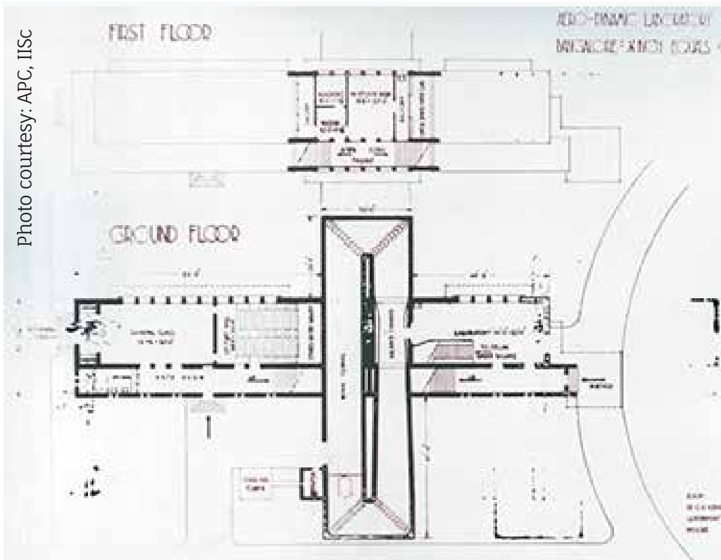


Photo courtesy: APC, IISc

Koenigsberger's design of the Aeronautical Engineering Building `

The external walls of the closed-circuit wind tunnel

In a journal called *Architecture Beyond Europe* , Lee provides a vivid description of this building. She writes: "The most ambitious element of Koenigsberger's design is undoubtedly the 30 m long elliptical low-speed closed-circuit wind tunnel. The wind tunnel loop, which has a test section of 2.2 m x 1.5 m, and a maximum wind speed of about 200 mph, was cast in concrete and partially embedded in the ground. Short granite buttresses provided additional support. Instead of covering the concrete structure, Koenigsberger, no doubt following his own aim of architectural honesty, exposed it. It was India's first closed-circuit wind tunnel, and Koenigsberger considered its construction, in light of the limited resources and technical expertise available, a huge achievement. Indeed, at the time, the Aeronautical Engineering Department at the IISc was the only place in India where facilities existed for training and research, both theoretical and experimental in Aeronautical Engineering."

Lee continues: "Straddling the wind tunnel is the main building of the Aeronautical Engineering Department. In contrast to the monolithic concrete wind tunnel, the Aeronautical Engineering building is built of white-painted plaster-covered bricks on top of a granite plinth. On the narrow east-facing elevation, a cantilevered porch canopy, which is somewhat reminiscent of a wing, marks the main entrance. The elongated rectangular block contains a laboratory, a lecture theatre and a drawing classroom at ground level, with offices for the professor and an assistant situated in rooms directly above the wind tunnel. Koenigsberger relies on passive techniques for ventilating the building. The south-facing access corridor protects the main spaces from solar gain and, because it is slightly lower than the main spaces, allows for ventilators to be fitted at the top of the walls in the teaching spaces. The narrow plan enables effective cross ventilation and the north-facing elevation provides natural light to the main spaces through two blocks of tall recessed window openings protected from glare and rain by thin bands of black-edged chajjas."

"Indeed, at the time, the Aeronautical Engineering Department at the IISc was the only place in India where facilities existed for training and research, both theoretical and experimental in Aeronautical Engineering"

A few years ago, the Department moved to a new, bigger building. But the old one still stands and with it the many stories of its glorious past, including that of its association with an exiled architect who left behind a minimalist modern architectural legacy.

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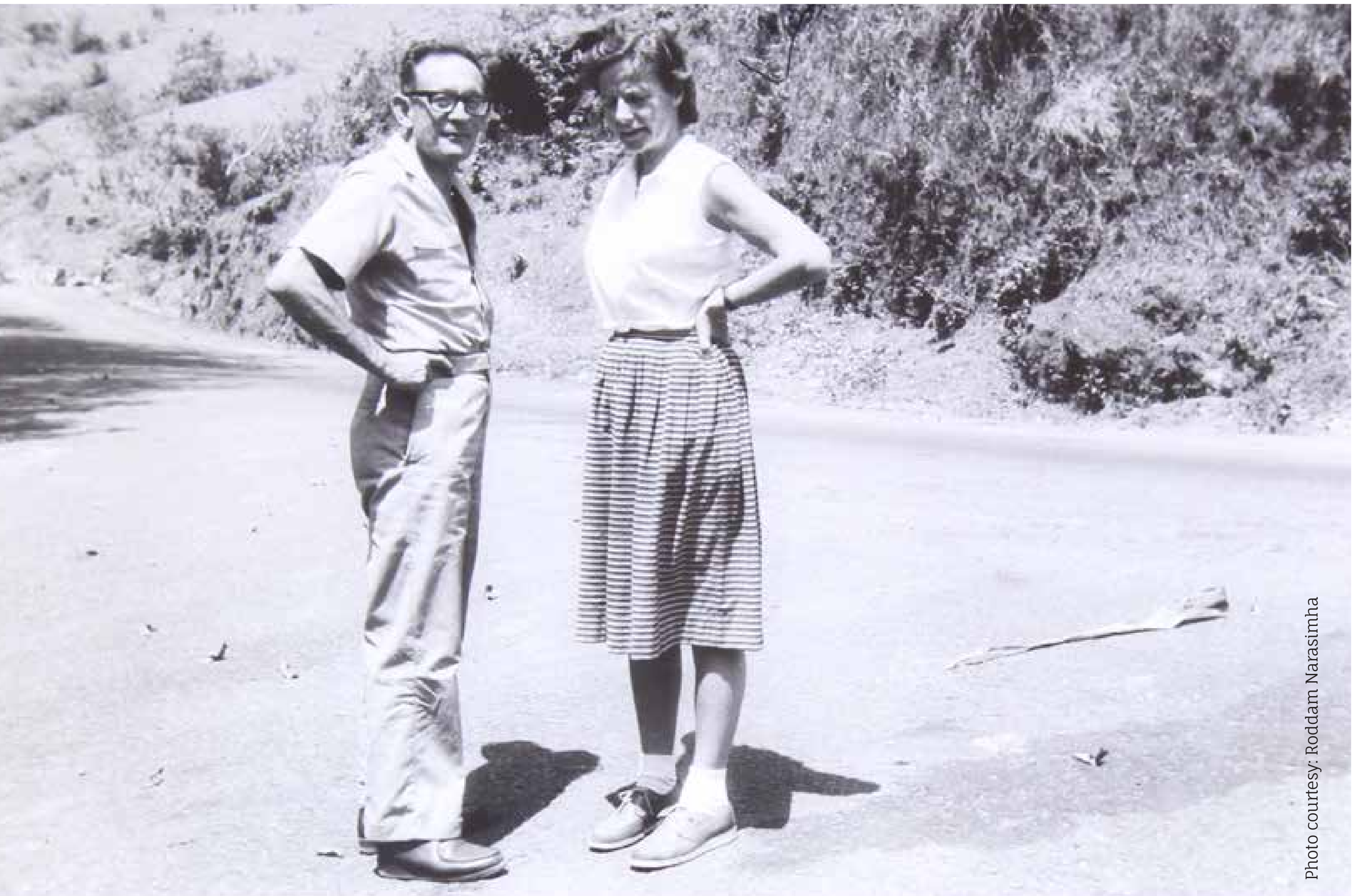


Photo courtesy: Roddam Narasimha

Hans Liepmann with his wife Dietlind

THE LASTING INFLUENCE OF HANS LIEPMANN

Nithyanand Rao

The Caltech professor mentored both Satish Dhawan and Roddam Narasimha

In 1964, Hans Liepmann from Caltech arrived at IISc for a term. SM Deshpande, then doing his ME in the Department of Aeronautical Engineering, remembers the "glorious combination" that resulted.

"Liepmann taught our batch," says Deshpande, now at the Engineering Mechanics Unit at the Jawaharlal Nehru Centre for Advanced Scientific Research. "We were very lucky. We were taught by Roddam Narasimha; his teacher was Satish Dhawan, and Dhawan's teacher was Liepmann."

Liepmann, who passed away on 24 June 2009, was a fluid dynamicist, and later Director, at the Graduate Aerospace Laboratories of the California Institute of Technology (GALCIT). He was renowned for his teaching prowess as much as for his research, with both Dhawan and Narasimha being his PhD students.

It was in 1946 that Dhawan arrived at Caltech, wanting to work with Liepmann. But the Indian students Liepmann had worked with until then had given him the impression that “perhaps the select group that came to Caltech from India had prejudices against manual labor and essential, but not highly intellectual and glamorous, routines.”

“I have often mused about the bifurcation points in one’s life,” wrote Liepmann, recalling this episode in his obituary of Dhawan, “the times when a small and sometimes even unwelcome choice of alternatives results in major changes in one’s future. One of these bifurcations (in, I believe, 1946) resulted in my meeting Satish Dhawan.”

Photo courtesy: Roddam Narasimha

Satish Dhawan

He did take Dhawan as his student, who impressed him immediately. Dhawan, for his PhD thesis, had an original approach to a difficult problem – that of measuring the skin friction of an object past which a fluid flows. Think of the wing of a moving aircraft. The air surrounding it can be thought of as having many layers, each of which has a different flow velocity. The boundary-layer is a thin layer of the air in contact with the wing; across the boundary layer, the flow velocity of air decreases to zero. The aircraft wing encounters resistance because of the friction its surface has with the boundary layer of the air. Theoretical estimates for this skin friction were known. But no one had directly measured it until Dhawan devised an experimental apparatus to do so. This was a problem that, according to Liepmann, was of “both fundamental and direct technical importance.” Dhawan also worked with Anatol Roshko, another of Liepmann’s students, on other projects. (Roshko later became the Theodore von Kármán Professor of Aeronautics at GALCIT, a position Liepmann once occupied. Roshko passed away in January 2017.)

This tradition of scientific research on engineering problems was what GALCIT was about, with its research programme emphasising a solid grounding in the basic sciences. Theodore von Kármán, the first director of GALCIT, had envisioned it “as a center for the fusion of science and technology.” Liepmann himself, in fact, was a physicist by training whose transition to fluid dynamics happened in somewhat unusual circumstances. As the story goes, Liepmann blurted out “hydrodynamics” when asked what he wanted to do next at a party in a pub in Zurich after his PhD defense. This led to an offer from Kármán; Liepmann joined Caltech in 1939.

Theodore von Kármán, the first director of GALCIT, had envisioned it “as a center for the fusion of science and technology”

Dhawan came back to India after his PhD and joined IISc’s Department of Aeronautical Engineering in 1951. (The department was later renamed Aerospace Engineering.) Two years later, Roddam Narasimha enrolled in the department for a two-year diploma (equivalent to a Master’s) in aeronautics. He learned to love fluid dynamics in those two years, not least due to Dhawan’s influence. “Dhawan’s lectures were advanced, simple and elegant all at the same time,” wrote Narasimha in a memoir, “and quickly gave students a sense of confidence.” Traits that Dhawan’s teacher, Liepmann, also had. “There was a permanent hint of a smile on his face while he lectured,” wrote Narasimha of Liepmann, “as if the way he was deriving his results was fun because it was so simple and offered such rich insights.”

After his diploma course, Narasimha was unsure whether to pursue research. Dhawan, he says, “solved the problem for me by saying, ‘I don’t know what you’re going to do. Why don’t you stay here for two years and do some research, and we can have some fun?’”

In the labs, Dhawan was building the instruments necessary for research, including the first supersonic wind tunnels in India. With his students, he once rigged up a supersonic wind tunnel that, as Narasimha recalls, “ran on compressed air from two wartime surplus oxygen tanks from a Dakota [aircraft].” Dhawan’s labs had other custom-made “gizmos” that “somehow managed to convey an impression of both science and engineering.” In this period, Narasimha says, “I learnt how, with some ingenuity, one can overcome what seem like insuperable difficulties.” An approach that Liepmann approved of.

At the end of two years Narasimha went to Caltech to do his PhD – with Liepmann. He completed his PhD in 1961, and, like Dhawan, he too returned to IISc.

Anatol Roshko, Roddam Narasimha and Satish Dhawan, all students of Hans Liepmann

"Many people who came to do [an] ME later used to say 'You were very lucky; we didn't have such a galaxy of great teachers,'" says Deshpande, who did his ME thesis with Dhawan and his PhD with Narasimha.

"They were heady times," says HS Mukunda, Deshpande's friend and former classmate, "far more because we were energetic young aspiring students arguing and disagreeing on issues – scientific and non-scientific – expecting far more than was given to us by our teachers." Mukunda is at the Combustion, Gasification and Propulsion Lab of the Department of Aerospace Engineering, IISc.

"That's really our main goal in life, if we take the professorship seriously," Liepmann once said of teaching. "And also, I think, it has the more lasting influence. Whether you like it or not, most of your startling papers are going to be footnotes in handbooks in the not-too-distant future, and that goes for everybody…But the teaching, the passing on of a certain style and approach to science, and also to knowledge, in a sense; that is, in my opinion, a more challenging and also more rewarding business."

Members of the Department of Aeronautical Engineering, circa 1964: Roddam Narasimha (extreme left), HS Mukunda (extreme right), Hans Liepmann (second from right), and SM Deshpande (fourth from right) (Photo courtesy: Roddam Narasimha)

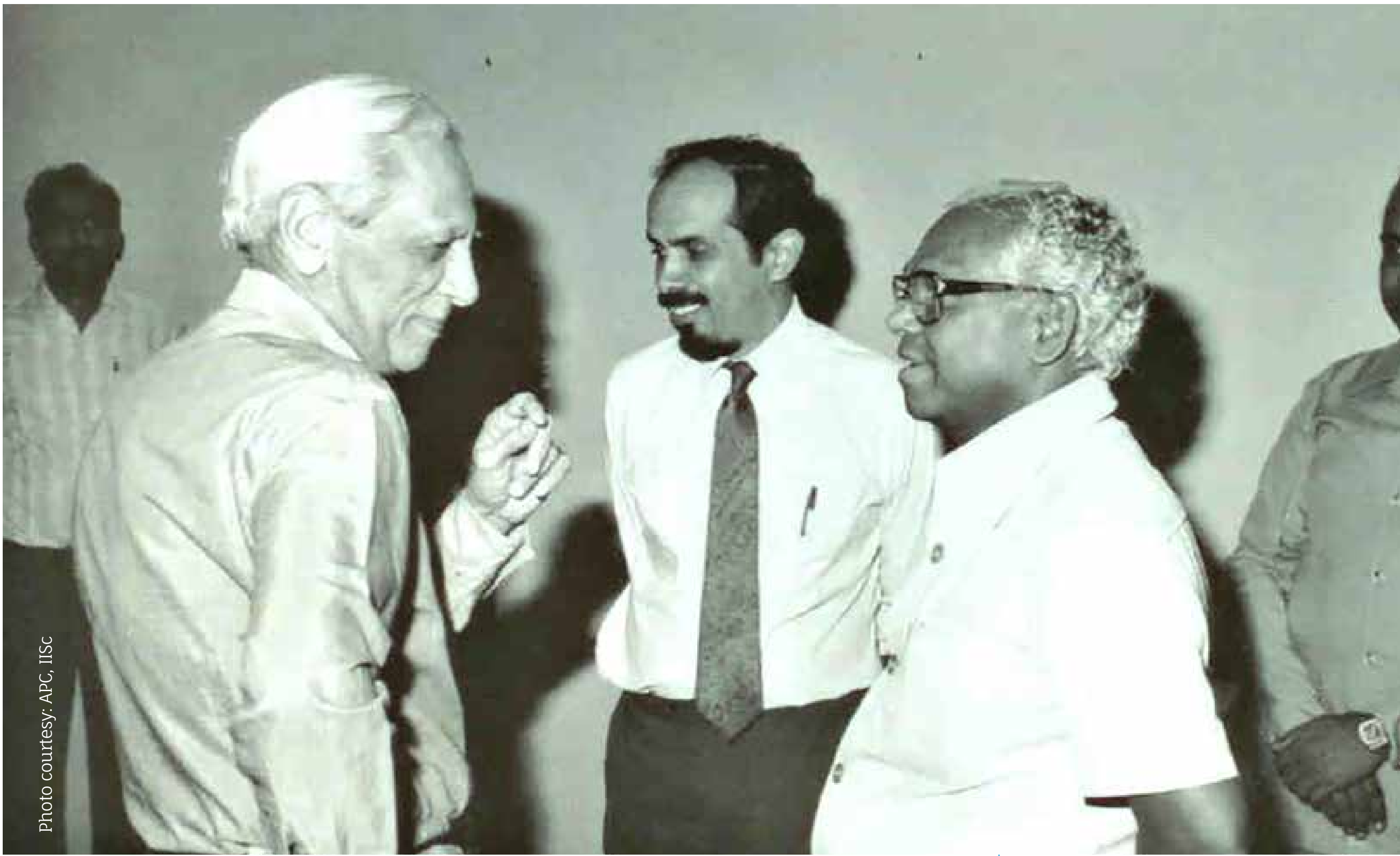


Photo courtesy: APC, IISc

Satish Dhawan (left) with Roddam Narasimha (centre) and KR Narayanan

'DHAWAN INTRODUCED A NEW TYPE OF PERSONALITY TO IISc'

Nithyanand Rao

Roddam Narasimha is the DST Year-of-Science Professor at the Engineering Mechanics Unit, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore. Narasimha, a former professor in the Department of Aerospace Engineering at IISc and a former director of NAL, was one of Satish Dhawan's earliest students. In this excerpt from a wide-ranging interview, he shares his memories of Dhawan.

What was Satish Dhawan like as a teacher?

When he came for his first class, what struck me was that here was the only faculty member who came to the lecture hall smiling. Good morning, he would say, with a big smile on his face. The others were not that way at all. He saw everything as fun. He took pleasure in making things simple. I think people absorbed a great deal more from his teaching than from that of the others. The other thing he did is that he didn't spend the lectures on details about the numbers and so on. He would derive the results and then pass on a large number of data sheets. He would work late at night getting his data sheets ready for the next day's lectures – he took it very seriously. The only man I'd compare with him on teaching was Tietjens, who was the head of the Department at the time, but they were otherwise very different in terms of personality.

Dhawan always answered students' questions, and even when he conducted oral exams he was pleasant. This did not necessarily mean you got very good grades [laughs], but if he thought you had understood what had been taught, he was generous with grades.

What was Dhawan like in your interactions with him outside the classroom?

He was, first of all, a very pleasant person. When he came on this campus, he was a very unusual faculty member. The Institute in general was a relatively serious place at that time. Most of the faculty members wore a coat and tie, for example. Dhawan wore colourful Californian shirts, had a red convertible MG (a sports car) and drove from his home to the lab.

Some of the faculty members did mix with students but never at the level at which Dhawan did. Once I became his research student I would, now and then, be at his house, and we would chat about various things. He had a great sense of humour, almost always had a smile on his face, and he made you feel at ease. But if you thought that he was only that, you'd be very mistaken. He was very serious about his work. He was also serious about the country, a real patriot. For him, patriotism was never a badge he wore, but was evident by the way he was committed to doing things here. He was a man who thought India should be doing a great deal more. He introduced a new personality to this campus – professionally as well as personally.

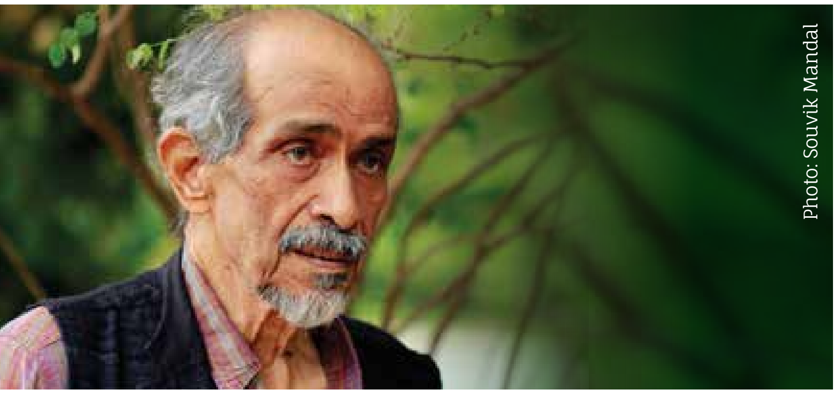


Photo: Souvik Mandal

What would you say was Dhawan's role in shaping IISc as we know it today?

I would say that he transformed the Institute. When I came here as a student, there were some departments which were very active in research; some not so active. But the war and independence had changed the needs of the country. Dhawan saw the need for doing things which the Institute was not doing – for example, theoretical physics, ecology, atmospheric science. In all of these Dhawan took a big initiative. He did another remarkable thing. He invited the finest scientists of the country to IISc and they went on to set up new programmes here: CNR Rao in solid state chemistry, GN Ramachandran in molecular biology, and George Sudarshan in theoretical studies. He encouraged many other areas as well – all the way from science and technology for rural areas to high-energy physics. And he changed the grading system governing students' performance, moving away from the old marks system.

The net result was that academic levels in different departments were much less non-uniform than before. Partly because of his broad background – he had a degree in physics just as in engineering, and his PhD minor was mathematics. So he had a very broad vision for the Institute. He could see that everything has its place.

In his work as Chairman of ISRO, did he bring something new to ISRO which made it the success that it is today?

Very definitely, yes. I think that the space programme as it is organised today is very largely the work of Dhawan. Vikram Sarabhai was the visionary who, ahead of his time in India, said we should start a space programme. So I would say the seeds were sown by Sarabhai, but the tree that you see is very largely the work of Dhawan. I think the architecture which you see – the different centres with well-defined projects – is really the work of Dhawan, if only because Sarabhai didn't have time to do it. The centres, the people who were picked to run those centres, the way the responsibilities were divided, the project system and the critical reviews they made of the projects with a lot of outside help – academics were involved in all of this. So that whole system was really Dhawan's creation. If today most people in the country look upon ISRO as the one organisation in the government which delivers, it's really because of the spirit and leadership structure that Dhawan set up.

And he had great confidence in Indian talent. I still remember the first big review they had of the SLV-3 project, of which APJ Abdul Kalam was the director. The number of people involved in that review was something like 250. It was held in an auditorium. And I wondered why instead of a small committee room he had this whole auditorium for the review. Dhawan wanted everybody to know – the mission of space and the projects had to be understood not just by the scientists in each project team, not just by the leaders and the centre directors, but by *every* engineer who had any part to play in the project. And they all knew that if it came to a technical discussion, everybody was equal. It did not depend on rank or hierarchy. All these principles have constituted what people now refer to as the ISRO culture. And in some ways, I think it's one of the greatest contributions that Dhawan made.

Satish Dhawan with Jyotsna, one of his three children, in Bangalore in 1962. He set up the swing in the photo for his children on the premises of the Director's Bungalow at IISc, where the family lived at the time

MY FATHER, SATISH DHAWAN

Deepika S and Karthik Ramaswamy

Jyotsna Dhawan is a cell biologist working at the Centre for Cellular and Molecular Biology, Hyderabad, and the Institute for Stem Cell Biology and Regenerative Medicine in Bangalore. Recently, Connect *invited her to IISc to talk about her father, Satish Dhawan, one of India's most well-known scientists and institution builders, particularly about his life away from the public glare. Here is an extract from that interview:*

Your mother Nalini was a cytogeneticist. How did she meet your father? Was it through your grandfather BS Nirody, who was working at IISc as a horticulturist?

No, it was a completely different connection. My mother had finished her PhD in cytogenetics from Washington University in St Louis [United States] and had returned to India. Her sister, Hira, who had also been in the United States for many years had [also] returned, and had been asked by *SPAN* magazine to interview my father – he was at the Aeronautics Department from 1951. After she interviewed him, my mother and her sister were walking in the Institute, perhaps to meet my grandfather. And right outside the Aeronautics Department, they bumped into my father and [my parents] were introduced. Very shortly thereafter, they decided to get married. Who says love can't bloom in the Aeronautics Department! [Laughs]

Satish Dhawan wore many hats: he served as the head of both ISRO and IISc at the same time. He was also associated with NAL, besides serving on multiple committees. And of course, he continued to do his own research. Did he also make time for his family?

Yes, he did. He was a very involved parent actually, especially in the early years. It's true that after 1972 things got very hectic because he had all of these different roles to play, but in the early years, we had many, many occasions together. Sundays were sacred. He made sure that he spent time with us. He was very good at organising activities for us to do. And not in a way that forced us to participate, but in a way that actually made us want to participate. For example, he organised these painting sessions. He was very good at painting and drawing. He would make a great ceremony of setting up paper and places for everybody to sit, including my mother. So there were three kids, and he and my mom. Everybody had their own little papers and pens and paints and water to do watercolours with. And [this continued] even at the busiest times, after he became Director [of IISc] and Chair of ISRO. It's only in retrospect that I realise how crazy it must have been for him – we didn't feel it. We felt he was always there for us. And he was always interested in what we were up to. He was never prescriptive. He never expected specific things from us. It was great.

> Sundays were sacred. He made sure that he spent time with us. He was very good at organising activities for us to do

You mentioned in a talk at IISc that when you were cleaning out his desk after he passed away, you found a hammer and a few nails. He was someone who is remembered for building things from scratch at the Aerospace Department. Was he a handyman at home as well?

Yes, very much so. He very much valued the idea of working with your hands. He felt that working with your hands is not separate from the intellect. It's part and parcel of it. And he had a great deal of respect for people who had the agility and capability to work with their hands. He worked with carpenters and trained people to build specific things for his own research programme. He built lots of our furniture at home. He also loved going to auctions in town to buy second-hand furniture which he would modify.

Photo: Souvik Mandal

Your parents were from different parts of India. You mentioned earlier that your mother's family was from a place near Kundapur, and spoke Konkani. Where did your father come from, and what language did you speak at home?

Yeah, so my father came from the North-West Frontier Province [in British India]. His father came from Dera Ismail Khan, which is near Rawalpindi. And he grew up in Lahore and Kashmir. We heard tales of his growing up in his maternal grandfather's house in Kashmir, where each of the grandchildren was given a fruit tree. And to us living in sleepy south India, the notion of a child being given a pear tree or an apple tree or an apricot tree was just glamorous and distant beyond belief. So when we were growing up, my mother tried to recreate that for us by planting three cherry trees [outside the Director's Bungalow] which I hope are still there.

The conversations were actually in English, even though my mother made heroic attempts to speak in Hindi – her Hindi was passable, not great – till we were three. But the moment we went to school, which was an English medium school, we dropped Hindi and went straight to English. So most conversations were in Indian English, with bits of Kannada, Tamil, Hindi and Konkani thrown in. I miss hearing Konkani, because it's a wonderfully expressive language. But we didn't hear much Punjabi, except for the occasional [laughs] unprintable word which my father would use while he was driving the car!

> We didn't hear much Punjabi, except for the occasional unprintable word which my father would use while he was driving the car!

Roddam Narasimha told us that your father loved to read. What were his favourite books?

Oh, he just read voraciously. He also had a Master's in literature. He read everything – biographies, fiction, history, political theory, literature. He loved poking around in second-hand bookstores and in those days there were several in Bangalore. Although he himself was not a religious man, he had a deep respect for Indian philosophy, and so he read a lot. One of his absolute favourite books was a book of short stories by a now-little-read author called HH Munro, whose pen-name was Saki. I still have my father's copy of Saki's short stories.

What do you think was your father's biggest legacy, and how would you like him to be remembered?

His professional legacy of course is there for anyone to see. At a personal level he had so much charm and grace and a sense of fairness. After my father passed away, my brother told me that some of his colleagues, who had joined ISRO as young engineers, said to him, "We joined when we were just boys. He made us human beings." I think that was his greatest legacy, and that's how I'd like him to be remembered.

Fluid dynamicist Rama Govindarajan, who received a PhD from IISc's Department of Aerospace Engineering in 1994

'THE AEROSPACE DEPARTMENT, LIKE THE WHOLE OF IISc, WAS A QUIETER PLACE THEN'

Deepika S

Rama Govindarajan is a renowned scientist whose work lies in the area of fluid dynamics. The recipient of several awards, in 2007 she received the Shanti Swarup Bhatnagar Prize for her "original contributions to the understanding of instabilities in shear and non-parallel flows, flow entrainment, turbulent transition and small-scale hydraulic jumps." She remains the only woman to have won the prestigious national award for work on fluid dynamics.

Although she originally studied chemical engineering at IIT Delhi and Drexel University in Philadelphia, USA, she made an unusual career choice to begin working in aerospace engineering at NAL, where she continued for a decade while also doing her PhD in aerospace engineering at IISc.

Fifty-four-year-old Govindarajan, who is currently a member of faculty at the International Centre for Theoretical Sciences (ICTS) in Bangalore, has previously worked at the TIFR Centre for Interdisciplinary Sciences in Hyderabad, and the Jawaharlal Nehru Centre for Advanced Scientific Research in Bangalore. Connect *interviewed her ahead of the Aerospace Department's 75th anniversary about her interest in the field, her memories being at IISc, her work, and more. Here are edited excerpts from the conversation:*

How did your interest in aerospace engineering begin, and how did that switch from chemical engineering come about?

I came to Bangalore in 1986 because my husband [Sriram Ramaswamy, Professor at IISc's Department of Physics], got a job here at IISc. At that stage I did not actually want to do a PhD, I wanted to work for industry and make something useful – that had been my dream all along. I looked for jobs and went to 37 interviews of various kinds. This direction [aerospace engineering] was the only one that worked out.

I joined ADA in 1987, but in a few months I decided this was not what I wanted to do, I didn't see my talent being used in a rapid way. That's when I contacted Narasimha [Roddam Narasimha, former Professor of Aerospace Engineering at IISc and former Director of NAL], and I moved from ADA to NAL in 1988. I was particular about doing my PhD while working because then I would not have to look for a job at the end of it. NAL gave me the time and computational resources to do my PhD at IISc, which I did as an external registrant from 1991 to 1994.

But it turned out that I did move completely into academics after that.


Photo courtesy: Rama Govindarajan

Govindarajan as a Master's student in 1985

Was working in aerospace a complete departure from what you'd done previously?

I liked fluid dynamics. That was my connection between chemical engineering and aerospace, although the way fluid dynamics is taught and learned and the areas of emphasis are different. Fluid dynamics is a very interdisciplinary field and it wasn't so difficult for me to make that jump.

You heard us talking earlier in the lab about singularities – those are questions which appear all the time in aerospace. But those are questions that can actually be asked in chemical engineering, as we found. Later when I became a faculty member, I was able to use both my interests to find new ways to look at problems which originate in chemical engineering, in the petroleum industry, for example, or geophysical flows, which I am looking at right now. A lot of my work now consists of looking at oceans, the atmosphere, clouds, and I wouldn't say it was that big a jump from aircraft boundary layers to this either.

Was there an aspect of working on your PhD that thrilled you in particular? Or that defined your time at IISc?

I would say it was the recognition of singularities and seeing how far you can take them.

There is the concept of a boundary layer. If you have an aircraft flowing through wind, you can reverse the problem and say the aircraft is standing still and it's the air that is moving past. The wind some distance away is moving at a constant velocity, which is the negative of the velocity of the airplane. But the wind close to the aircraft is stuck to the aircraft. So it's moving at zero velocity relative to the aircraft. This very thin layer of air – about a centimetre thick – the boundary layer, determines how much drag there is on the aircraft. If you can zoom it down to a point, that's what you would call a singularity. If you understand this mathematics well, as well as the math relevant to far thinner layers within the boundary layer, you can write down very simple equations.

I enjoyed that very much. Instead of solving boundary layer equations for stability (in those days they used to run it on a supercomputer, and it used to take two or three weeks to get one answer), because we understood this structure very well, we could minimise those equations, simplify them and I could get an answer on my little desktop in those days within a second, or five seconds. I could get the same answer, or one very close to, the one it would normally take three weeks to find out. This idea was bought from us by Boeing for a small amount of project money.

> **We could minimise those equations, simplify them and I could get an answer on my little desktop in those days within a second, or five seconds. I could get the same answer, or one very close to, the one it would normally take three weeks to find out**

You come from a prestigious line of scholars in the forefront of boundary layer theory – you had the opportunity to

learn from Roddam Narasimha, who worked with Satish Dhawan, and like him, worked on his PhD at Caltech. Did that influence your decision to do your postdoc at Caltech? Did being at the famed aerospace department at Caltech, which had been home to other renowned scientists like Hans Liepmann and Anatol Roshko, influence you in any way?

All of us knew about the reputation of Hans Liepmann. He had been a towering figure for us, and it did influence my decision to go there. By the time I reached there, Liepmann would still come in to GALCIT to attend seminars and it was awesome to sit in the same room as him. I worked directly with Professor Anthony Leonard, who is also a very old friend of Professor Narasimha. Professor Leonard's group and Anatol Roshko's group would meet every week and we would discuss things, and Roshko has also been a mentor to me. Definitely, being there influenced my work in a very significant way, because for the first time I could spend time in a department where a lot of people were interested in exactly the kind of problems that I was. I learned about vortex dynamics and nonlinear dynamics during my stay there and that expanded my worldview beyond boundary layers. A lot of my future work depended on what I learned there.

One of my biggest interests now is vortex dynamics, and I look at vortices in clouds, how vortices affect mixing, what vortices do to particles – these are all new dimensions, but the fundamentals were inculcated during that period. That and things like chaotic movement of particles in fluid – that was a short project I worked on with Tony Leonard, and that too actually is something I use till this day.

Govindarajan at UN Sinha's lab at NAL, circa 2004

What does your work today involve – is it computational, experimental, or theoretical? What are you working on right now?

My work involves all three. My group does three types of work today – one involves particles in turbulence, or particles in vortical flows. The main thing driving us in this line of work is clouds and how raindrops grow out of them. Clouds are turbulent, they have water vapour, they have aerosol particles, tiny little water droplets suspended in them. Sitting in a super-saturated environment, raindrops could grow due to diffusion. That process should take hours and hours, whereas in a real cloud, big raindrops take between 5 and 15 minutes to form. This is called the 'droplet growth bottleneck' – people don't understand how raindrops can form this fast. There are lots of people who think turbulence is the answer to this, so we didn't come up with it, but we ask specifically how vortex dynamics can influence this process. In particular, we have shown in a simple model flow that caustics, or regions where raindrops can collide against each other rather than merely coming closer to each other, can contribute to the creation of big drops in a very short time. This work we've done analytically. We take a single vortex, write down simple equations for small water droplets in the vicinity of that vortex, see where they go, see how much they collide into each other to make bigger droplets – so those things can be actually written down analytically. In the next step we have done computations in two dimensions where we have a large number of vortices and a large number of raindrops. We're trying to extend this work to three dimensions, to get numerical confirmation of what we're talking about in a situation closer to that in a real cloud.

In a real cloud, big raindrops take between 5 and 15 minutes to form. This is called the 'droplet growth bottleneck' – people don't understand how raindrops can form this fast

We do another class of work on fluid structure interactions, where we ask about flexible solids and how they interact with fluid interfaces. We ask how bending, surface tension and hydrodynamics compete with each other to produce some particular dynamics of flexible solids. That is mainly experimental, with a smaller component of theory. We have a very good experimental collaborator, Professor Narayan Menon at the University of Amherst, and the work is carried out in both Amherst and in the KS Krishnan lab at ICTS.

The third kind of question we ask is on flow instability.

A lot of instabilities result in flow going from laminar [orderly] to turbulent [disorderly], so we ask questions about the laminar-turbulent transition process in situations where fluid properties such as density and viscosity are a function of space and time. This is directly related to my PhD work on boundary layers, but I now look at these transitions in other scenarios like in oceans, or in industrial flows.

In all these projects, I gratefully acknowledge the huge contributions of fantastic students, postdocs and collaborators.

Since you began working on boundary layer theory in the 1980s, have there been exciting new areas into which the field has branched out today?

The concept of a boundary is not even restricted to fluid dynamics. They can happen wherever there are large gradients of something or the other, in a vast variety of systems, so it need not just be flow next to a wall. In that sense, they can be represented as belonging to a class of singular perturbation problems. Many mathematical features of these singularities have been since worked out, and they have been shown to occur in a range of fluid dynamical problems. In our work, we've found such singular behaviour in pipe flow or channel flow, inside some critical layers. These behaviours actually have their origins in the fact that there is a wall nearby and shear flow close to it.

The atmospheric boundary layer is another ballgame. It is studied by a vast number of people now. And for all climate scientists the atmospheric boundary layer is very important.

Even the understanding of the boundary layer over the aircraft wing, which I worked on a long time ago, has undergone a transformation.

What was IISc like when you studied there, and what was the Aerospace department like?

Different! I would say this is not just for the Aerospace Department but for the whole of IISc, it was a quieter place then. Not every lab was ambitious as they all are today, as I gathered from discussions with my fellow students in different groups and departments. In those days we used to have pockets of excellence, with some labs doing really really well. Now it's more like every lab in every department is doing well. There is a sea change in the level of activity and global connectedness, which makes a huge difference. When I started my PhD, I don't think we had email yet, if I remember right. International travel was harder – so was travel within India. So many faculty and students were far less well-known, especially abroad.

Did you ever get to interact with Satish Dhawan during your studies at IISc? Was access to him easy?

He had already retired by then, but he used to come for seminars and such events, and anyone could go up to him and talk. He was a very nice person. In that sense everybody had access.

I never had an elaborate conversation with Satish Dhawan, and that's one of my big regrets. Because I was too shy, basically, to approach him. He'd come for a couple of my talks which I felt very happy about and he would ask questions and we would discuss them. But I wanted to learn a lot more from him which I never did, mainly because I was shy in those days.

I never had an elaborate conversation with Satish Dhawan, and that's one of my big regrets

Were there any other women in the department at the time?

There was one doing her PhD at the same time as me, and one Master's student.

Even today few women take up engineering of this sort. In electrical engineering or computer science there are a lot more of them. But even in those days, I met several young women who were very crazy about anything to do with aircraft, or spacecraft. They were completely enamoured by this area but unfortunately most of them maybe fell by the wayside...

In what way?

They went into other careers or into no career. It's probably a little easier now but it's still not that easy for women, for a range of reasons.

It was only in 2010 that IISc's Aerospace Department hired its first (and so far, only) female member of faculty. Does it feel strange to hear that, even after all these years?

That's probably also been true of Mechanical Engineering until very recently, or, say, Civil Engineering. It's not just Aerospace. We in science have gotten used to it – we shouldn't be used to it, we shouldn't be happy with it. It is true that there is this leaky pipeline effect. Certainly, a fraction of women who are PhD students don't make it to junior faculty and so on. That's changing a little bit, but not fast enough. Not at all fast enough.


Photo: Karthik Ramaswamy

The open-circuit wind tunnel in the old Aerospace Engineering building

THE OPEN-CIRCUIT WIND TUNNEL

Akhila Thomas

V Surendranath on the love of his life – and how it has contributed to nation building

V Surendranath is a Principal Research Scientist at the Department of Aerospace Engineering. Since he joined the Institute 27 years ago, he has been closely associated with the open-circuit wind tunnel housed in the original home of the Department (the Department now also has a high-speed wind tunnel complex in its new home). Construction of this wind tunnel began in the early 1950s when the Department was headed by OG Tietjens. It was completed under the stewardship of Satish Dhawan in 1959 and inaugurated by the Maharaja of Mysore, Jayachamarajendra Wadiyar, the same year.

Surendranath spoke to Connect *about this facility, its contributions to the growth of aviation in the country, and why he thinks that this old warhorse deserves continued attention.*

Could you tell us about your tryst with the Department?

I joined the Department on 4 April 1990. I had taken up two or three jobs before coming here. Once I came to Bangalore, my fascination with the Institute and the renowned Aeronautical Engineering Department [the original name of the Aerospace Engineering Department] only grew because my friend was here at that time and I used to visit him regularly. I have been very fortunate enough to be a part of this Department.

Why do we need wind tunnels?

Wind tunnels help in fine-tuning the design of aircraft, launch vehicles, complex buildings – everything and anything that requires aerodynamic harmony to function perfectly. The designs engineers come up with based on theoretical and empirical equations may not work flawlessly in the real world. Therefore we need these wind tunnels to validate the designs. They are required to show us how efficiently our models work outside the labs, in the real world.

> "They [wind tunnels] are required to show us how efficiently our models work outside the labs, in the real world"

Coming to this particular wind tunnel, could you tell us a little bit about it, including some of the significant objects that have been tested here?

The tunnel has been operational since 1960, working relentlessly for the scientific advancement of the country. This large wind tunnel was conceived by people who I believe were visionaries. The ample size of the tunnel makes the test section large and this helps us to test even big objects.

Here we have tested all sorts of objects: chimneys, cooling towers, factories, launch vehicles, ships, and of course many aircraft. We have also provided our service to the LCA [Light Combat Aircraft], AMCA [Advanced Medium Combat Aircraft], ship development and other flight configurations. This was the country's biggest wind tunnel for many years, and so most of India's requirements were met by this tunnel. Even now, the lion's share of the testing is done here.

Are the objects tested to scale?

Yes, they are tested to scale.

V Surendranath is passionate about the open-circuit wind tunnel at IISc

What are the models typically made of?

Earlier, especially about 50 years ago, all the models were made of wood. But now with the development of materials science, people are also opting to fashion models out of metal and composite materials such as carbon, glass and even paper. But at the end of the day, we are testing external aerodynamics. We are testing shape, not material. Therefore even models made of gold, platinum, wood or charcoal will give us the same result. What matters is the accuracy with which we fabricate the model.

What has been your most satisfying achievement?

One of our landmark achievements was the flight experiments on the LCA, even before the LCA had flown. But I cannot specifically say that these are my achievements because all the tunnel tests have been a group effort. I am happy that I have contributed to the country in some way.

I believe that the fans in the tunnel have a legacy of their own? Could you tell us more about them?

Our fans were originally made of Andaman Padauk [*Pterocarpus dalbergioides*] wood. It is a special kind of high-quality wood. We have still preserved one or two blades of the old fan made out of this wood.

A few of the many objects tested at the open-circuit wind tunnel

Each blade, at top speed, can experience about 30-40 tonnes of load. Surprisingly it has witnessed only two accidents in the 57 years since it started functioning. The first was due to fatigue failure, which happens to all mechanical systems over time. The second accident was due to shear failure. The object went through the mesh and hit the blades of the fan. Since it was rather large, it wrecked the fan blades completely. Due to these structural failures we replaced the wooden blades with composite ones under the guidance of my mentor Prof. SP Govinda Raju [a retired aerospace engineer from IISc], and these fans have been running to this day.

How much does it cost to maintain this facility?

It is difficult to estimate the expenses accurately as this is a government institution. Salaries have to be paid to the staff and the professors. There is a lot of expenditure on maintenance, owing to the large size and the age of the facility. But we also earn money from the projects that we take up here. A large-scale upgrade for this facility which includes replacement of old motors, improvement of the systems and general maintenance would require funding of about Rs 3-5 crore. Due to high maintenance cost and salary outflow, it is difficult to both sustain and upgrade the facility. We are looking for this kind of bulk funding so that this wind tunnel can be raised to the standards of a world-class facility.

"This was the country's biggest wind tunnel for many years, and so most of India's requirements were met by this tunnel. Even now, the lion's share of the testing is done here"

How many people work here?

When I joined the Department, the number of staff working here was 11. Right now the official number of staff stands at three. Next year it will be two.

The importance accorded to this facility seems to be diminishing. Do you see a continued role for this facility to serve IISc?

I believe wind tunnels will have an important role even for the next hundred years to come. It should function and it will function. Of late, a new field called computational fluid dynamics is gaining importance, and therefore actual experiments are being sidetracked. But computation of some things is extremely complex, whereas a wind tunnel can generate data in ten minutes. This is worth its weight in gold. In order to achieve accuracy, both theoretical and experimental work have to be blended in the right proportion. This is why I strongly believe that whatever advancements may take over the field of aerodynamic science and research, wind tunnels are irreplaceable and they will survive long.

One must also remember that this facility is not just about producing publications, but also about contributing to various projects of national importance. This facility belongs to the nation as much as it belongs to IISc. Therefore the number of publications that result from a wind tunnel must not be the yardstick to measure its importance. My only wish is that with my retirement, the doors of this facility are not locked. It takes just seconds to put a lock on something, but it takes years to open it back again.

"One must also remember that this facility is not just about producing publications, but also about contributing to various projects of national importance. This facility belongs to the nation as much as it belongs to IISc"

What fascinates you about this wind tunnel?

This facility has earned its place in history, and its legacy will live forever. When I have a small cold, I run to the Health Centre and get the necessary medication. That is for our maintenance. But for the last 50 years, these fans have been working continuously. All we do is apply grease once in a year. We don't even clean the dust on it. This is what fascinates me. When a system runs with this kind of zealous dedication, it is hard not to return the same feeling towards the facility. These fans, they are my babies and I have given them my all. That is the kind of commitment I have towards this facility and it is the kind of commitment that this facility deserves.

Photo courtesy:APC, IISc

The tail of the building is the open circuit wind tunnel

This building also has a closed-circuit wind tunnel that has been shut down for several years. Could you shed some light on it?

The closed-circuit wind tunnel was built during the time of World War II by a renowned German architect named Otto Koenigsberger. It was an elliptical section, a standard tunnel – the kind often seen in [scientific] literature. It used to work on a single fan and was an efficient tunnel. However, due to shortage of staff and insufficient funds, it gradually got phased out. But this structure which is of great historical importance now houses the estate office.

**Akhila Thomas is a first-year undergraduate student at Christ University where she is studying English (Honours)*

The High-Speed Wind Tunnel Complex

TESTING FACILITY FOR THE FAST AND FURIOUS

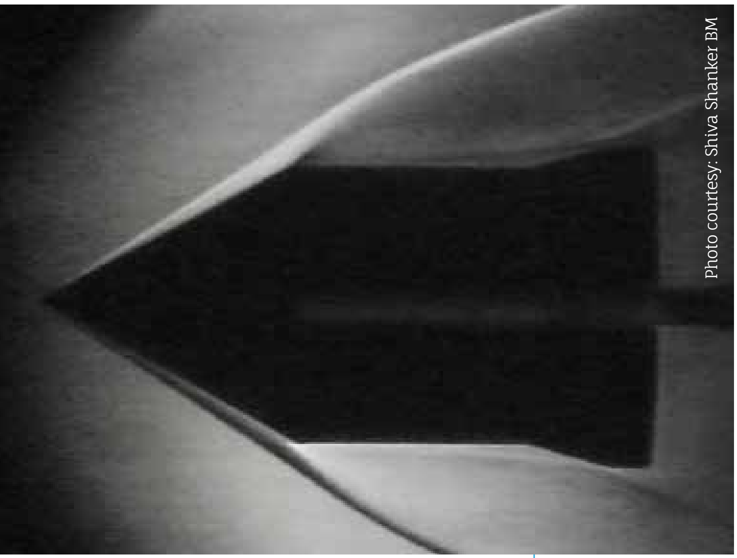
Rohini Krishnamurthy

What goes on at the high speed wind tunnel complex?

In 2015, an Italian tiltrotor military aircraft AW609 was on a test flight at high speeds and it crashed a few minutes after taking off, claiming the lives of both its pilots. Investigating the crash, the air-accident investigation agency ANSV pointed out that insufficient wind tunnel testing of the aircraft's new tail configuration caused the accident. But what are wind tunnels and how do they ensure flight safety?

Wind tunnels are passages where the effects of high-speed air flowing past a scaled-down model of an object are studied. The object – be it a race car or bike, an aircraft, a missile, or even a flying dinosaur – experiences aerodynamic forces inside the wind tunnel, mimicking real world conditions. The data obtained from these tests help engineers improve designs, ensuring flight safety while also saving a great deal of money.

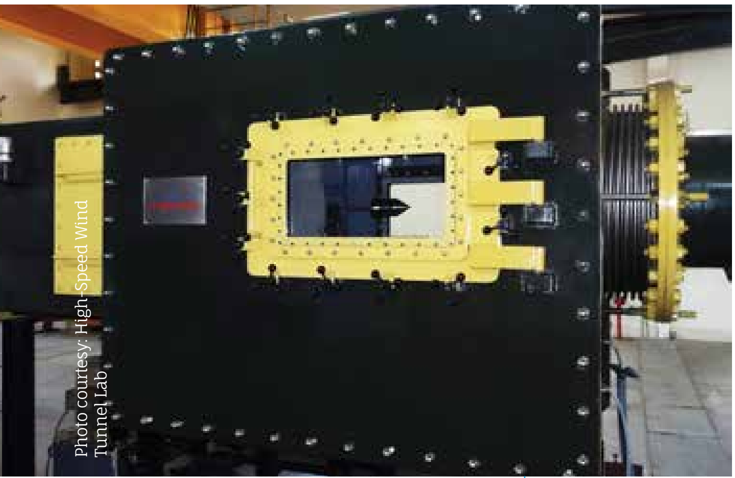
"We have to simulate conditions in a wind tunnel which must be geometrically similar to external conditions like total pressure, temperature, velocity, Reynolds number (ratio of inertial forces to viscous forces), Mach number (ratio of velocity of object to velocity of sound) and so on," says B Vasudevan, Principal Research Scientist, Department of Aerospace Engineering, IISc. "Once these conditions are simulated, we perform tests to find out exactly what happens, for example, to a missile moving at high altitudes."



Shockwaves formed in front of a model at high speeds

Many missiles travel at supersonic speeds – that is, they travel at speeds ranging from one to five times the speed of sound, which is 344 metres per second at sea level. Hypersonic objects are those that travel even faster, at speeds as high as five to 10 times the speed of sound.

To test objects moving at such high speeds, researchers use wind tunnels that can propel air to supersonic or hypersonic speeds. The first such facility in India was established at IISc in the 1950s in the form of the high-speed aerodynamics lab. "We [now] have three supersonic wind tunnels and two hypersonic wind tunnels," says Vasudevan.



The hypersonic wind tunnel built in 1984 (left) and 2012 (right)

The work for India's first hypersonic wind tunnel was begun in the early 1970s by Roddam Narasimha who was then a Professor at IISc, after obtaining a grant from the Government of India. Owing to a dearth of information on construction of hypersonic wind tunnels, as other countries with such facilities were hesitant to share details, the project faced hiccups. Nevertheless, Narasimha and team continued building the wind tunnel. "We were almost close to finishing it when Narasimha left IISc to become director of NAL. Before leaving he handed this part of the work to me," Vasudevan recalls. After more than a year of relentless efforts, they installed a hypersonic wind tunnel with a diameter of 0.3 m in 1984 and in no time they bagged multiple projects. In 2012, Vasudevan and his group constructed another 0.5 m hypersonic wind tunnel.

Wind tunnels are passages where the effects of high-speed air flowing past a scaled-down model of an object are studied

How wind tunnels help

Wind tunnel testing at hypersonic speeds is important because aerodynamic forces behave differently at such speeds and understanding them can prevent mishaps. Apart from the aerodynamic forces, motion at supersonic and hypersonic speeds cause shockwaves that lead to a change in temperature, pressure, and density of air. As an example of an explosion caused due to shockwaves, Vasudevan says that "a supersonic plane called SR71 that took off in 1966, exploded mid-air. They didn't know shockwaves can kill a vehicle." This happens because shockwaves can heat up structures, making them vulnerable to explosions. This can be avoided by using materials that can withstand high temperatures.

Travelling at speeds faster than sound poses another challenge – it can cause disruption in radio communication. Shockwaves can dramatically increase temperatures in front of the plane, blocking radio transmission due to the formation of charged gas, also called plasma. Studying shockwaves and its effects on models of an aircraft or a missile in a wind tunnel, therefore, is essential.

To evaluate the performance of a model, researchers use sophisticated instruments to obtain data, many of which have been developed indigenously at the lab. A strain gauge balance is one such instrument. "A strain gauge balance is a structural element which is fixed to the model being tested. Based on the proportion of the load [aerodynamic forces], it gives us an electrical output," says Vasudevan. "There are only a few agencies in the world which have the capability to design and build such instruments. We design instruments for NAL and other defence centres. We have built instruments for Europeans and Canadians as well."

IISc has taken the road less travelled by constructing instruments and wind tunnels from scratch. "We learned it the hard way," says Vasudevan. "In this process, we have built over 100-150 instruments." The instruments are constructed in-house and can cost more than Rs 1 crore, if imported. Currently, the facility boasts of having about 30 strain gauge balances. In addition to the strain gauge balances, the lab developed the first fibre optic wind tunnel balance to measure load, twenty years ago. "We were perhaps the first in the world to do that," he says.

Although bigger wind tunnels give better results, lack of space on campus prevents the facility from expanding. The Chairperson of the Department of Aerospace Engineering, S Gopalakrishnan, says that the Government of India had expressed interest in setting up a hypersonic wind tunnel at IISc's second campus in Challakere. "The wind tunnel, if approved, could have accommodated a model half the size of the Light Combat Aircraft," he says. But this proposal didn't materialise for various reasons. The government is on the lookout for other locations to set up a large hypersonic wind tunnel.

The lion's share of investment in hypersonic flight research goes into the military sector

Collaborations

IISc has collaborated with both DRDO and ISRO. Vasudevan recalls that IISc set up its first hypersonic wind tunnel at roughly the same time that DRDO was developing its Agimissile. "Agni was in its early stages of development, and they [DRDO] wanted to get a lot of experimental design information and performance evaluation," he says. The team has run perhaps 12,000-13,000 experiments for DRDO since then and the association with them stands strong even today.

Through contractors, the high-speed wind tunnel complex team has worked with leading industry players too, like Honeywell, United Technology Corp, Airbus, and Boeing. The most recent project completed was for HCL Technologies. "They approached us as contractors for Airbus. We had to simulate rainstorm and sandstorm in our tunnel testing. This is important in places like Dubai," Vasudevan says. He adds that they have completed over 100 scientific projects for industries and defence labs so far. The high-speed wind tunnel complex at IISc also provides services to other defence and industrial labs that do not have the facility.

What does the future hold?

The lion's share of investment in hypersonic flight research goes into the military sector. India, too, is investing in the development of hypersonic missiles. Hypersonic passenger aircraft, meanwhile, may be possible one day, but given the fate of a supersonic passenger jet airliner, Concorde, which first flew in 1969 but stopped operations in 2003 due to difficulties recovering money and environmental issues, there are many hurdles to overcome.

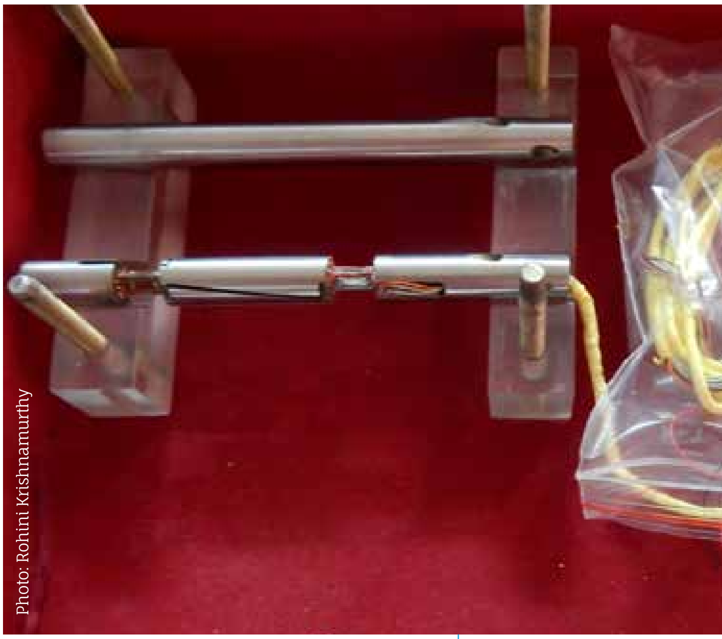


Photo: Rohini Krishnamurthy

A strain gauge balance

In the recent past, the private sector has begun investing in hypersonic travel. For instance, in 2015, Airbus patented an idea for a hypersonic plane that could travel from Paris to Tokyo in three hours, a journey that today takes 12 hours. They are trying to develop, in collaboration with other countries, two other hypersonic vehicles that aim to travel at six times the speed of sound. Hypersonic wind tunnels will play a crucial role in developing such aircraft and ensuring their safety. Development of spacecraft, too, will rely on wind tunnels to obtain data to model the launch, re-entry, and landing phases.

In recent years, computer simulations using computational fluid dynamics (CFD) has become a widely used tool for performance evaluation. However, says Gopalakrishnan, "for missiles and aircrafts, certification agencies need CFD and wind tunnel data to check for aerodynamic performance. CFD and wind tunnels cannot replace each other." Wind tunnel testing, therefore, will continue to play an indispensable role in aerospace engineering.

Photo courtesy: Shiva Shanker BM

A scaled-down model at the facility

Photo: SK Karthick/LHSR

The Free-Piston Driven Hypersonic Shock Tunnel 3

SHOCK TUNNELS TEST MORE THAN JUST SPACECRAFT MODELS

Megha Prakash

One of the largest shock tunnels in a university setup, India's first hypersonic shock tunnel (HST) was built in 1973 at IISc by NM Reddy, who had studied under Irvine Israel Glass and Satish Dhawan. After holding several positions abroad, Reddy returned to India in 1970 and introduced shock tubes and shock tunnels in India for the first time, a facility which was extensively used for development or testing of ISRO launch vehicles, such as India's first Satellite Launch Vehicle (SLV-3) and Polar Satellite Launch Vehicle (PSLV).

Until recently, shock tunnels were predominantly used by space scientists and aeronautical engineers to study heat transfer rates over space vehicles, such as re-entry vehicles, or components such as launch vehicle nose cones and bulbous heat shields. But today, the shock tunnel facility housed in the new Laboratory for Hypersonic and Shock Wave Research (LHSR) has five hypersonic shock tunnels, which are used for different purposes.

To learn more about the shock tunnels and how this facility has grown over the years, Connect *spoke to Jagadeesh Gopalan (Professor, Department of Aerospace Engineering and Chairperson, Centre for Excellence in Hypersonics at IISc). Here are edited excerpts from the conversation:*

Photo: SK Karthick/LHSR

Jagadeesh Gopalan

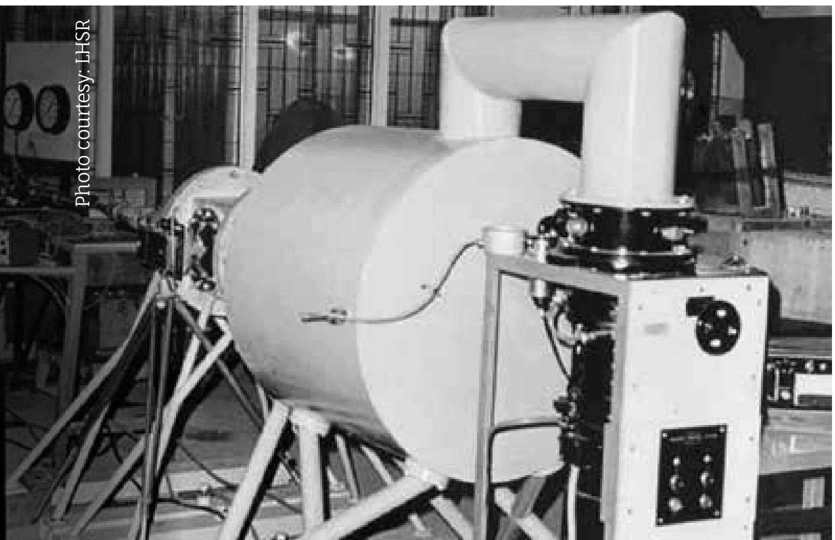
IISc got its first hypersonic shock tunnel in the early 1970s. Could you trace its history and growth?

Professor NM Reddy had just returned to India, and started the High Enthalpy Aerodynamics Laboratory (HEAL) at IISc, which is now known as the Laboratory for Hypersonic and Shock Wave Research. In 1972, he built the first working shock tube. Subsequently, the country's first hypersonic shock tunnel (HST1) was built in 1973, using an aluminium shock tube of 50 mm diameter with a conical nozzle and variable throats capable of producing Mach numbers in the range of 4 to 13.

To give a fair idea, during the 1960s and 70s, a shock tube was the only way by which high temperature, of the order of 4000 degree Kelvin, could be generated. It was around this time that India began its programme on Satellite Launch Vehicles (SLV) and Agni missiles. So a programme on shock tubes was started at IISc, as a requirement from the space community to measure the surface heat transfer rates in a typical launch vehicle nose cone and SLV model. But it was not enough to just look at heat transfer, and the space scientists wanted to see it in a real vehicle. Gradually, a nozzle was added at the end of the shock tube to create a Mach 6 flow, and that is how it became a shock tunnel.

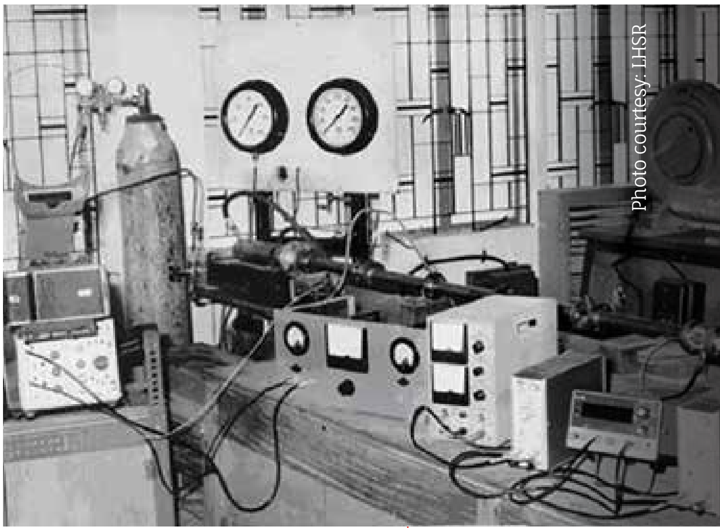
How has the shock tunnel facility expanded since then?

At present, LHSR houses five hypersonic shock tunnels – Hypersonic Shock Tunnel (HST1), Hypersonic Shock Tunnel 2 (HST2), Free-Piston Driven Hypersonic Shock Tunnel 3 (HST3), Hypersonic Shock Tunnel 4 (HST4) and Combustion Driven Hypersonic Shock Tunnel (HST5) – all built for different purposes. HST2, made of stainless steel, was built to overcome the limitations on performance capabilities of HST1.



India's first Hypersonic Shock Tunnel (HST1)

Subsequently, in the early 1990s, KPJ Reddy [Professor, Department of Aerospace Engineering] built India's first free-piston driven hypersonic shock tunnel which can operate at very high enthalpy.



HEAL's first Hypersonic Shock Tube

IISc is home to India's first wind tunnel, an open-circuit wind tunnel, and also the hypersonic shock tunnel. How is a shock tunnel different from a wind tunnel?

A shock tunnel is an impulse facility which has the ability to produce high stagnation pressures and temperatures, with minimum power requirements and with reduced contaminant of test gas. Essentially, a shock tunnel is a short duration wind tunnel or an extension of a shock tube into a wind tunnel used in the experimental testing of aircraft, wing structures etc., and it is used to generate flows of hypersonic Mach numbers.

In a wind tunnel, the bodies of interest (test vehicles) are kept stationary; an air flow is created which has the same velocity with which the test vehicle is supposed to fly.

The major advantage of using a shock tunnel is that highly energetic flows of high stagnation enthalpy can be generated, which is required to study the features regarding flow around atmospheric re-entry vehicles, ballistic missiles etc. However, the most glaring disadvantage is that all tests have to be performed within milliseconds.

How are shockwaves formed?

Shockwaves are found not only around vehicles which travel at a speed faster than the speed of sound. When there is a massive energy dissipation which takes place in the shortest possible time, shockwaves can be formed naturally. It could be a nuclear explosion, an earthquake, a volcanic eruption, or a massive explosion in the outer galaxy when a new star is born. In fact, when the first nuclear explosion took place, they only saw the radius of the shockwave, which was hundreds of kilometres away. With the radius of the shockwave, we can actually work back and say what the energy [of the explosion] is.

Apart from shock tunnels, there has also been work at IISc on shock tubes – Prof Satish Dhawan had been working on one. Could you talk about his research and how work on shock tubes progressed from there?

Dhawan was of course a visionary. Along with his former student NM Reddy [who was then working with CG Miller at NASA, and joined the Institute on Dhawan's invitation], he built a small table-top shock tube. But it was not translated into a big shock tube where we can do meaningful measurements for industrial use, and it was not used to measure heat transfer. It was much later that NM Reddy happened to build the first shock tube, in which he was able to test the heat transfer rate on SLV.

Photo courtesy: SK Karthick/LHSR

Top row: Satellite launch vehicle (SLV) models tested in shock tunnels; Bottom row: Hypersonic vehicle models with different forebody shapes tested in shock tunnels

Today, we have a hand-held shock tube called the Reddy Tube, named after its inventor Prof KPJ Reddy, which has applications in diverse areas like artificial insemination of cattle, investigating brain injuries due to accidents, removal of brain tumours, water purification, and oil extraction, among many others.

Considering that the facility started as a requirement for the space programme in India, what kind of research happens now?

What started out in this department 25 years ago was just for the space application. It was in 2001 that the shockwaves laboratory was established to understand what really happens when shockwaves travel through multiple media. Though numerous applications have sprung up using shockwaves, LHSR predominantly continues to work on aerospace-centric problems because such facilities are invariably required for very high military as well as space applications. But it would not be wrong to say that over the years, LHSR has also transformed into a hub of interdisciplinary research by bringing together materials scientists, chemists, biologists and industry people to solve many challenging problems in science.

For example, E Arunan [Professor, Inorganic and Physical Chemistry] uses shockwaves as a fundamental tool to understand high-temperature chemical kinetics, and has found out the minimum delay time for burning of jet fuel like JP-10 aviation fuel. This understanding is important because India is building what is called the scramjet engine, a supersonic jet engine.

Over the years, LHSR has transformed into a hub of interdisciplinary research by bringing together materials scientists, chemists, biologists and industry people to solve many challenging problems in science

Similarly, in collaboration with biologists, a first-of-its-kind experiment was conducted in which a micro-shockwave was used to put DNA inside a cell. This device has been patented. It has a few other applications, like putting preservatives in bamboo or removing bio-burden from a natural extract by killing bacteria.

Shockwaves are also finding application in managing chronic diseases. In diabetics, wounds take a long time to heal. A small hand-held device has been developed to reduce this healing time, which has been tested and is undergoing human trials.

In another collaboration with Dipshikha Chakravortty [Professor, Department of Microbiology and Cell Biology], India's first, in fact the world's first, needle-less drug delivery system has been developed.

What lies in the future?

India has not flown any air-breathing engine till now. Though ISRO did some experiments with hydrogen fuel a year back, there is no working system. So the next step is to build a hypersonic flight experiment where the engine development will be done by IISc.

One of our future goals is to build our own scramjet engine and do flight experiments so that India will join the bandwagon of select countries. The BRAHMOS-IISc Centre of Excellence in Hypersonics, to a large extent, will look at the fundamental technology and scientific issues associated with hypersonic flight.

Another jump for us would be the Centre's new building which is expected to be ready before the Department's 75th anniversary celebrations this year.

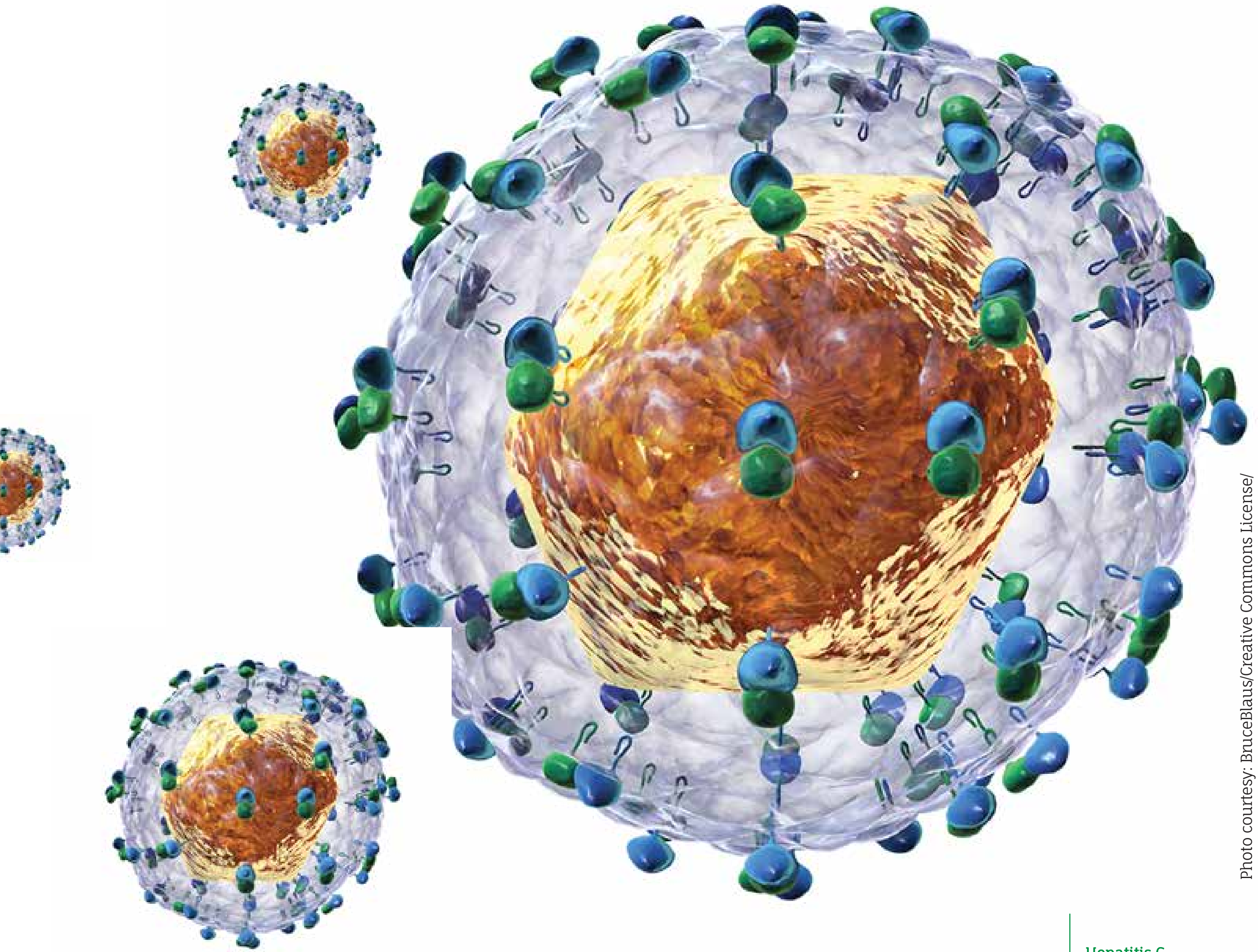


Photo courtesy: BruceBlaus/Creative Commons License/ Wikimedia Commons

Hepatitis C Virus

OUTSMARTING THE HEPATITIS C VIRUS

Nithyanand Rao

How researchers at IISc are working on turning research on translation to translational research

When Saumitra Das was a postdoc at the University of California, Los Angeles, he discovered how to inhibit polio virus translation. That is, how to stop the virus from hijacking its host cell's machinery to manufacture its own proteins. Das had used a small RNA derived from yeast to stop the polio virus. Soon, he discovered why he was successful. "Another paper at the time showed that polio virus translation is quite different from cellular protein synthesis," says Das. The polio virus, he learned, shuts off its host cell's protein synthesis but uses a different mechanism, called internal initiation of translation, to make its own proteins. The small RNA from yeast in his experiment was, he realised, somehow preventing the polio virus from using this mechanism.

Some years later, in 1998, Das joined IISc's Department of Microbiology and Cell Biology. When he started his own lab, Das zeroed in on another virus, the one that causes hepatitis C, which he felt might be vulnerable to a similar approach. Since then, Das and collaborators have developed antivirals that attack various stages of the hepatitis C virus (HCV) lifecycle, along with mechanisms for their targeted delivery to the liver. Much of this work has been done as part of a multidisciplinary Centre of Excellence for Hepatitis C Virus Research, a collaborative effort involving nine labs across India, that he heads.

Das and collaborators have developed antivirals that attack various stages of the hepatitis C virus lifecycle, along with mechanisms for their targeted delivery to the liver

Hepatitis, a disease of the liver, can be due to many causes, including viruses. There are five hepatitis-causing viruses. One of these, the hepatitis C, discovered in 1989, infects an estimated 175 million people worldwide, with 3-4 million persons infected each year through contact with infected blood, via infected needles or blood transfusions. The immune response to HCV infection results in inflammation of liver tissue, which could lead to liver cell damage and hepatocellular carcinoma (liver cancer). In 80% of the patients, HCV causes chronic infection. In India, approximately 15-20% of cases of chronic liver diseases are caused by HCV infection.

There is no vaccine available yet for HCV. Developing antiviral therapies, meanwhile, is a challenge because the RNA virus mutates quickly, leading to variants that may be immune to the antiviral.

An important attribute of an antiviral agent is that it must be specific – it should inhibit only the virus and should leave the host cells unaffected so as to avoid side effects. Das found that for HCV, a key to developing an antiviral agent lies in the way the virus translates its genetic information to make proteins. HCV, like other viruses, hijacks the host cell's machinery for this. In any cell, the ribosome is the organelle that translates genetic information to synthesise proteins. Once HCV has entered a cell, it tries to use the ribosome to synthesise its proteins. However, as with the polio virus, the way HCV translates its RNA is different from how its host cell does it – the ribosome binds not to the end of the viral RNA, but to an internal sequence. The virus has evolved in such a way that it has less competition with cellular RNA to bind to the ribosome. "It's as if somebody is entering through the back gate," says Das. Antiviral agents inhibiting this translation – specifically, the ribosome-HCV RNA interaction – offered a way of stopping the viral RNA replication. What's more, this mechanism is common to all strains of HCV.

Over the years, Das has successfully demonstrated various approaches to inhibiting translation of HCV. One method is to use a small RNA derived from the HCV RNA.

The way HCV translates its RNA is different from how its host cell does it – the ribosome binds not to the end of the viral RNA, but to an internal sequence

"If we use this small RNA as a competitor, it will sequester the host factor and the virus cannot exploit that for protein synthesis," says Das. With collaborators, he also found success with another approach, one that used one of the virus' own proteins against it. The virus, once it enters the cell, cannot keep making proteins lest it be caught by the host's immune system. "They [the virus] have to have a regulation. After they have a little bit of synthesis, they try to stop," says Das. "One of the viral proteins does this job. It's like a feedback mechanism." This particular protein of the virus was identified, a peptide was derived from the RNA-binding region of this protein, and this was found to prevent the viral RNA translation. This is because the peptide locks the binding site on the ribosome, preventing the viral RNA from binding. This interaction was studied by N Srinivasan (Molecular Biophysics Unit) using computational modelling of the structures involved.


Photo: Nithyanand Rao

Saumitra Das

HCV infects only humans and chimpanzees; it does not infect mice, meaning that studying HCV infection in animals to understand the host-virus interactions and to develop drugs has been difficult. Now, however, there are "chimeric" mice available which carry a transplanted human liver (their own liver being compromised), which can be infected to study HCV and to test treatments. In such chimeric mice, the above treatments have proved effective.

"So on one hand, even if the virus has entered the cell, you try to prevent their protein synthesis. The other strategy is to block their entry into the cell, using monoclonal antibodies," says Das. Of the people infected with HCV, about 15% clear the infection on their own. Das' colleague in the Department, MS Shaila (now retired) and Anjali

Karande (Department of Biochemistry), isolated the antibodies that such people develop and made similar antibodies in the lab, called monoclonal antibodies. This was found to be effective in preventing HCV from entering the cells in the first place.

Das has also been working with collaborators in other departments at IISc to develop methods that can deliver these drugs selectively to the liver, to minimise the potential side effects from toxicity. The idea is to use a carrier that can bind to the drug molecules, carry it to the liver, and bind to the appropriate receptor on the target cells. The carrier is sensitive to the pH (a measure of acidicity) of the environment it finds itself in, and can be designed such that the drug molecule that it captured at a certain pH gets released at a different pH. One approach for liver-targeted drug delivery, which N Jayaraman (Department of Organic Chemistry) and Ajay Sood (Department of Physics) have developed, is to use dendrimers. (Dendrimers are polymers that have a branching, tree-like structure.) They have used a class of dendrimers known as PETIM dendrimers, which is able to form a complex with drug molecules via electrostatic interactions. The dendrimers were functionalized to specifically target liver cells.

This has also been studied using simulations by Prabal Maiti (Department of Physics). Another approach is to carry the drug molecule in a "cage" made of polyelectrolyte nanocapsules, which Ashok Raichur (Department of Materials Engineering) is working on.

All this work was on antivirals that can either stop HCV from entering cells or stop its translation if it has already entered. But Das and collaborators have also worked on stopping the virus in the next step in its lifecycle inside a cell – its replication. Following a government initiative to search through herbal compounds for potential treatments for various diseases, Das' lab began screening natural products for their antiviral action against HCV. They found that the peel of pomegranate (*Punica granatum*), a fruit long known for its health benefits, especially for the liver, had compounds known as the ellagitannins, which inhibit virus replication. Existing antiviral treatments, even if they treat the hepatitis, can leave behind a damaged liver. "Even after six months of treatment, and even if the patient has completely cleared the virus and recovered, they may still have liver damage which can lead to hepatocellular carcinoma," says Das. The compound identified in pomegranate, however, was found to protect and heal the liver. Das' lab had earlier identified a similar compound in extracts from the root and leaf of *Phyllanthus amarus*, a type of amla (gooseberry), which was also found to inhibit HCV viral enzymes and replication. "This bhui amla is traditional folk medicine that people have used for jaundice and hepatitis," he says.

They found that the peel of pomegranate (*Punica granatum*), a fruit long known for its health benefits, especially for the liver, had compounds known as the ellagitannins, which inhibit virus replication

Pomegranate and Phyllanthus amarus

"Anything of this sort has to go through clinical trials," says Das, "to ensure there are no long-term side effects." After the paper on the HCV-fighting abilities of pomegranate was published, Das received phone calls from people with hepatitis asking if they should drink pomegranate juice, and how much. "I told them this is an observation. All I can say is that drinking one glass of pomegranate juice is not going to hurt you. But don't drink ten glasses a day," he says. "Also have consultations with your clinician, who will know what else you are taking."

This roadmap – finding a unique mechanism in the virus translation which can be targeted – could be used for developing treatments for other virus infections too. "Research on translation to translational research – that is my research theme," says Das. "All this was possible because of the untiring efforts and the wonderful teamwork of my students and postdocs over the years, and also at other labs in the HCV-Centre of Excellence," he adds. "We started with protein synthesis, which is called translation, and ended up with translational research." He is now looking to team up with partners in industry to further this research and commercialise it.

Illustration: Bhama Sridharan

DEALING WITH DEMENTIA

Doctors and scientists are on a mission to understand this complex neurodegenerative disorder

Rohini Krishnamurthy

One morning, Ragini, a resident of Chennai, caught a glimpse of her 67-year-old mother, Lakshmi, using a toothbrush on her own reflection in the mirror. Ragini was taken aback by what she saw – her mother was in good mental health and sprightly for her age. "From then on, things rapidly took a turn for the worse," says Ragini. Lakshmi was seen defecating in the open several times after that. Now diagnosed with dementia, she is supported round-the-clock by her two caretakers.

Lakshmi is among 47 million people in the world grappling with dementia, a term that is often used interchangeably with Alzheimer's disease (AD) which is, in fact, one of the many types of dementia. "Dementia is like an umbrella term for diseases which cause a decline in cognitive ability. There are many causes. For example, consider jaundice. This could be due to the presence of a stone or hepatitis. The same applies to dementia," clarifies Ratnavalli Ellajosyla, a neurologist at Manipal Hospital in Bangalore, who recently gave a talk on this neurodegenerative disorder at IISc.

"Dementia is like an umbrella term for diseases which cause a decline in cognitive ability. There are many causes"

Dementia manifests itself as a deterioration in one's cognitive skills, affecting mental faculties like the ability to recall, comprehend, calculate, learn, evaluate and so on. These symptoms result from a progressive and irreversible loss of neurons and shrinking of the brain. The most common type of dementia is AD, first reported in the early 1900s, when a woman in her fifties approached a clinical psychiatrist and neuroanatomist named Alois Alzheimer, complaining of memory loss, paranoia and sleep deprivation. He kept close tabs on her declining mental health until she died. After her death, he examined her brain and something odd caught his attention – he found abnormal depositions of protein clumps or plaques. In 1910, following the chronicling of this condition in more patients, fellow psychiatrist Emil Kraepelin named this disorder after Alzheimer in recognition of his colleague's discovery.

Other common types of dementia include vascular dementia, characterised by reduced blood supply to the brain; frontotemporal disorders (FTD), which affect the front and sides of the brain; and Dementia with Lewy Bodies (DLB), commonly known as AD's cousin, also involving abnormal protein deposition in the brain.

Diagnosis and recent advances

Ellajosyla says that while an occasional lapse in memory may not be significant, recurring episodes of forgetfulness, or bouts of disorientation – in space or time – may indicate the onset of dementia. "Any change in mood, personality also may [also] be an early sign of dementia," she adds.

To diagnose the condition, doctors do a complete evaluation of their patients by taking into account their medical history, performance in neuropsychological tests, and brain imaging to identify any abnormalities associated with the condition. Apart from a battery of neurophysiological investigations, they also perform tests to rule out other possible causes of cognitive decline like vitamin D deficiency, diabetes, hypertension, thyroid, tumours, and stroke.

If dementia is diagnosed, doctors then attempt to determine its specific type based on the clinical evaluation and investigations. But the diagnosis of specific subtype of dementia is challenging particularly in the early stage due to the complexity of clinical presentation, says Sivakumar PT, Professor of Psychiatry at National Institute of Mental Health and Neurosciences (NIMHANS) in Bangalore. "For someone with diabetes, you do a blood test and can make diagnosis reliably. Diagnosis of dementia hasn't reached that stage."

> **"For someone with diabetes, you do a blood test and you know the result. Diagnosis of dementia hasn't reached that stage"**

"Research studies have shown that there is a significant proportion of individuals with dementia having discordance in the clinical and pathological diagnosis," Sivakumar reveals while emphasising the need for more reliable tests and biomarkers to diagnose dementia and its specific type. He says that a definitive diagnosis of the specific type of dementia is often possible only after the pathological evaluation of the brain post-mortem.

However, tests to diagnose dementia are getting better. One set of tests that has been gaining ground in recent times detects biomarkers indicative of the condition. When measured from blood or cerebrospinal fluid (CSF), these biomarkers reveal their relationship between clinical symptoms and rate of disease progression. Considerable progress has been made in identifying biomarkers for AD in CSF and molecular imaging, a relatively new innovation that helps doctors visualise cell functioning and molecular processes in the body.

Currently, CSF is widely used to measure the levels of biomarkers like β amyloid peptide and another protein called tau to diagnose AD. The search for other such protein markers is being actively pursued. On the other hand, the use of blood-based biomarkers, which can be less expensive and invasive, is still work in progress. The biggest challenge holding it back lies in detecting biomarkers from a fluid as complex as blood. Researchers, however, predict that blood-based biomarkers could be put into clinical practice in a few years from now.

Another tool commonly used is neuroimaging, which not only helps in the diagnosis of dementia, but also eliminates other causes of cognitive decline like tumour or haemorrhages. Additionally, it can provide clues about the type of dementia. Recently, amyloid-labelled PET scans have been used to indicate the levels of amyloid plaque deposition in patients with suspected AD. In the near future, given the progress in medical diagnostics, these and other tests could aid in the diagnosis of dementia in its early stages itself.

For now, though, Ellajosyla espouses the use of neuropsychological tests that assess cognitive attributes of an individual, also called culture-free tests, over biomarkers. Biomarkers which are not widely available in India are expensive and require more technical expertise while culture-free tests are relatively cheaper and can be tested on people without formal education, though a certain amount of knowledge is necessary. "All they [subjects] have to do is name things," she says. Her findings suggest that culture-free tests may help predict the likelihood of Mild Cognitive Impairment (MCI) progressing to AD. "Not many have looked at visual association tests which are very easy. We will explore these tests more in the future."

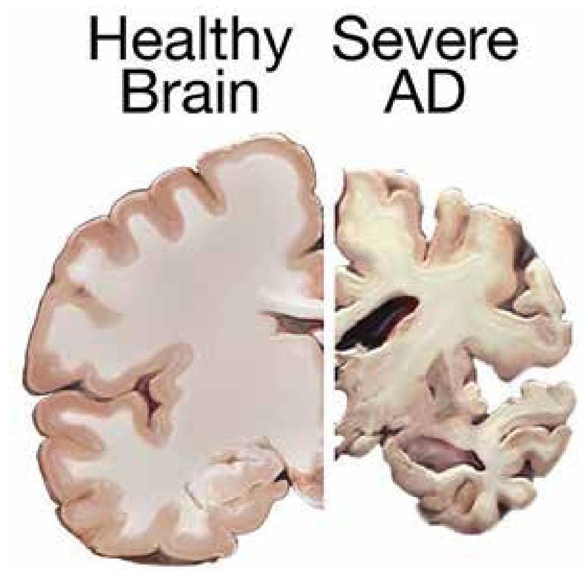


Photo courtesy: National Institutes of Health [Public domain], via Wikimedia Commons

AD brain appears smaller in comparison to healthy brain

Genes, environment and their complex interaction

The likelihood of developing dementia increases with age. However, understanding the root causes of this disorder is not easy, mainly because dementia, like cancer, has several types and each of them can be caused either due to genetic or environmental factors, or often, due to a complex interaction between the genotype of an individual and the environment.

But progress has been made. Researchers have identified mutations in genes whose presence can increase the probability of developing dementia. Some of the well-known genes associated with dementia are *Apolipoprotein E* (*ApoE*), *amyloid precursor protein* (*APP*), *presenilin 1* (*PSEN1*), and *presenilin 2* (*PSEN2*). Researchers have also found that a genetic predisposition to dementia is more likely to trigger early-onset dementia. Because it is rare, dementia in young people can often be misdiagnosed. The three most common types of early-onset dementia are AD, vascular dementia and FTD.

In India, while the prevalence of AD is less than that in Western Europe and North America, the number of people with the disease is increasing as people live longer. However, the quality of data available on the incidence of AD and other related diseases in India is poor.

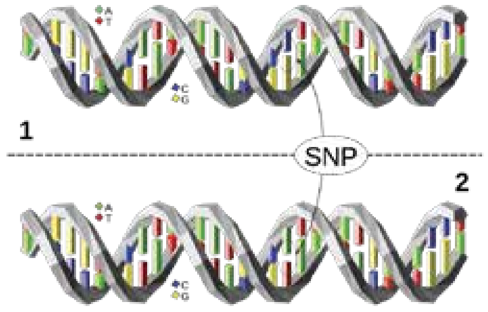
India also lags behind in research on the genetic susceptibility to dementia in its population. Recently, however, studies probing the role of genetic risk factors in Indians have been initiated by the Centre for Brain Research (CBR), which was set up in 2015 at IISc by a generous grant from the Pratiksha Trust run by Kris Goplakrishnan, co-founder of Infosys, and Sudha Gopalakrishnan. CBR is an autonomous centre of IISc focussing on clinical aspects of neurodegenerative disorders.

Ganesh Chauhan, a statistical geneticist who recently joined CBR as a scientist, scours through genes looking for genetic variations for disorders like AD and stroke. In a collaborative long-term study that is being initiated with NIMHANS in Bangalore, Chauhan and his colleagues will try to identify genes associated with dementia by comparing results between normal and affected individuals, and also hope these results might aid in designing appropriate medications.

"People usually develop [AD] at 65. But we will be studying people aged 45 years and above in a community, and monitor them for their whole life," explains Chauhan. He believes that this will help not only understand the genetic risk factors associated with AD, but also how the disease progresses with age.

A study that CBR undertook, in collaboration with Centre for Neuroscience (CNS), IISc, investigated the frequency of *ApoE* polymorphisms (variations) among Indians. Previous studies which have addressed this problem showed low levels of variation in this gene. But Chauhan and his colleagues were not entirely convinced of these results. "Our results show that *ApoE* polymorphisms are not that low in the Indian population. Those studies might have been misreported either due to the poor sample size or use of inefficient technology," he says.

But pinning down genes associated with a disease is a huge challenge. How does one read the entire genome of an individual which is 3 m in length and contains thousands of genes?



Courtesy: David Eccles (gringer) / Creative Commons License/ Wikimedia Commons

Scientists study variations in nucleotides occurring at specific positions in the genome between individuals. They do this with the help of a common DNA marker – Single Nucleotide Polymorphisms (SNP) – and determine whether these variations are associated with diseases like AD. In this image, the arrows indicate variation (change in colour) in a single nucleotide at the same position

In the last few years, thanks to dramatic breakthroughs in gene sequencing technologies, scientists can dive into these investigations. Today, they can carry out either Genome Wide Association Studies (GWAS), which looks for common polymorphisms or Whole Genome Sequencing (WGS), which reads the entire genome. Though GWAS is an economical option, it fails to detect rare polymorphisms, says Chauhan.

Besides genes, some environmental factors too have been shown to be associated with dementia. These include exposure to nitrous oxide, carbon monoxide, tobacco smoke, pesticides, consumption of alcohol, and deficiency of vitamin D.

People with a particular variant of the *ApoE* gene, ε4, have an increased susceptibility to faster cognitive decline. Yet, not all people with this mutation develop dementia. Why?

But what scientists are discovering is that many diseases, including those that cause cognitive decline, result from a complex interaction between an individual's genetic makeup and environmental agents that one is exposed to. For example, people with a particular variant of the APoE gene, ε4, have an increased susceptibility to faster cognitive decline. Yet, not all people with this mutation develop dementia. Why?

Many studies have shown that the environment one is exposed to and also the lifestyle one adopts affects what neurologists refer to as cognitive reserve, which is the degree of resilience to cope with brain damage. Think of cognitive reserve as a buffer which could delay the onset of symptoms of dementia or even keep them from ever developing.

Studies have shown that cognitive reserve is governed many factors. One study reported that people with less than eight years of education had 2.2 times higher risk of developing dementia than those with more education. The same study showed that people with skilled jobs were more immune to dementia.

Recent research is also shedding light on the importance of a healthy lifestyle. Cognitive reserve is higher for those who keep themselves physically and mentally active. "It is important to do physical exercise or perform yoga, engage in cognitive activities and maintain an active social engagement to keep dementia at bay," explains Sivakumar.

"It is important to exercise or perform yoga, and maintain an active social engagement to keep dementia at bay"

The role that lifestyle factors play in stalling dementia was highlighted in a presentation made at the Alzheimer's Association International Conference 2017 (AAIC) in London this year. It claimed that one-third of global dementia may be preventable. A review by LANCET described the role of nine factors which increases susceptibility to dementia: low levels of education, midlife hearing loss, physical inactivity, high blood pressure (hypertension), type 2 diabetes, obesity, smoking, depression, and social isolation – as risk factors for dementia. Knowing how some of these factors interact with genetic factors could help people make informed lifestyle choices.

But a thorough understanding of the diverse and complex causes of dementia still eludes us. Many debates are yet to be resolved. For instance, some researchers have suggested that being able to speak more than one language may help delay the onset of AD. However, these results have been contradicted by a study conducted by Ellajosyla on 600 patients in her clinic. But she adds, "We found an effect for FTD, where bilinguals had an onset eight years later compared to monolinguals, after controlling for education and severity of dementia." "Ideally," she explains, "we would like to do a community study and follow normal elderly people without any cognitive impairment over several years and study the contribution of diet, vascular risk factors and also education and bilingualism."

Photo courtesy: Ratnavalli Ellajosyla

Ellajosyla and her team

Coping with dementia

In spite of the progress in our understanding of the causes of dementia, treatment options are dismal. Medication helps, but we have no cure for it yet. Patients with AD have low levels of acetylcholine, a neurotransmitter that helps in learning and memory. To treat this condition, doctors widely prescribe cholinesterase inhibitors. These drugs inhibit the action of cholinesterase, an enzyme which under normal conditions breaks down acetylcholine. Inhibiting cholinesterase protects acetylcholine from further depletion. Unfortunately, this treatment is suited only in the initial stages of dementia and may help reduce symptoms of cognitive impairment. More sophisticated approaches to stop or delay disease progression, also called disease-modifying treatments, are yet to see the light of day.

Besides cognitive decline, dementia can also lead to other psychological issues. It is not uncommon to find patients battling dementia also experiencing hallucinations and delusions. In addition to that, they may also develop changes in personality, experience dramatic mood swings, and, in some cases, become aggressive and agitated. This places a heavy burden on the family members of those suffering from dementia who often find themselves unable to cope with the situation, and are forced to rely on care centres for additional support. What Rita* went through is a case in point.

In addition to that, they may also develop changes in personality, experience dramatic mood swings, and, in some cases, become aggressive and agitated.

Rita's father was falling sick repeatedly. As his health deteriorated, she was hoping for support from her mother, Claire*. But instead, Claire, who was showing some symptoms of dementia, became indifferent to the plight of her ailing husband, an emotional Rita recalls. Soon, her mother developed other major behavioural issues. She grew violent and began making false accusations against her family. After about six months, Rita's father passed away. At his funeral, Claire did not show any emotion. This was a trying time for the whole family.

Rita soon realised that she couldn't look after her mother anymore as her condition worsened and it started taking a toll on Rita's own health. Her doctor suggested that Rita seek help for her mother from a residential care facility. Claire was taken to one such support home in Bangalore. "They did the most amazing service for six years until my mother passed away of old age. She was one of the most obstreperous residents, beating her caregivers and accusing the Director of being 'Hitler', but she was treated with patience, sympathy, and firmness. Counselling for families with a dementia patient is available. The support structure is extremely good," says a grateful Rita.

**Names changed*

Photo: P Ramya Bala

Participants in the yatra being led on a shortcut by Bibasra

WHAT I LEARNT MEETING RURAL INNOVATORS IN ODISHA

Ramya, who has just finished her PhD from IISc, spent a week walking through Odisha villages observing how local residents engage with science and tech

P Ramya Bala

The Shodh Yatra is a walk organised twice a year through rural India, aimed at unearthing and disseminating grassroots knowledge and innovations. Ever since I found out about the yatra, I have wanted to go on one. Recently I had my chance: I had just completed my PhD and a few months of Research Associateship, and I was faced with long months of nothingness ahead of me. To my delight, I learnt that the next Shodh Yatra would be organised in the summer of 2017. I read the announcement carefully. It said the maximum temperature on the journey was expected to be 45°C. (45!) It said that we would walk 18-22 km a day in the scorching heat. Could I manage that?

Family and friends strongly dissuaded me with horrifying stories of dehydration. I called the organisers. Someone at the other end told me that foreigners were signing up. What did I mean by asking if I could bear the heat? Of course I could! His confidence and my eagerness to not miss this opportunity helped me make up my mind. I was going! I signed up and paid the registration fee in typical PhD style: on the day of the deadline.

I took a train from Bangalore to Chennai, another to Bhubaneswar, and a third to Barpali to join the 39th Shodh Yatra, organised by the Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI), a voluntary organisation located in Ahmedabad. The yatra is organised twice a year with the help of the Honey Bee Network (a group of individuals and institutions who aim to document and share local traditional knowledge), covering a distance of 100-120 km in a remote rural district of India. The summer yatra happens in places of extreme heat and the winter ones in places that face extreme cold.

This summer, the yatra was held in western Odisha during 11-17 May

The Shodh Yatra aims to felicitate local innovators and traditional knowledge holders, promote traditional recipes and local biodiversity conservation, and conduct village meetings to know and understand local issues and problems. It also identifies centenarians, enterprising women and children, artisans, rural researchers and people contributing to the preservation of natural resources. It prepares registers of local knowledge and local plant diversities, promotes low-cost and sustainable agricultural technologies, and shares open-source information collected by SRISTI which may be of use to local people. To me, the yatra seemed to offer an experience I had longed for during my PhD, and I couldn't wait to begin!

Our starting point was Barpali, a town in the north-western district of Bargarh, that owes its place in history to Gangadhar Meher – considered one of the greatest Odia poets. It is equally famous for its rich weaving tradition, and on the very first day of the yatra, a small conference of sorts was organised. We were fortunate to see several award-winning woven items, including a shirt that was not tailored, but woven seamlessly, and fabric that had Meher's famous poems woven into it. We got a glimpse of the rhythmic Sambalpuri folk dance, enthusiastically performed by children from a local school, and sampled tasty food. The most popular stall was one by local women who made delicious local items that vanished in no time. (SRISTI specifically focuses on recipes which use rare, less known or forgotten plant produce.)

'Explain general theory of relativity?'

Over the course of the yatra, our pre-conceived notions about the local people were challenged. Take for example Bibasra, a man we met on the way to Rengalipali from Pada. He stopped someone from our team while we walked along the road to ask a question: "There are two fundamental forces: attraction and repulsion. We see many examples of attraction. Where can I see an example of repulsion? Is there research being done on repulsion? Can I see it somewhere?" After a while, he asked, "Can someone explain to me what this general theory of relativity is? I have been trying hard to understand but I am unable to. I would like someone to explain it to me." He promised to show us a short cut through the fields, and we followed him, listening to all of the things he had wanted to ask and trying to answer them as best we could. People pointed to me and said, "Catch her. She is the scientist," but I had to tell him the truth – I had no clue! I felt quite stupid. These were the things that Bibasra, the farmer, mused about as he toiled under the sun with his back bent over his work. We asked him why he did not pursue formal education. He told us he did get a job where he could have sat at an office in a comfortable place. But, he said, "If I don't sit at that job, someone else will. Why not do agriculture? I like working on my land!"

When we got to the village of Rengalipali, where a 10-year-old showed us his homemade air conditioner created from a bucket of cool water and a ventilator fan, we also spotted an extremely old treasure in the hands of an 85-year-old sixth-generation healer. As we watched, he read out from these palm-leaf manuscripts several medicinal recipes. It was a sight to behold. He still treats patients that come to him and is a practicing 'vaidya'. He also had a treasure of old medical book collections in Sanskrit and Odia, probably some of the last of their kind.

A 10-year-old showed us his homemade air conditioner created from a bucket of cool water and a ventilator fan

One interesting aspect I noticed on the yatra was that people married early, and consequently, were grandparents while still young, and helped bring up their grandchildren. It made me wonder about the 'grandmother hypothesis' and whether grandparents helping parents with raising children can have significant evolutionary consequences. Elsewhere on our journey, in the village of Sargibahal, a co-yatri asked why the women in this village were largely missing. She was told that they were out working in other states like Tamil Nadu as skilled labourers in weaving industries, while the men stayed back at home looking after the children and working the fields when conditions were suitable.

At Goibahali, we met a dynamic anganwadi worker who interacted with us for a long time. She told us that during training, workers were instructed that it was sufficient to breastfeed children until the age of one. But local mothers breastfeed their children even until 5 years of age. All the children we saw seemed healthy, despite the widespread poverty. For me, this was a great point to note – in the rush of modern urban life, perhaps we are missing out on a great resource for our children.

Local inventors

We were floored by some of the inventions and inventors we came across. At Bandapali on the first day of our yatra, we were introduced to a weaver named Ramprasad Mehr who had designed a warping machine that reduced the manual labour of counting threads and laying them out (which takes around eight hours). He created a device that could perform this task multiple times in six hours. Another friend of his, Prafulla Mehr, from the same village made a larger device that could perform the same task on an industrial scale. The first invention was meant to cater to women primarily employed in the time- and work-intensive process of laying out threads, which makes it difficult for mothers to find time for their children. Ramprasad has already sold many pieces in his district. When asked whether they would like to share this knowledge with the larger community, the innovators readily agreed, saying their intention was to help their fellow weavers. Anil Gupta, the brains behind the yatra, discussed with the participants the idea of making such innovations available under the Creative Commons license to prevent cheating and unfair commercial use by other companies, while freeing innovation from the burden of patents that stops its replication at the grassroots level.

At Bandapali on the first day of our yatra, we were introduced to a weaver named Ramprasad Mehr who had designed a warping machine that reduced the manual labour of counting threads and laying them out

At Pada, our halt on the second night of our yatra, we met a man who had attached a motorcycle engine to a bicycle. The idea was to cycle when the going was easy and use the engine only when necessary. Even with the engine in complete use, he could still drive 60-70 km on a litre of fuel. He demonstrated the vehicle for us and it worked beautifully! I was really excited by this one.

The Lemon Tree Doctor

We came across farmers who had created exciting new agricultural hacks in response to particular problems that they faced. There was the paddy farmer from Gudarpali

Photo: P Ramya Bala

The vaidya's old medicine book

who accidentally discovered that the plant veru (*Chloroxylon swietenia*) could be used for pest control after the skin on his shoulder was burned by the sap oozing from the cut stems he was taking home. He thought if it could burn his skin, surely it could burn a worm's skin too, and so, he used it on all his crops after mixing it with gomutra (cow urine). Another farmer from the village claimed that he used alcohol diluted with water for his crops, and it was yielding good results. Why did he use alcohol, we asked. "It works on people, so I thought, why not try it on plants?" he told us.

Perhaps one of SRISTI's oddest finds is a farmer who grew lemon trees. The trees were badly affected by worms that would eat at their roots, most often killing them. There was no way to know which tree was afflicted, and the worms were taking a toll on his business. One day, during a bout of illness, the doctor came to visit him with a stethoscope hanging around his neck and... eureka! He borrowed a stethoscope and went to one of his lemon trees. The moment he put his stethoscope to it he could hear scratching noises from the tree trunk. He dug up the roots and saw plump white worms eating away at the roots! Now, he's known as the Lemon Tree Doctor, and his idea, like so many others, is being shared with fellow farmers through the Honey Bee Network.

We also saw an example of an innovation spotted on a previous yatra being shared in Odisha. When the chatty anganwadi worker from Goibahali told us that farmers in the region weren't able to harvest their groundnut crop on time because the lack of rain meant the soil was too hard, we were fortunate to have in our midst Amruthbhai, an innovator from Gujarat's Saurashtra region. Groundnut is grown in arid loamy soils and it is necessary for the soil to be wet for them to be harvested. As Amruthbhai had faced the same problem, he had designed a machine to extract groundnuts from dry soil. It was an opportunity for us to see how the Honey Bee Network functioned: connecting people with similar problems from distant regions and spreading the knowledge from one to the other. Amruthbhai immediately agreed to send a model of the groundnut digger to Goibahali, where it would be tested for utility in the local conditions. If it is found to be satisfactory, this innovation will be procured by SRISTI for the village.

Smart villages

At Salepali, we met Sadhu Patel, a young innovator whose father had been one too. At a very young age, Sadhu was exposed to his father's ways of tinkering about in the empty space in their backyard and was gradually drawn to it himself. His father had tried very hard to build a wooden tractor and had successfully built a wooden bicycle. One of his father's innovations that Sadhu completed was a wooden petromax lamp. This lamp had a large cylinder to store a lot of kerosene and would glow throughout the night. It also had an adjustable wick which could be used to manage the flame and at its maximum, the flame was nearly a foot high. Sadhu's pet project was the hand pump piston-handle unit that was used to pump water out of surface wells up to 50 ft deep. His unit could also be used to pump water from borewells to houses, even if the borewells were some distance away. His innovation was quite popular and Sadhu has already set this up at nearly 80 houses in his own village and supplied units elsewhere in his district.

We met a young boy at Telmaul Chowk who had designed a model for a smart city. It had several lovely features such as rainwater harvesting tanks where water would get stored and could be distributed across the city, as well as wastewater recycling units. It also had smart roads where houses and traffic signals would all be fitted with CCTVs. This was followed by a discussion amongst us on the possibility of smart villages (why do we always think that only cities can be smart?), and what this might entail.

During an idea competition at Karmelabahal, an 8-year-old had an idea for a new device. As she stood up to talk about it, mid-way through her first sentence, she began to cry. It was a moving sight. She wanted to design a machine that would have a rotating arm with a sponge at the end that could wash vessels to lessen the workload of her mother, a domestic worker. She felt for her mother so much that she was overcome with emotion and couldn't complete her first sentence, despite encouragement. She was led away while a discussion on how such a device can be easily built continued.

Photo courtesy: Maria Belen Rodriguez

A little boy tries out the prototype of an invention to collect mahua flowers from under a tree, as shown in the poster behind him

An 8-year-old wanted to design a machine that would have a rotating arm with a sponge at the end that could wash vessels to lessen the workload of her mother, a domestic worker

The highlight of our entire journey was meeting Dharamveer Kamboj, an innovator from Haryana, with whom SRISTI had once met and shared input, and who had an incredible rags-to-riches story. He was a rickshaw puller in Delhi when he met with an accident that forced him to return to his village, where he put his exposure to the big city to good use. He realised that primary farm produce was not as lucrative as processed food and immediately set to work on designing a juicer. He made one that could create juices out of various fruits. With the positive response his business was generating, he modified his juicer to make sure that fruits with large seeds could also be directly fed without coring them. In addition, he designed features such as a heating unit followed by one for condensation to distill essences out of herbs and flowers. In this way, he made gulaabjal, tulsi ras and many more essences. He now sells juices and essences manufactured at his industry, and is now a leading name in processing equipment. He owns a workshop and a processing unit where he employs more than 20 women. His machine won him a prestigious award for innovation and he spent two weeks at the Rashtrapati Bhavan.

SRISTI is in the process of compiling a knowledge database from all of the communities that they have visited over the years, and a version of this is already available online. But my experiences on the yatra left me wondering: how many more Dharamveers are out there, yet to be discovered?

**P Ramya Bala is a Research Associate at the Divecha Centre for Climate Change and enjoys nature-inspired writing.*

Photo: Karthik Ramaswamy

'A TEACHER IS SOMEONE WHO FACILITATES LEARNING'

Karthik Ramaswamy

What is the nature of science? How do we learn? How can we use storytelling to communicate science? These were some of the many questions that participants – graduate students, postdocs and faculty members – grappled with at a workshop titled Science Pedagogy and Communication held in IISc on 26 and 27 May 2017.

The workshop, conducted by Meena Balgopal, an associate professor at the Colorado State University (CSU), specialising in science education, was organised by Maria Thaker, Kartik Shanker – both faculty members at the Centre for Ecological Sciences (CES) – and Balgopal through a grant called 'Partnering to Sustain India's Biological Diversity in the Context of Rapid Environmental Change: Research, Education and Community Outreach' to facilitate the exchange of faculty and students from CES with those from CSU. The grant is part of the 21st Century Knowledge Initiative which seeks to build *partnerships between Indian and American institutions of higher learning.*

After the workshop, Balgopal (MB) and Thaker (MT) sat down with Connect *for a freewheeling chat about the workshop, their own journeys as teachers, and a host of issues related to pedagogy and science communication. Here are edited excerpts from the conversation:*

Maria, how did this workshop come about?

MT: It's a combination of luck and my interest aligning. Paul Ode [Balgopal's husband], also from CSU, had come down to Bangalore a few months ago and I got to know about Meena and her work in science education through him. This was brilliant news to me because I am passionate about teaching science, and have been trying to sneak in different ways to communicate more effectively in the classroom. So I thought it would be great to bring Meena here and do a workshop.

How do you view the role of a teacher?

MB: A teacher is someone who facilitates learning. In the workshop I challenged the participants to re-think what teaching is, and to reframe it so it's not about one-way transmission. I wanted them to think about the process of learning and what the teacher can do to aid this – how they can create an environment conducive to learning, design curriculum based on the learning goals, and think about instructional strategies to support learning.

MT: That's right. I too think that teachers should be facilitators of learning. The traditional form of teaching which primarily involves talking to the students is outdated and not as effective. And it was obvious to me that I wouldn't be an effective teacher if I just stood there in class, yacked at my students and expected them to absorb information like sponges. What I want them to do is learn how to think, ask the right questions, learn to design studies to answer their questions, and learn to use information critically.

> **...I am passionate about teaching science, and have been trying to sneak in different ways to communicate more effectively in the classroom. So I thought it would be great to bring Meena here and do a workshop**

One of the things emphasised in the workshop was to get participants to think of science not just as a noun but also as a verb. Could you elaborate on this?

MT: Science is as much a process to me as it is a product. The product of science is the product of a good process. And so I emphasise this right from the first day of my undergraduate and my graduate classes. I seed them with this idea. I get them to ask questions and design studies to answer them. I discuss this with them in groups so that we can catch each other's mistakes. This allows them to troubleshoot their way through it while my job is to guide them. This is what I mean by facilitating learning.

Photo: Karthik Ramaswamy

Meena Balgopal, an associate professor from CSU, specialising in science education, conducted the workshop

MB: What I'll add to that is that when you have a group of undergraduate students, we don't know what they've experienced in their high school. We don't know if they really understand the importance of inquiry in science. That's the reason why it's not a belief system that is stagnant and static. It's not called science-ism. Inquiry is what pushes us to ask new questions and learn new answers. So it's really important to emphasise this right at the beginning.

Teaching is not an essential part of the training that scientists get as graduate students or as postdocs. I suspect you may have something to say about it.

MT: Yes. I'm glad IISc has formalised a rule where PhD students cannot get their degrees without at least one semester of teaching as a TA [Teaching Assistant]. But my personal view is that it's not enough practice. It definitely helps, especially if you can TA for a professor who will also involve you in lecturing and not just marking assignments.

Speaking about my own experience as a graduate student, I had a Research Assistantship. I didn't have to teach. But I chose to teach because I wanted to get good at it and also because I enjoyed the process. I not only got a feel for teaching, but I also became a better scientist. There's no doubt that I got cleaner in the way I thought about things since I had to explain it to someone else. And if I couldn't do that it in the classroom, how am I expected to do that effectively in a conference or anywhere else? Besides I think that we have to work on becoming better teachers because we have a responsibility to our students.

MB: I have a couple of things to add to that. I think professors in many graduate schools assume that their students are going to become professors in research institutions just like them. And they don't encourage their graduate students to work on their teaching. Only now are we beginning to have a conversation that our job is not to train an army of "mini mes". Just like in your own undergraduate classes, you don't want to have a group of little Meenas or little Marias.

> I wanted the participants to think about the process of learning and what the teacher can do to aid this – how they can create an environment conducive to learning, design curriculum based on the learning goals, and think about instructional strategies to support learning

Another important reason why teaching is under-valued is because of the emphasis on research productivity and not on teaching when it comes to performance evaluation and promotion of faculty. So I think that there is bound to be some conflict for young assistant professors starting their careers about how much time and energy one can devote to teaching.

How does someone with little or no real teaching experience go about teaching a course in university or college for the first time?

MT: The first thing they should do is find out from students who they think gives good lectures and is a good teacher at that college or university. And then ask that person if they can observe their class. It's also important to find out about what the culture at the university is and what the expectations are [with respect to teaching]. Find good mentors and good allies with whom you can talk about teaching.

MB: I completely agree. I think that we need mentorship programmes. We have professional learning communities (PLCs) in our professions – like our conferences – but we don't necessarily have them for teaching. We need to have a platform where we meet regularly and share teaching resources. We need to observe each other teaching. The PLC can be formal or informal, but I think if we name it, then it becomes legitimized in the university. Then the administrators take notice.

> Another important reason why teaching is under-valued is because of the emphasis on research productivity and not on teaching when it comes to performance evaluation and promotion of faculty

Tell us a little bit more about the importance of self-reflection for teachers. It came up in the workshop repeatedly.

MT: IISc has a student feedback form that's now digitized. Students assess their teachers on a scale. They are asked questions about whether the teacher did a good job, was the teacher prepared, etc. I don't find it particularly useful as a teacher and so have my own evaluation form in addition. I ask students questions about the topics I covered and what they found interesting and useful. I even ask them what they would change. I try to phrase questions in a way that gives me useful, targeted feedback. This allows me to reflect on my own teaching, which means that, every year, students get a better version of me. But if I just did an assessment based on the rank or scale with questions about whether I was good or prepared, it doesn't give me the opportunity to change much of anything.

MB: Teaching is just like doing science – it's an iterative process. We're only able to move forward if we pause to find out what we're doing well, what we're not doing well and how we could do things better. And that's why I called it scientific teaching.

And also, we're modelling for our students. If we want them to be reflective learners, then shouldn't we be reflective learners as well? We should constantly be learning about teaching and about ourselves as teachers.

Talking about modelling, Meena, you used many different teaching strategies yourself in the workshop: problem-

based learning, group discussions, case studies and the like. Why would you recommend that teachers consider using such teaching methods as opposed to just lecturing?

MB: This is a question that I've heard from other people as well. It's important to engage students in different ways. Nobody wants to eat the same meal all the time. But mixing things is important not just for variety. Each student is different. Not everyone learns from just listening to lectures or from just doing hands-on activities. I don't adhere to this principle that you have only one learning style. We know from literature that the idea that there are only visual learners or auditory learners has been debunked.

But at the same time we are comfortable using strategies that have worked for us. So I actually like to take the middle path. I usually do what is called an interrupted lecture. I will lecture for a few minutes, then pause and have perhaps a class discussion, and eventually return to the lecture. And that's a compromise. Because students do need some information, they need to know what some of the big ideas are. At the same time, they also need some opportunities to grapple with things and identify their confusion or misconceptions.

At the end of the day, we need to have some level of consistency in our teaching style. Students need to know what to expect. So when I come into class, I'd let them know about what the learning agenda for the day is and this is how I'm going to present the material.

MT: The more that we break up the straight up PowerPoint lecture with something different, the better. Sometimes, I'll say, "Let's derive this equation on the board together." This way students also learn the process and not just the information. So basically if we are actively involved in the process of teaching, we end up having a more energised classroom.

Meena also said some other things during the workshop that was valuable to me. It helped to reinforce my teaching style. She talked about why it is useful to take some time to write on the board. And not turn your back to the students when you talk to them. Make eye contact. Build trust. Some of us do this naturally, but some of us have to work at it.

You talked about the difference between *performance* and *understanding*. How does one help students achieve both?

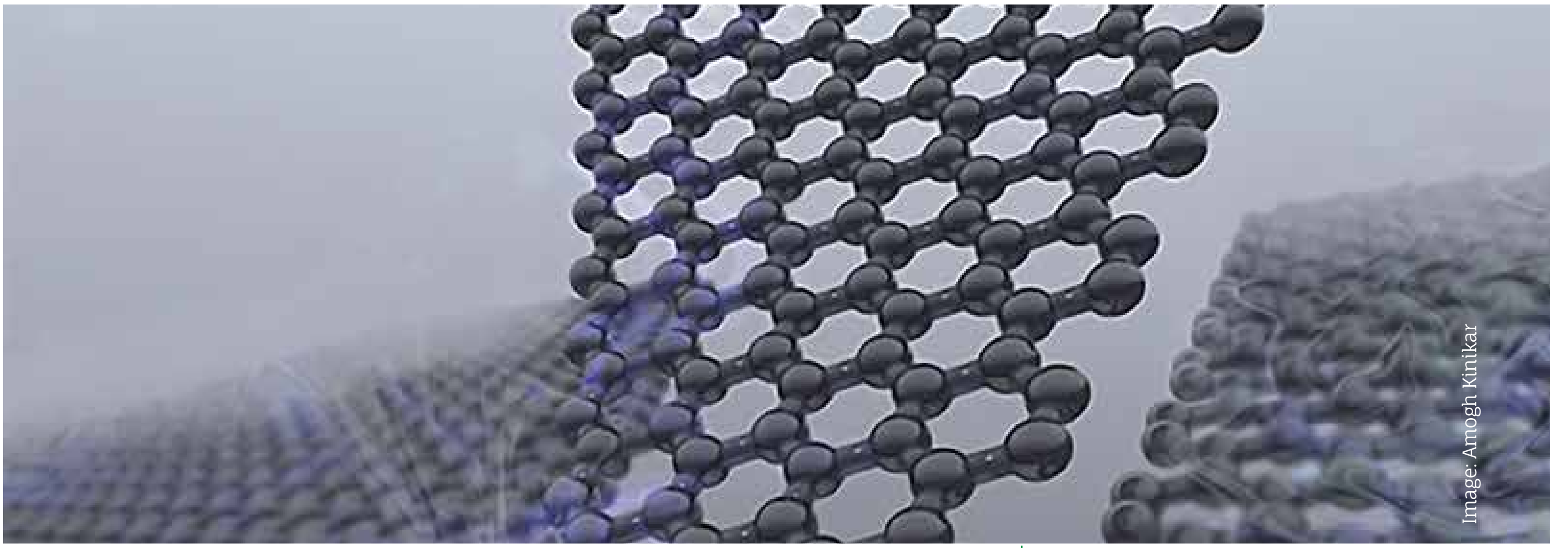
MB: From the teacher's perspective, I can see how there can be a conflict between helping students perform and understand. I talk to my students on the first day of class itself about how understanding is different from performance. And that my goal is to help them understand. At the same time, I realise that the reality is that they need to perform well and score good marks to get into good professional schools or Master's programmes. So I do share tips regularly about different strategies they should explore to increase their performance on exams, including on the standardised tests that they may have to take. But it doesn't mean that there is no overlap between the two. You might be able to perform well and also understand well. However, I feel sad when students perform well, but don't understand. To me, that's not success.

Maria Thaker, an assistant professor from IISc, organised and helped conduct the workshop

> Find good mentors and good allies with whom you can talk about teaching

The other term you emphasised was *understanding by design*. What exactly did you mean by that?

MB: In *understanding by design*, you first say what your goals are and then decide on how you would assess whether these goals are met. After which you design your curriculum and instructional strategies. This ensures that teaching and assessment are aligned.



This image shows exfoliation of graphene. The horizontal plane is graphite; only its top-most layer is shown for clarity

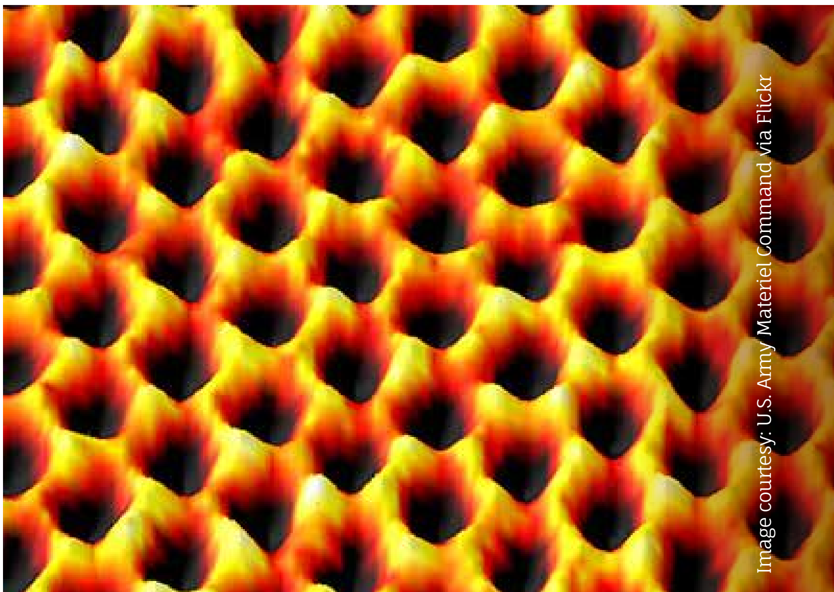
THE PROMISE OF GRAPHENE

Amogh Kinikar

Amogh Kinikar, who did his Master's in Physics at IISc, on why it is such a fascinating material

In 2012, I found myself in the Department of Physics at IISc, holding a five-and-a-half feet tall, extremely top-heavy object called a dip stick. It was a long narrow vacuum chamber that could be inserted into vessels containing cryogenic fluids. This particular one was made nearly two decades ago by Sohini Kar-Narayan, currently a faculty member at the University of Cambridge, during her PhD in the department. And in it was the apparatus which allowed me to measure electrical properties of the cleanest graphene flakes. I used a sharp metal tip to exfoliate graphene from its parent graphite crystal. Both the metal tip and the graphite crystal are conducting, so I could measure the graphene as it was being exfoliated, and because this graphene was not exposed to the air or any chemicals, it was as clean as graphene could get.

For the better part of the last century, many discoveries in physics – ranging in scale from sub-atomic particles to the cosmos – have captured the public imagination. But in 2004, the relatively obscure field of condensed matter physics caught public attention with the discovery of a new form of carbon with extraordinary properties called graphene. In the years since, several superlatives have been used to describe the significance and implications of this discovery. But why is graphene so fascinating?



This image of graphene's 2D hexagonal lattice is obtained by a scanning tunneling microscope. There is a carbon atom on each point of the hexagon, and the distance between two carbon atoms is around 1.4 angstrom, about one tenth of a billionth of a metre

It was in the summer of 2003 that a scientist known for pushing the boundaries of materials science, Andre Geim at the University of Manchester, tasked his postdoctoral associate, Kostya Novoselov, with making the thinnest layer of graphite, a familiar crystalline material so soft that it is commonly used in pencil leads and solid lubricants. For the past thirty years, physicists all over the world have used graphite to calibrate microscopes (called scanning tunneling microscopes) which can see atoms, because graphite could be obtained in very high-quality crystals. To clean the surface of these graphite crystals, they would remove the top-most layer with a simple adhesive tape. The crystal was so soft, a thin layer of it would be exfoliated as the tape was peeled off. Novoselov took the next leap and peeled off another layer from the layer that was already stuck to the tape. He did this a few more times, ending up with a very thin layer of graphite – so thin that at a few places it was just a few atoms thick. And thus graphene was discovered. (Technically, it was rediscovered. The first experimental evidence and procedure to create graphene was documented in 1962 by Von HP Boehm, A Clauss, GO Fischer, and U Hofmann. Despite being presented in an international conference and published in a widely-read journal, the discovery was ignored. The very modestly written paper made little of the fact that it was reporting the discovery of the thinnest material.)

Graphene was clearly a unique substance: it was the thinnest material ever made. And it had an uncomplicated structure, a hexagonal array of carbon atoms with each atom bonded to three other carbon atoms.

IISc has developed a rich association with graphene, having produced a few of the most cited papers in the field

After its discovery, physicists worldwide began investigating its properties. IISc too has developed a rich association with graphene, having produced a few of the most cited papers in the field. Arindam Ghosh's lab in the Department of Physics showed, in 2013, that graphene has the highest responsivity of any photodetector (it had the largest change in current produced per photon intensity). However, graphene by itself is very transparent, absorbing only 2.3% of the light that falls on it. To develop a photodetector, Kallol Roy, a student in Ghosh's lab, placed graphene on top of another 2D material, molybdenum disulphide (MoS_2). Unlike graphene, MoS_2 absorbs light very well, but does not conduct electrons, something graphene is good at. So if you put one layer of graphene on top of a few layers of MoS_2, you can combine the best of both worlds to get the highest responsivity from any photodetector.

But one Institute member made a significant contribution to graphene research decades before it was actually discovered – this was none other than Sir CV Raman. Raman spectroscopy, based on the Raman effect, the discovery for which the physicist won his Nobel Prize, is one of the most widely used techniques in material and chemical sciences, and it finds extensive use in graphene research too. Over 20% of the research papers published on graphene in the year 2016 used the technique in some form. This is because Raman spectroscopy can be used to study the vibrations of materials as described by quantum mechanics. All objects constantly vibrate, and although these vibrations can be thought of like waves on a string, light interacts with them as though they were particles. This is the wave-particle duality of quantum mechanics. Using the Raman effect we can measure the frequency of these vibrations, and in these frequencies are fingerprints that reveal a material's properties. A pioneering discovery in this field was made by Anindya Das when he was a graduate student in the Department of Physics, where he is now a member of the faculty. He was the first to demonstrate how applying an electric field changes graphene's Raman spectrum. As Raman spectroscopy is a widely available and relatively straightforward technique, this discovery provided an easy way to characterise properties of graphene.

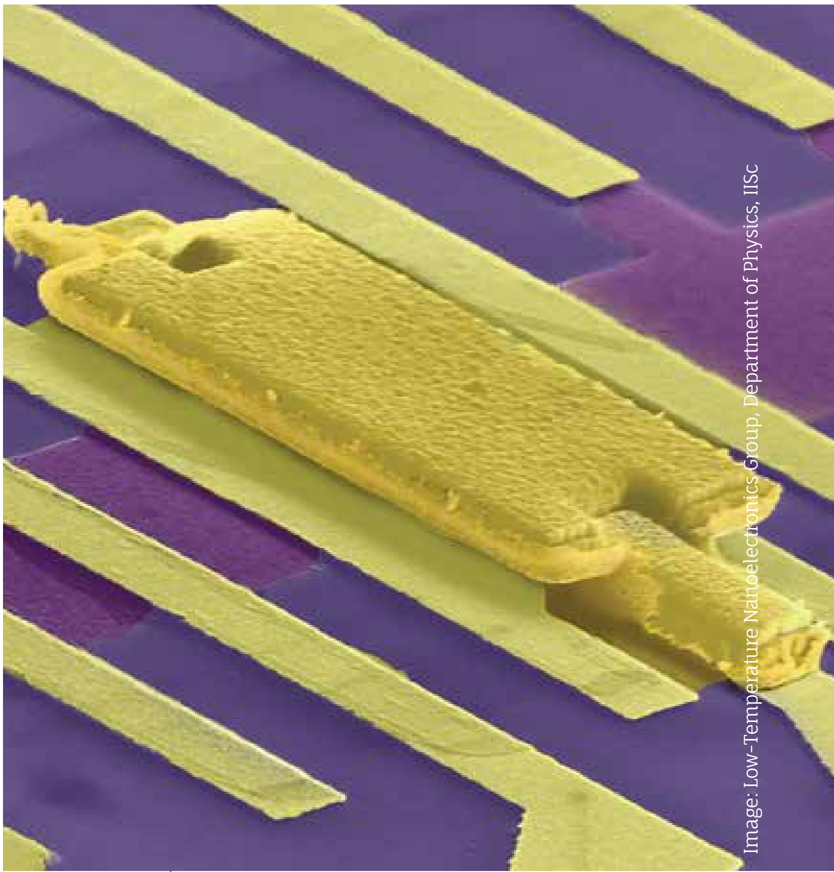
Amongst all its superlative properties, the best known is graphene's strength – it is perhaps the strongest material known to humans. It has been claimed that a layer of graphene as thin as plastic cling-wrap is so strong that you would need to balance an elephant on top of a pencil to be able to pierce it. However, that statement needs to be taken with a tiny grain of salt. The strength measurements (which did not include elephants) were performed on tiny flakes of graphene, which are generally free from defects. And that is crucial because defects are the places where things begin to break. A defect-free sample would necessarily be much stronger than one with defects. The techniques currently used to make graphene on large scales, by chemical vapour deposition (CVD), leave a lot of defects in the graphene layer. But CVD graphene is the only feasible way to ensure the properties of graphene find applications; exfoliated graphene is prohibitively labour-intensive and expensive.

So how does CVD graphene fair in the elephant-on-a-pencil test? Not very well, it turns out. CVD graphene is very delicate, although there are ways to improve its strength. If you can remove certain kinds of defects it is nearly as strong as exfoliated graphene. But doing this on a large scale remains a challenge.

CVD graphene is also crucial for applications such as flexible or transparent electronics. It is not just the mechanical properties of graphene that are important in these applications, but also the electrical ones. Again, because of the defects, CVD graphene is not as good as exfoliated graphene, as each defect is an obstacle which scatters the electron from the path it was travelling on. But it is getting better. A different problem with CVD graphene may now have a solution, thanks to Mayank Shrivastava at the Department of Electronic Systems Engineering. When we put metal contacts on CVD graphene, the "contact resistance" is very high – it takes energy for the electron to leave the metal and jump into graphene. So if we were to make computer chips out of graphene, they would be very power-hungry because of the high contact resistance. Shrivastava has proposed a design that has the record lowest contact resistance. The key to its success lies in designing contacts with the right kind of defects, so that the electrons in those defect sites can easily jump into the metal and also into graphene. It replaces the barrier with a slide.

To make graphene devices, we need to place the graphene layer on a substrate. This is achieved by pressing the tape with exfoliated graphite onto silicon dioxide, the most frequent substrate. In this image you can see different thickness of graphene layers. The lightest layer, a triangle a little above the centre of the picture, is a single layer of graphene. The large ripped region below it is bilayer graphene. The purple region towards the top is five to ten layers of graphene, and the yellow chunk is bulk graphite with hundreds of layers of graphene. The blue patches all over the image are the adhesive residues from the tape

The Nobel Prize in Physics 2010 was awarded to Geim and Novoselov not just because they measured graphene devices. The prize also recognised paradigm shifts in our understanding of the material world. We suddenly had access to a two-dimensional material which was strong, absorbed little light, and could conduct electricity. A host of physics and chemistry thought experiments suddenly became practical. And even the most enthusiastic of graphene's admirers will perhaps be surprised at the applications graphene is now finding in biology, which include using it as a drug delivery system or even as a biosensor. But its most revolutionary application yet may be in DNA sequencing. DNA is a very long and extremely narrow molecule – the width of a single strand of DNA would be similar to that of a few of graphene's hexagons. A collaboration across various departments in IISc and the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR) led by CNR Rao demonstrated, in 2008, how DNA nucleotides interact with the surface of graphene. Following this, Cees Dekker at TU Delft, Netherlands, showed in 2010 that if graphene had a tiny hole, you could thread the DNA through it and that it would be stabilised by its interactions with the graphene. If you were then measuring the current across the hole, depending upon what nucleotide was passing through, the value of the current would change. This allows for extremely rapid DNA sequencing.



A false-coloured image of a graphene device. Graphene devices are made using electron lithography, where an electron beam is used to draw patterns on a surface. Then metals or other materials are deposited. The dark blue surface is the substrate, the purple region is graphene, and all but the central gold region are contacts through which current passes. The central gold region is a gate, which can apply an electric field on to graphene to change the number of electrons in it

Such advances have been made possible over the last decade because of graphene's extraordinary properties. And it is in terms of mastery over materials that the stories of civilisations are often described, from the stone age to the silicon age. In time, graphene, whose superlative properties we are still trying to unsheath and wield, may usher in a new age.

New playschool on the block

A CLOSER LOOK AT DAY CARE FACILITIES ON CAMPUS

Rohini Krishnamurthy

IISc now houses a play school besides its two crèches, one of which is over 25 years old

As I walk past the Canara Bank down the road lined by Gulmohar trees in IISc's campus, a clamour suddenly interrupts the usually tranquil Institute. The sounds emanate from the IISc Employees' Association Crèche. For many years, the IISc Employees' Association had lobbied with the administration for the setting up of a day care facility on campus. And in 1990, realising the perils of losing the valuable services of its women employees, the Institute set up this facility in a small room at the Tata Memorial Club. Two years later, the crèche, which was inaugurated by IISc's then Director CNR Rao, moved to its own building, nestled between a playground and the Employee Association Union office.

A narrow passage leads me to a gate of the crèche. As I enter its premises, a brightly painted wall catches my attention. Soon I find myself in a room filled with children belonging to different age groups. The room is bustling with activity – most children are playing games as they wait for their parents, though some are engrossed in their books, while others are enjoying an evening snack.

Since its inception, the facility has been managed by Uma Manohar. With the help of four support staff, Manohar works on creating an environment conducive for play and learning, while ensuring that children are fed on time. She also looks after the admission process and fee collection.

Uma Manohar with children at the IISc Employees' Association Crèche

The facility began functioning with only five children; today the strength is 85. Manohar takes me by surprise with her eidetic memory – she recalls names of the first five children. "Pawan was the first child to walk into our doors. These children have grown up to be successful in their respective fields. It is heartening to see them pay me a visit even after so many years," she adds with a hint of pride and happiness on her face.

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During my visit, the children were clearly having a good time. A playful 8-year-old Krithika says, "I like coming here because it's very pleasant and I can play with my friends after school." Eleven-year-old Sudhavna, a regular here for the last nine years, divides his time playing and studying. "When I have difficulties studying, I approach my friend at the crèche or my teacher [Manohar]," he says.

Located just across from the TMC, IISc's second day care center, Shubhodaya Children Care Centre, was set up five years ago. It is run by the IISc SC/ST Employee Welfare Association. The caretakers, Geetha and Gowramma, currently look after 15 children aged between 2 and 15. "Children spend their time playing games or watching cartoons on television," says Geetha, who has been associated with Shubhodaya since its establishment.

In addition to these facilities, IISc is now also home to a new play school and day care centre. It is a franchisee of Little Elly, a prominent chain of play schools operating in several cities in the country.

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The play school, called Elly Day Care Centre, is housed in an old bungalow, once home to several illustrious faculty from the Institute. The Centre, which began operating a month ago, has opened its doors to children between the ages of 6 months to 12 years.

Now renovated, this place has an inviting feel to it. Showing me around the facility – open to children of permanent staff, students, and faculty – Jayashree, the coordinator of the centre, tells me that currently, 43 children are on roll. She adds that the learning curriculum here is theme-based. We are interrupted by a sudden synchronised shout of "orange fish!" which helps me understand what Jayashree meant. I inch closer to find a group of enthusiastic young children sitting around an aquarium discussing the theme for the day – goldfish. They describe various attributes of the fish: its colour, how it moves, how it breathes and so on. This discussion encourages easy and creative learning. The school aims to train children to become better communicators with well-developed social and cognitive skills.

Activities at the playschool (top two images) and Shubhodaya Children's Care Centre (bottom image)

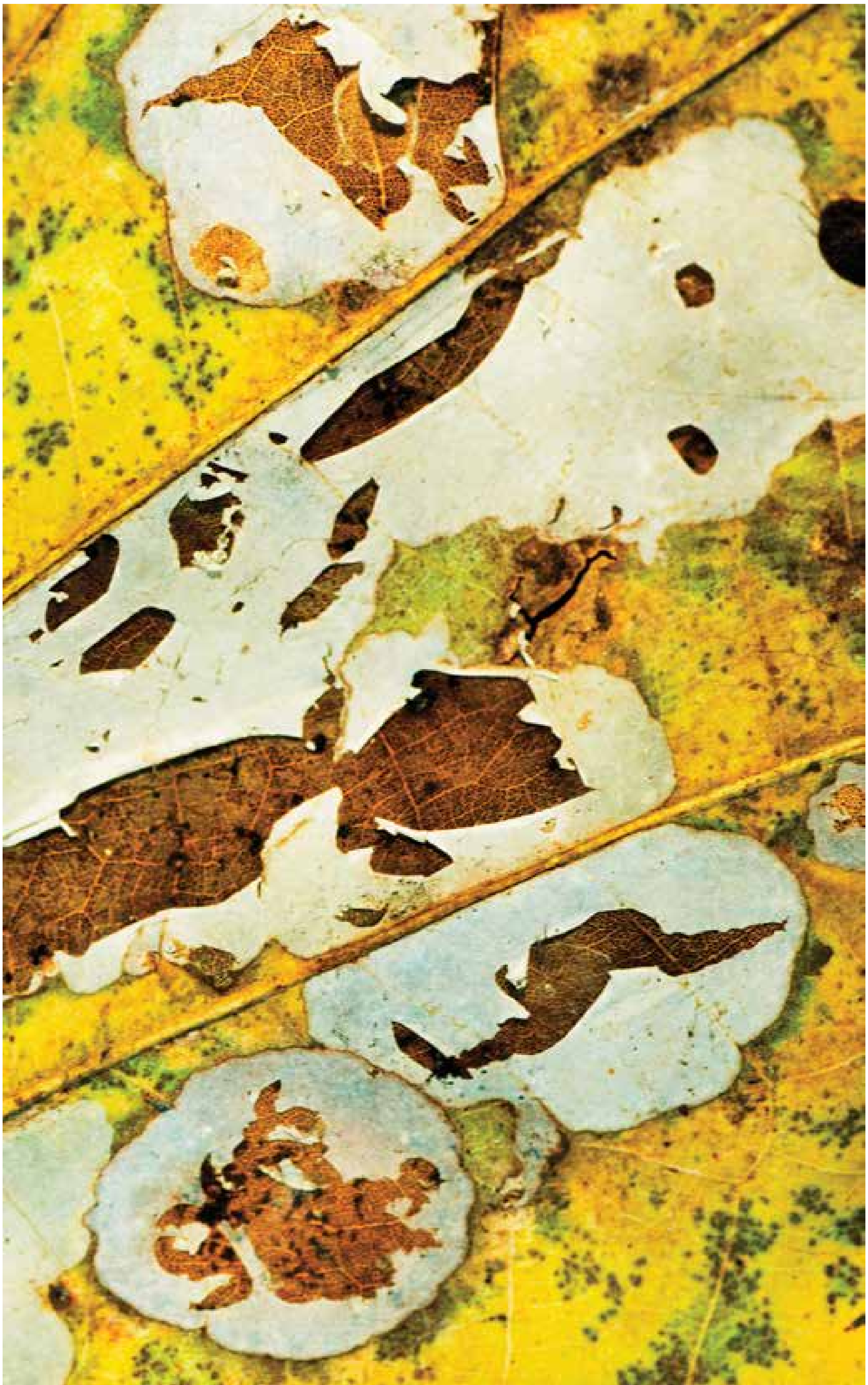
The interior of this building has brightly painted walls, toys, even a TV to show movies. And behind the building is a tiny playground with swings and slides, keeping the children in high spirits. A CCTV camera helps teachers and support staff keep an eye on children at all times.

Day care centres like the ones at IISc not only ensure that children have a safe place where they get to play and learn, but they also encourage women to continue with their jobs. According to Frederico Gil Sander, Senior Country Economist, World Bank, 65% of Indian women of employable age with college degrees are not working. This is partly due to limited childcare options. Another survey conducted in 2015 by one of the apex trade associations, ASSCHOM, revealed that 25% of first-time mothers quit their jobs to raise their children.

In a bid to encourage women to pursue their careers even as they have their families, the Government of India, under the amended maternity benefit law, has introduced a mandatory rule that offices should provide crèche facilities if they have more than 50 employees.

ABSTRACTS

IISc Photography Club



A leaf on campus changing colour as it decays