

EDITORIAL HIGHLIGHTS

07-10-2026

GS 2: DOVERNANCE THE HINDU PAGE: 02

Anti-dam protests: withdraw forces from Siang belt, demands Arunachal youth body

The Hindu Bureau
GUWAHATI

A tribal youth body in Arunachal Pradesh has asked the government to withdraw the Central Armed Police Forces and State Police personnel deployed to allegedly quell protests against the pre-feasibility report and related surveys for a proposed mega hydropower project.

The All Adi Youth Association condemned the situation arising out of clashes between the protesters and security personnel at various places in Siang and Upper Siang districts over the past few days.

The association's secretary, Okut Taki, told journalists in the State's capital, Itanagar, on Tuesday that the "militarisation" of the Siang river belt has brought law-and-order



Anti-dam protesters say the Siang Upper Multipurpose Project would destroy swathes of wildlife habitats. SPECIAL ARRANGEMENT

concerns for locals.

Pointing to the protests and frequent clashes, he rejected the Bharatiya Janata Party government's claim that most families who would be affected by the Siang Upper Multipurpose Project favoured the pre-feasibility report.

The National Hydroelectric Power Corporation Limited is pursuing the Siang Upper Multipurpose Pro-

ject, estimated to generate at least 11,000 megawatt (MW) of hydropower.

The Centre and the State government insist that the project would counter the 60,000 MW Medog hydropower station that China is building on the Yarlung Tsangpo, which flows into Arunachal Pradesh as the Siang.

The Siang meets the Dibang and Lohit further

downstream in Assam to form the Brahmaputra.

"The Adis have traditionally resolved disputes through customary institutions such as the Kebang. The deployment of heavy security forces is not the appropriate way to address differences over the project," Mr. Taki said.

'Not all in favour'

The association alleged that the memoranda of understanding the government signed with the villagers "in favour" of the pre-feasibility report did not reflect the views of all 27 villages that will be affected by the project.

Anti-dam protesters say the Siang Upper Multipurpose Project would spell disaster for the Adi community and destroy swathes of forestlands and wildlife habitats.

GS 3: INTERNAL SECURITY

THE HINDU PAGE: 03

Surya, India' first indigenous fleet support ship, launched

It is a floating supply powerhouse that can sustain protracted, high-intensity naval engagements; Rajnath urges Indian shipyards to look beyond self-reliance and aim at international markets

V. Kamalakara Rao
VISAKHAPATNAM

Union Defence Minister Rajnath Singh launched the Navy's first indigenous fleet support ship (FSS-1), named *Surya*, and laid the keel for the fifth vessel of the series, FSS-5, at Hindustan Shipyard Limited (HSL) in Visakhapatnam on Tuesday.

The ceremony was attended by Chief of the Naval Staff Admiral Krishna Swaminathan, Defence Secretary Rajesh Kumar Singh, Secretary (Defence Production) Sanjeev Kumar, Flag Officer Commanding-in-Chief of the Eastern Naval Command



Homemade vessel: Rajnath Singh speaking at the launch of the fleet support ship, *Surya*, in Visakhapatnam on Tuesday. V. RAJU

Vice Admiral Sanjay Bhal-la, HSL CMD Rear Admiral C. Raghuram, and other dignitaries.

The Minister urged Indian shipyards to look beyond self-reliance towards global competitiveness, aiming to serve inter-

national markets, build a presence in marine technology, and provide advanced ship repair services.

The massive Fleet Support Ship (FSS) initiative is backed by a landmark ₹19,000-crore contract

between the Ministry of Defence and HSL to construct five indigenous auxiliary vessels.

The FSS platform, with 82% indigenous content, serves as a floating supply powerhouse, engineered to sustain protracted, high-intensity naval engagements and battle groups far from home ports.

Its internal storage holds up to 20,000 tonnes of high-speed diesel, 2,500 tonnes of aviation turbine fuel, fresh water, alongside dry cargo containers for ammunition and spares. It can simultaneously transfer fuel, stores, and personnel to multiple warships to maintain continuous high-seas deployment.

GS 3: INTERNAL SECURITY

THE HINDU PAGE: 04

Govt. inks pact to buy BrahMos fire control systems, launchers

The Hindu Bureau

NEW DELHI

The Defence Ministry on Tuesday signed a ₹661.50-crore contract with BrahMos Aerospace Private Limited (BAPL) for procurement of BrahMos Fire Control Systems and launchers for Indian Navy ships, aimed at strengthening the Navy's maritime strike capability and advancing defence indigenisation.

The Ministry said the contract, signed in New Delhi in the presence of Defence Secretary Rajesh Kumar Singh, has been placed under the Buy (Indian-IDDMM) category, with a minimum of 68% indigenous content.

The project is expected to encourage greater participation of the Indian defence industry, including micro, small and medium enterprises (MSMEs), and

generate employment over a period of three years, the Ministry said.

The procurement is also aimed at strengthening India's maritime security architecture and enhancing indigenous capability in advanced military technology.

The BrahMos weapon system, fitted onboard various frontline Indian Navy warships, is the Navy's primary surface-to-surface missile system for maritime strike operations. The system is capable of engaging both land and sea targets at extended ranges with high precision while travelling at supersonic speeds.

The latest contract marks another step towards increasing the indigenous content of critical weapon systems and reducing dependence on foreign sources for advanced military equipment.

GS 2: SOCIAL ISSUES AND GOVERNANCE

THE HINDU PAGE: 06

More than half of overnight travel is by bus: NSO survey

India's first national travel survey finds 55.8% of overnight household journeys are by bus and 17.7% by rail; two-wheelers are main mode of transport for daily work, accounting for 42.6% of journeys

Jagriti Chandra
NEW DELHI

Buses are used significantly more than trains for overnight travel in India, with more than half of all household overnight journeys undertaken by bus, according to the country's first-ever National Household Travel Survey released by the National Statistics Office (NSO) on Monday.

The survey found that 55.8% of overnight household journeys are undertaken by bus, compared with 17.7% by inter-city railways. Together, buses and railways account for nearly three-fourths, or 73.5% of all overnight travel. Cars account for 15.1% of such journeys, while two-wheelers make up another 8.8%.

Railway use is significantly higher among urban households. About 22.7% of urban households use rail for overnight journeys, compared with around 14% of rural households.

Overnight journeys, however, are largely not undertaken for tourism. The survey found that 70.2% of



The survey found that 70.2% of overnight household trips are for social, communication, and religious purposes. FILE PHOTO

overnight household trips are for social, communication, and religious purposes. Culture, leisure, sports and tourism account for just 7.4% of such trips.

The daily commute

The pattern changes sharply when it comes to daily travel to work. Two-wheelers are the dominant mode of transport for workers, accounting for 42.6% of journeys. Their share rises to 52.3% among urban workers, compared with 37.1% in rural areas.

Public transport has a much smaller share of daily workforce mobility nationally. Buses account for

6.7% of work trips, while trains, the monorail, and trams together account for 2.1%. However, urban mass transit is considerably more important in some States and cities.

In Maharashtra, metro, suburban rail, monorail, and trams account for 20.7% of urban worker commutes, followed by West Bengal at 16.5% and Delhi at 14.4%, against the national urban average of 5%.

The survey also shows that most Indians have relatively short daily commutes.

The average journey to a fixed workplace takes 25

minutes, with the average rising to 27 minutes in urban areas.

The average monthly expenditure on commuting to a fixed workplace is ₹785 per worker.

Urban workers spend substantially more, at ₹1,044 a month, compared with ₹612 for rural workers. Male workers spend an average of ₹835 on their commute each month, against ₹533 for female workers.

The survey also highlights a gender disparity in workforce mobility. While 61.9% of male workers undertake work-related trips of more than one kilometre, the corresponding share for women is only 41.9%.

There is also a gender gap in commuting expenditure: male workers spend an average of ₹835 a month, compared with ₹533 for female workers.

The National Household Travel Survey, conducted between July 2025 and June 2026, covered 4,92,023 households and 20,34,371 people across 14,274 villages and 10,377 urban blocks.

GS 3: DEFENCE

THE HINDU PAGE: 06

DRDO's flight trial of high-altitude platform successful

The Hindu Bureau
NEW DELHI

The Defence Research and Development Organisation (DRDO) has successfully carried out the flight trial of an indigenously developed High-Altitude Platform (HAPS), with the experimental platform reaching an altitude of 21 km above mean sea level and remaining at 20 km for more than 30 minutes.

The Defence Ministry said the platform, developed by the Aerial Delivery Research and Development Establishment, Agra, was a lighter-than-air system being designed as a long-endurance stratospheric aerial surveillance platform. The platform carried several instrumentation and control electronic systems, including an inertial measurement unit, Global Positioning System receiver, onboard



The High Altitude Platform System. DRDO

cameras and an altitude-control mechanism, besides other subsystems.

'Key milestone'

Defence Minister Rajnath Singh congratulated the DRDO, the IAF, public sector undertakings and industry involved in the trial, describing the achievement as an important milestone in India's Aatmanirbhar Bharat drive.

GS 1: HISTORY

THE HINDU PAGE: 07

Silk Road: Eurasia's web of trade



Cultural crossroad:
The main routes of the Silk Road.
KELVIN CASE
(CC BY-SA)

Vasudevan Mukunth

Contrary to the name, the Silk Road was a network of multiple land and maritime trade routes connecting parts of east, central, south, and west Asia. The network took different shapes over more than a millennium but became especially important from around the second century BC, when China's Han dynasty expanded west and established contacts with Central Asian states. Because Chinese silk was a prized commodity then, the network was called the Silk Road. Since it offered well-travelled roads, the Silk Road also became the routes that technologies, religions, artistic styles, languages, and natural philosophy took to spread across Eurasia. It is in fact how papermaking spread out from China, as did how Buddhism travelled from India through Central Asia into China. Christianity, Manichaeism, and later Islam also

spread along parts of the network — just like musical traditions, and astrological and medical knowledge.

The network also benefited from the Mongol Empire bringing much of Eurasia within a connected political system in the 13th and 14th centuries, and encouraged long-distance journeys. The Road's import gradually declined by the early modern period as trade became cheaper over sea routes, especially in the Indian Ocean, while political conditions changed on land. Even so, the network proved instrumental to make premodern Eurasia as economically and culturally interconnected as it had become, despite its size.

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GS 2: POLITY

THE HINDU PAGE: 08

Twenty-five years of leadership, an India transformed

In my 48 years in public life, I have seen political parties rise and fall. I have seen leaders emerge with great promise and fade away. I have seen governments change, economies transform and technology alter our lives beyond recognition. One lesson has become increasingly clear to me: ultimately, leadership matters.

In today's world, technology, knowledge, capital and ideas are freely available. But the true differentiator for nations is leadership – one with vision, integrity, credibility and the ability to execute.

On October 7, 2026, Prime Minister Narendra Modi completes 25 uninterrupted years in executive office – first as Chief Minister of Gujarat and, since 2014, as the Prime Minister of India. It is a remarkable journey of leadership sustained by public trust. Through changing circumstances, Mr. Modi has remained remarkably consistent in his purpose: the development of India and the empowerment of its people.

The world around us has been turbulent. We have witnessed a global financial crisis, a once-in-a-century pandemic, wars, geopolitical realignments, technological disruption and economic uncertainty. Several democracies have experienced frequent changes of leadership and consequent policy uncertainty. Through all this, India has remained steady at the wheel and an oasis of economic hope.

Leadership built on trust

Such stable leadership cannot sustain itself for 25 years merely through politics. It requires trust. Mr. Modi has earned that trust through an established track record, impeccable personal integrity and tireless self-discipline. In today's world, public leaders effectively live in glass houses. Every decision and every action can be seen and questioned. To retain the confidence of people over decades under such scrutiny is an achievement in itself.

Mr. Modi brings a unique ability to understand people's aspirations, translate them into action and communicate those results back to the people.

The results are visible. Over the last decade, India's National Highway network has expanded from about 91,287 kilometres in 2014 to more than 1,46,000 km. The airport network has grown from 74 airports in 2014 to over 160. Railway electrification has accelerated dramatically. India's installed renewable-energy capacity has now reached nearly 296 GW,



N. Chandrababu Naidu

The Chief Minister of Andhra Pradesh

including large hydro, with solar alone crossing 168 GW. Infrastructure today is being conceived not as isolated projects but as an integrated national network through initiatives such as PM Gati Shakti (Prime Minister Gati Shakti – National Master Plan for Multi-Modal Connectivity).

At the same time, India's welfare architecture has expanded basic security and dignity. Around 80 crore people receive free foodgrains, including five kilograms a person per month for eligible priority households. Tapwater coverage in rural homes has risen from about 17% in 2019 to over 82%. An estimated 24.8 crore Indians moved out of multidimensional poverty between 2013-14 and 2022-23. The significance lies not only in the scale of these programmes, but in their reach. Technology has enabled the State to deliver basic entitlements more directly, transparently and at a scale that was once unimaginable.

Technology in nation-building

Mr. Modi has a deep appreciation of technology and its role in transforming India. He understands emerging technologies, adopts them early and, more importantly, applies them to nation-building. He sees technology as a tool to improve governance, empower people, create opportunities and accelerate development. India's Digital Public Infrastructure has shown how technology can democratise access to banking, welfare and public services at unprecedented scale. This deep appreciation of technology has enabled him to launch a host of frontier policies aimed at making India take a giant leap and put it in the league of global tech titans. India's quantum mission, semi-conductor mission, and a host of Production Linked Incentive (PLI) schemes across electronics and advanced manufacturing are instances of this vision.

India's space sector is another great example. For decades, India's extraordinary capabilities in space were centred overwhelmingly around government. By opening the sector to private enterprise and creating an enabling ecosystem, the government has unleashed a new generation of entrepreneurs. Companies such as Skyroot Aerospace, Pixxel, Agnikul, Dhruva and Bellatrix demonstrate what young Indians can achieve when regulation gives way to innovation.

As a Chief Minister first and then a Prime Minister, Mr. Modi has a strong belief in "Team India". He knows that India cannot be transformed from Delhi alone. Growth needs to be decentralised with States and cities

competing. His emphasis on cooperative and competitive federalism has given States a larger role in India's development journey.

India's place in the world

In his tenure, India's stature abroad has also changed profoundly. Today, India's voice is heard with greater respect on global platforms. India protects its national interest while engaging with different centres of global power, preserves strategic autonomy while building deeper partnerships, and projects its civilisational confidence as a modern, technology-driven nation. India today is among the world's fastest-growing major economies. But I believe the most consequential phase of our journey is still ahead.

Few countries possess India's combination of strengths. It has a demographic dividend, an extraordinary entrepreneurial energy, technological capabilities and a young generation that is ambitious, confident and increasingly connected to global opportunity. If we make the right decisions now, the benefits will last for centuries. This is why leadership at this moment assumes historic importance.

Mr. Modi's 25 years in executive leadership have demonstrated the qualities such a moment demands. The Narendra Modi who became Chief Minister of Gujarat on October 7, 2001, and the Prime Minister leading India today are connected by the same clarity of purpose and unshakeable belief in India's potential.

Twenty-five years have established his record. The next 20 years can establish India's place in history. The true significance of these 25 years, however, will be judged by what they enable India to achieve next. Mr. Modi has shifted the country's development trajectory – from incrementalism to ambition, from hesitation to confidence, and from managing limitations to believing in possibilities. I am confident that the direction he has set and the institutional momentum created during these years will help India realise its ambition of Viksit Bharat 2047 and reclaim its place among the world's leading nations.

Few leaders are given the opportunity to shape a generation. Rarer still are those who can shape the destiny of a nation. After 25 years of leadership, Mr. Modi's greatest contribution may ultimately be that he made India believe once again in the scale of its own possibilities – and gave the nation the leadership to turn that belief into reality.

Prime Minister Narendra Modi's 25 years in leadership reflect India's transformation and its rising national ambitions

GS 2: INTERNATIONAL RELATIONS

THE HINDU PAGE: 08

The China-U.S. rapprochement

The world, understandably, has been watching carefully the unfolding summitry between the United States and Chinese Presidents over the last several months. It had been a long time between drinks: just under a decade in the case of President Donald Trump's last visit to Beijing in late 2017; and just over a decade since President Xi Jinping stood on the White House lawns in 2015 with President Barack Obama.

Whereas now it is four summits in little more than six months: Beijing, Washington, Shenzhen and then Miami. Now it is everything, everywhere, all at once, with some speculating that we are seeing the birth of a new G-2.

More a new phase

It is natural for the world to wonder what, if anything, has fundamentally changed in the strategic architecture of the U.S.-China relationship. It is always hard to parse the difference between the language and theatre of politics and diplomacy, and what is actually happening on the ground.

Despite the pomp and circumstance in both the Beijing and Washington summits, the reality is that nothing much has changed in the fundamentals of the relationship. Whatever public language might be used, the U.S. and China remain fully engaged in an all-pervasive strategic competition on which of them will emerge as the dominant Indo-Pacific and then global power for the 21st century – militarily, in the economy, technology, foreign policy as well as the underlying ideological contest between democratic capitalism and China's alternative authoritarian model.

Whatever the diplomatic surround sound might be, core decision-makers in both Washington and Beijing continue to have a deeply realist view of this ongoing strategic contest – or what the Chinese Communist Party (CCP) has long called the "struggle for the future of the international order". Strategic competition is not going away. The real question is whether that competition can be managed within the framework of some mutually acceptable rules of the road. Or whether it is left unmanaged with a rolling risk of crisis, conflict or even war.

What the U.S. and China appear to be doing is moving towards an imperfect form of bilateral management mechanism. This process began in



Kevin Rudd

Global President and CEO of Asia Society, New York, and the 26th Prime Minister of Australia

There is no 'G-2' yet in U.S.-China relations – Washington and Beijing may manage their tensions, but their strategic competition remains entrenched

May last year with the regularisation of the political channel between U.S. Treasury Secretary Scott Bessent and Chinese Vice Premier He Lifeng. This followed the imposition of trade-destroying tariffs of 125% in April 2025 by Mr. Trump, which were then promptly matched by 125% from Mr. Xi. To preserve their respective national economic interests, both sides then walked back from the brink of a full trade war. Since then, Mr. Bessent, Mr. He and their teams have now met eight times – on average every two months. And after a tumultuous decade across every dimension of the relationship, the Bessent-He channel has indeed had a stabilising effect.

Beijing's push for stability

China in particular has sought stability as it moves into 2027. Later next year, the CCP convenes the 21st Party Congress when Mr. Xi will be appointed to a record fourth term as General Secretary and where he hopes to appoint a fresh phalanx of personal loyalists to the party's most senior positions. While Mr. Xi's authority remains unchallenged, he will want as benign a domestic economic environment as possible.

China's dilemma is that the domestic drivers of economic growth are performing poorly. Private domestic consumption is in the doldrums. Private residential construction is into its sixth year of recession. Private fixed capital investment is also flat-lining. That leaves public investment (i.e., China's gargantuan techno-industrial strategy) and net exports as the two primary pistons driving the Chinese growth engine.

The last thing Beijing wants is for the U.S. to resume a full-scale trade war which Mr. Trump is perfectly capable of doing. Just look at what he did in 2018 and in 2025. China therefore has been doubling down on its "stability narrative" with the U.S. Its new concept of "constructive strategic stability" is about maximising "cooperation", managing "competition within defined bounds", while also managing "strategic differences", which is code language for Taiwan. In China's conceptual universe, if these three pillars are properly attended to, then the cardinal objective is achieved: stability.

It is an elegant schemata. It is China's effort at "managed strategic competition" with the U.S. Moreover, the U.S. has formally accepted this framework in official readouts from the Beijing

Washington Summits. But the U.S. has added the explicit caveat that any such bilateral framework be both "fair and reciprocal".

For Washington realists, that is enough to drive a bus through any "constructive strategic stability" narrative on any day of the week. Furthermore, Beijing would be wildly optimistic if it concluded that Donald Trump is likely to be constrained in his future freedom of manoeuvre because of some grand, overarching foreign policy narrative. The President just does not operate that way.

A fragile truce

What concerns China most is if what is called the "Busan Tariff Truce" agreed to last October falls apart. That original 12-month truce has only been extended two months. If the U.S. concludes that China has not been helpful on U.S. agricultural exports, or in the normalisation of the critical minerals and rare earths trade with the U.S., there is a real risk that the Busan Truce collapses. And if the European Union were to move in the same direction on tariffs given the crisis in European manufacturing, the consequences for an export-dependent Chinese economy would be large.

For all these reasons, both tactical and strategic, the U.S.-China relationship remains deeply fragile. Even if the Busan Truce extends beyond December, the effective general U.S. tariff rate against China will remain much, much higher than, for example, India's. Beyond trade, there also remains a formidable array of export controls on critical technologies, including world-class chips where China remains several years behind the U.S. And that leaves to one side a bilateral foreign investment regime which remains deeply restrictive at both ends of the relationship.

Therefore, breathless reporting about an emerging "G2" between the U.S. and China in some sort of global strategic condominium is fanciful. Whatever tactical accommodations may occur in the trade relationship, the fundamental nature of the strategic competition between Washington and Beijing continues. Remember it was Donald Trump, on the very eve of Mr. Xi's state visit to Washington DC, who stated, "Whoever wins in AI, wins." That is Xi Jinping's view too. That does not exactly sound like an emerging G-2 to me.

GS 3: SCIENCE AND TECHNOLOGY

INDIAN EXPRESS PAGE: 04

• NOBEL PRIZE IN PHYSICS

Through 'ghost particles' in ice, window to universe

Francis Halzen found a new way to study neutrinos, the elusive particles that can reveal the mysteries of the cosmos, under Antarctic ice sheets



AMITABH SINHA

NEUTRINOS, VERY small sub-atomic particles produced mainly in nuclear reactions in stars, are among the most abundant particles in the universe, second only to photons (or light particles). And they can reveal a huge amount of new information about the universe. The problem has been that they are extremely difficult to detect, the reason they are often described as ghost particles.

The quest to detect neutrinos, and attempts to study them, have already led to several Nobel Prize wins. Another one was added on Tuesday, with the 2026 Nobel Prize in Physics being awarded to Francis Halzen, a Belgian-American scientist who designed an elaborate set-up under ice sheets in Antarctica to detect these elusive particles.

The IceCube facility in Antarctica is not the first observatory to detect neutrinos. Neutrinos were first proposed in the 1930s and first detected in the 1950s. Several observatories around the world are dedicated to detecting and studying these particles.

Studying distant space

What the IceCube facility managed to do was something unique. It was successful in detecting a special variety of high-energy neutrinos that was coming from far away in space. Till now, only those neutrinos that originated in the close vicinity of the Earth, primarily being produced in the Sun, were being detected. Most of the neutrinos passing through the Earth are produced in the nuclear processes inside the Sun.

For scientists, the detection of extra-galactic neutrinos has opened a new source of information about the universe. Initially, visible light was the only tool available to scientists to study the cosmic phenomena. Then, detectors were developed for the full electromagnetic spectrum of radiation and for cosmic rays. The detection of gravitational waves in 2015 opened an entirely

• 'For decisive contributions to the IceCube Neutrino Observatory and the discovery of high-energy neutrinos of astrophysical origin'



"His idea was to use glacial ice at the South Pole to capture the secretive particles called neutrinos. The result was the IceCube Neutrino Observatory, which can track neutrinos that originate in the distant cosmos."



FRANCIS HALZEN, 82
University of Wisconsin-Madison,
Madison, US.

ON WEDNESDAY:
NOBEL PRIZE IN CHEMISTRY



The IceCube Neutrino Observatory at the Amundsen-Scott South Pole Station, in Antarctica. ICECUBE/NSF

new window for scientists looking at the universe. Extra-galactic neutrinos add another dimension of possibilities.

Together these different kinds of signals enable what is called multi-messenger astronomy, the ability to study the same cosmic event using different kinds of signals, said D Indumathi, a scientist at the Bengaluru-based Indian Institute of Astrophysics who was formerly associated with India's effort to build a neutrino detector.

'Shy' particles

The reason neutrinos are so difficult to detect is that they have an extremely low propensity to interact with matter. The Nobel Prize committee described them as the "shiest particle". They simply pass through very dense regions of matter without any disturbance.

A very common example often cited is the fact that nearly 65 billion neutrinos pass through human finger nails every second without anyone ever noticing. Because they are also electrically neutral, they do

'Shy' particles

Neutrinos are difficult to detect because of their extremely low propensity to interact with matter.

They simply pass through dense regions without disturbance. Nearly 65 billion neutrinos pass through your fingernails every second.

not respond to electromagnetic fields the way charged particles do.

The detections happen on the very rare occasions that they do interact with matter. That happens to, maybe, one in billions or trillions of neutrinos. That is why neutrino observatories the world over are very large facilities, built in extremely isolated, often underground locations, that maximise the chances of interaction and minimise noise.

The elusive nature of neutrinos is also what makes them particularly interesting to study. They pass through regions of cosmic space that other signals may never be able to cross. Very dense regions in space, for example, can absorb or scatter all electromagnetic radiations, but neutrinos simply flow through. They can thus reveal processes happening within or beyond that dense region, which are otherwise inaccessible to scientists.

The IceCube facility

The 82-year-old Halzen, who had been studying cosmic rays since the 1960s, came

to know of the attempts of Soviet researchers to build a neutrino detector in Antarctica, a press release from the Nobel Prize committee said. When a neutrino collides with an atomic nucleus in the ice, it creates an electric spark. This produces radio waves which could be detected using radio antennas.

Halzen thought of a slightly different idea. He realised that light sensors could be installed in glacier ice. These sensors could produce flashes of light from collisions of neutrinos with the nucleus of ice atoms. The area around the South Pole was a favourable location. It was isolated and, at significant depths, there was a lot of darkness with no disturbance from other radiations or signals.

He discussed his ideas with some of his colleagues and did most of the theoretical work on designing an observatory deep below the ice sheets. IceCube is one cubic kilometer of ice equipped with over 5,000 light sensors on long cables, along with an overground facility where signals are collected. On the rare occasion when the neutrino interacts with an atomic nucleus of ice, a charged particle is produced. If that charged particle travels faster than the speed of light in ice, it produces a faint glow. From the characteristics of this glow, scientists are able to reconstruct the energy and direction of the neutrino involved in the collision.

This exquisite set-up became operational in 2011. By that time, it had already recorded a couple of events that suggested the involvement of extra-galactic neutrinos. In 2013, the observatory presented the first evidence of having detected very high-energy neutrinos. Since then several such incidents have been recorded and verified.

"It's a very special detector and the work that Halzen has done is really very exciting. It has opened new avenues for astronomy and astrophysics," said Naba K Mondal, former project director of India-based Neutrino Observatory (INO), a much-delayed effort to build a neutrino detector in India. "In neutrino research circles, this award to Halzen was expected for a few years." INO was supposed to be located initially in Kerala and then in Tamil Nadu but ran into opposition from local and political groups over land acquisition and environmental grounds. A new location is yet to be finalised.