मई
May
2025

खंड/Vol. : 50 अंक/Issue :79

02/05/2025

समाचार पत्रों से चयनित अंश
Newspapers Clippings

डीआरडीओ समुदाय को डीआरडीओ प्रौद्योगिकियों, रक्षा प्रौद्योगिकियों, रक्षा नीतियों, अंतर्राष्ट्रीय संबंधों और विज्ञान एवं प्रौद्योगिकी की नूतन जानकारी से अवगत कराने हेतु दैनिक सेवा

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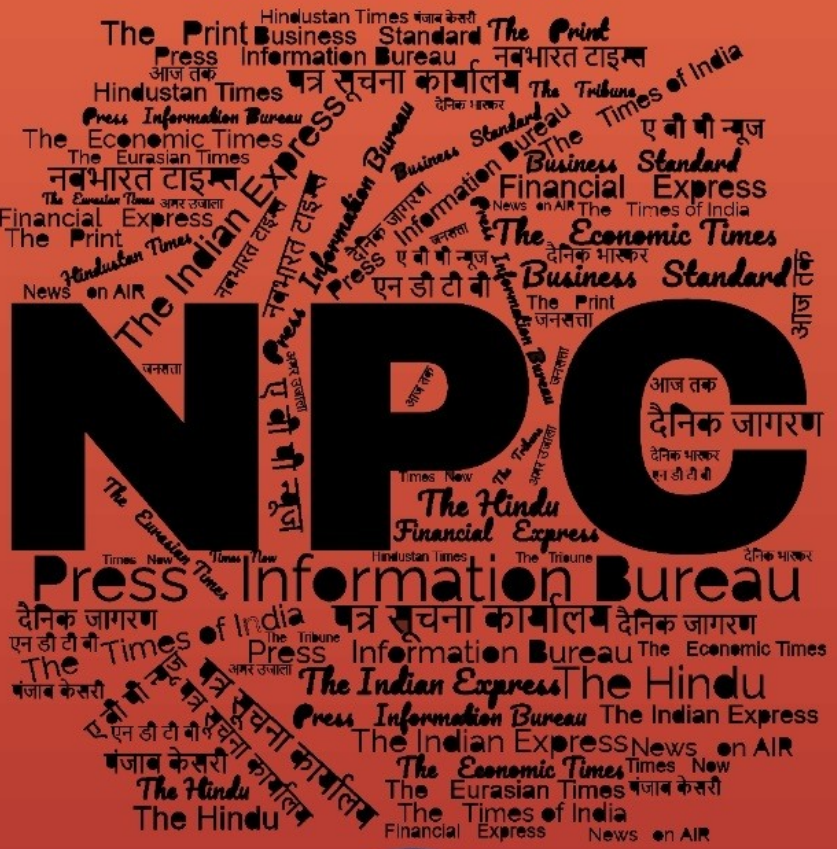

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Defence News

Defence Strategic: National/International

US clears $131 million sale of defence software, equipment to India

Source: The Times of India, Dt. 02 May 2025,
URL: https://timesofindia.indiatimes.com/india/us-clears-131-million-sale-of-defence-software-equipment-to-india/articleshow/120803517.cms

Trump administration has approved the proposed sale of Indo-Pacific maritime domain awareness related software and equipment worth $131 million to India.

Given its increasing role in the crucial Indo-Pacific region, India had recently requested the US for purchase of the SeaVision software, technical assistance field team training, remote software and analytic support, and other related elements of logistics and programme support.

"This proposed sale will support the foreign policy and national security objectives of the US by helping to strengthen the US-Indian strategic relationship and to improve the security of a major defence partner which continues to be an important force for political stability, peace, and economic progress in the Indo-Pacific and South Asia regions," the US defence security cooperation agency said in a notification to US Congress.

The proposed sale will improve India's capability to meet current and future threats by bolstering its maritime domain awareness, analytical capabilities, and strategic posture, the agency added.

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'We stand with India': US Defence Secy Hegseth speaks to Rajnath Singh, offers "strong support"

Source: The Economic Times, Dt. 02 May 2025,
URL: https://economictimes.indiatimes.com/news/defence/we-stand-with-india-us-defence-secy-hegseth-speaks-to-rajnath-singh-offers-strong-support/articleshow/120807785.cms

US Secretary of Defence Pete Hegseth spoke to Defence Minister Rajnath Singh and extended condolences over the loss of lives in the terror attack in Pahalgam in Jammu and Kashmir.

Further, Defence Secretary Hegseth reiterated the United States' "strong support" to India.

In a post on X, Hegseth said, "Today, I spoke with Indian Defence Minister Singh @rajnathsingh to personally extend my deepest condolences for the loss of life in the heinous terrorist attack last week. I offered my strong support. We stand with India and its great people."

This comes amidst mounting tensions with Pakistan following the April 22 terror attack in Pahalgam in Jammu and Kashmir in which 26 people were killed.

Meanwhile, the Pakistan's military is continuing its build-up on the borders with India and has deployed air defence and artillery units at forward locations.

Directors General of Military Operations of India and Pakistan talked over the hotline on Tuesday to discuss the unprovoked ceasefire violations by Pakistan, defence sources said on Wednesday. They said India warned Pakistan against the unprovoked ceasefire violations by the Pakistan Army along the Line of Control (LOC) and the International Border.

The Indian Army has effectively responded to the Pakistan Army's unprovoked small arms firing across the Line of Control (LoC). The Army responded swiftly to the ceasefire violation on the night of April 27-28 in areas opposite Kupwara and Poonch districts in Jammu and Kashmir (J-K), officials said.

On Wednesday, External Affairs Minister S Jaishankar held a telephonic conversation with US counterpart Marco Rubio and discussed the recent terror attack that took place in Jammu and Kashmir's Pahalgam.

Jaishankar stated that the perpetrators, backers, and planners of the attack must be brought to justice.

"Discussed the Pahalgam terrorist attack with US @SecRubio yesterday. Its perpetrators, backers and planners must be brought to justice," Jaishankar posted on X.

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Solving the “Made In” dilemma for drones

Source: The Economic Times, Dt. 01 May 2025,
URL: https://economictimes.indiatimes.com/news/defence/solving-the-made-in-dilemma-for-drones/articleshow/120786185.cms

Just a few weeks ago, social media was abuzz with the rumour of an Indian defence drone of Israeli origin being hacked by China, which was refuted by the Army. Weeks prior to that, the government had reportedly scrapped deals for 400 defence drones with parts made in China. These may be unrelated, but an urgent review of the drone policies is imminent, especially with the pervasive use of Chinese sub-systems in domestic drones.

Drones or Unmanned Aerial Vehicles (UAVs) are not just modern warfare or surveillance tools, but are redefining efficiency and strategy across multiple sectors ranging from logistics to agriculture and commercial innovation. The numbers speak volumes: In 2024, India’s drone market was about $1.6 billion, it is projected to soar to $4.8 billion by 2030, at a CAGR of 20.4%. Even more staggering is the drone services market – another $4 billion by 2030.

“Make in India” has been the national narrative for some time now, and it has emerged as a transformative initiative for the Indian defence industry, aiming to bolster self-reliance and reduce dependency on imports by focusing on indigenous design, development, and manufacturing. This has triggered an increase in the indigenous content of the various defence equipment and systems while reducing the import dependencies.

While this campaign has delivered some positive results, it is critical to evaluate the deep tech and sensitive domains like drones from a more granular perspective than a blanket mandate of domestic manufacturing. With defence and surveillance drones, it becomes crucial to consider the national security and strategic autonomy of the supply chain before the economic consideration of indigenisation.

As drones are increasingly used by the Indian armed forces and law enforcement agencies, they are most vulnerable to malicious attacks, including hacking or GPS blockers. The most imminent threat is cyber-attack that can neutralise entire fleets of drones. Worse, it can be controlled by the rogue agents to create damage to the forces and critical infrastructure. Recent incidents of the pager attacks in Gaza and reports of Chinese hacking of Indian drones highlight this risk.

The most effective safeguard is securing the supply chain, especially for critical components that handle data and control systems. Continued reliance on parts from adversarial nations like China increases the likelihood of large-scale breaches. Anything that can trigger an adverse action based on location, date, time or scene can be a potential hazard. Globally, most countries are limiting critical Chinese tech in drones – the US has banned Chinese drones for government sector use, citing security risks. EU and Australia are putting in similar policies. But, many Indian drones still rely on Chinese components, to the tune of over 70%. This must change urgently. The government should enforce strict import bans, buyers must specify country of origin clause in tenders, and the industry must either identify alternate sources and fast-track alternatives or build indigenous manufacturing capabilities.

Further, India remains dependent on imports for a range of non-critical yet hi-tech components, which is an Achilles’ heel that exposes the nation to sanctions and embargoes amidst ever-changing geopolitics. To preserve strategic autonomy, even these seemingly peripheral technologies must be indigenised. Reorienting the armed forces' outlook from one of parity to one of superiority is key.

The desired reduction in import reliance and the resulting saving of foreign exchange will only materialise once the above twin objectives are met. Notably, the current Defence Acquisition Procedure (DAP) already embeds provisions to ensure indigenous content within procurement cycles. Hence, launching a parallel, nationwide initiative solely to boost localisation would be a suboptimal deployment of institutional bandwidth and national resources.

The time is ripe for the government to reassess and future-proof the drone policy in order to drive an environment that encourages innovation and localisation. Emphasising the use of locally designed, developed, and manufactured drones will address India’s unique geographical, climatic, and operational challenges and also boost global competitiveness, which will drive exports, and promote international collaborations. Ultimately, indigenisation is more than just a policy objective; it’s a strategic imperative to secure the nation’s technological and economic future.

To realise this vision, India must adopt a comprehensive strategy that covers the following:

- The best-in-class mindset: MoD must embrace a mindset that strives for best-in-class procurement of critical systems like drones. When the requirements from the end users and buyers are of high standards, the industry automatically acquire the expertise to innovate with localised R&D. Autonomous drone tech and swarm intelligence systems are the vogue globally and India must match this to be at par with China or the USA.
- Financial incentives: Although India has a dismal record of funding R&D, sunrise industries like the drones deserve special grants and assistance to build capacity and indigenisation. Consider bringing the PLI schemes and tax incentive schemes to encourage capex commitments. Some analysts believe a budget of Rs 8000 Cr is needed for driving advanced Defence R(D.
- Adoption and sustained demand: Sustained demand is crucial for any budding industry to develop further. Currently, drone makers are challenged with a sub-optimal rate of adoption, which hinders speed of development. The government must assume the role of demand generator by mandating drone use in border security, surveillance and infrastructure monitoring.
- Export policy and “Made in India” branding: Make sure that Indian regulations for drones follow the global standards such as FAA/EASA to drive exports to lucrative markets like North America and Europe. Markets like Africa and SE Asia could be primed for “Made-in-India” drones if cost effectiveness and safety can be ensured – as an alternative to Chinese products.
- Stringent enforcement of policies: Policy without execution is futile. Though the government has banned drone imports, Chinese drones continue to be procured via the government’s eMarketplace portal, often under the radar. Enforcing rules with intent and rigour is critical to avoid such loopholes.

The question is not whether India can design and manufacture world-class drones, but of scaling up to become a global leader. The government must act decisively at this juncture by taking a stand: Innovate or remain dependent?

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Pakistan continues military buildup along Indian border, Chinese howitzers being inducted in artillery regiments

Source: The Economic Times, Dt. 01 May 2025,
URL: https://economictimes.indiatimes.com/news/defence/pakistan-continues-military-buildup-along-indian-border-chinese-howitzers-being-inducted-in-artillery-regiments/articleshow/120795019.cms

As tensions between India and Pakistan rise in the wake of the Pahalgam terror attack, the Pakistmilitary is continuing its build-up on the borders with India and has deployed air defence and artillery units at forward locations.

The Pakistani military has deployed radar systems and air defence weapon systems opposite the Longewala sector, Barner in Rajasthan, defence sources told ANI.

The Pakistan Air Force is currently conducting three exercises simultaneously: Fiza-e-Badr, Lalkar-e-Momin, and Zarb-e-Haidari. These exercises involve all major fighter aircraft fleets, including the F-16, J-10, and JF-17.

These exercises started on April 29 and are seeing participation of the Saab airborne early warning and control systems aircraft. The Pakistan Army Strike Corps elements are also carrying out training in their areas of responsibility, they said.

The Pakistani military has also deployed the Airport Security Force for the protection of ground assets and the peripheral security of the air bases. The SH-15 howitzers from China continue to be inducted into the Pakistan Army and the units are getting deployed in forward locations.

Tension escalated between India and Pakistan following Pahalgam terror attack on April 22 in which 26 people were killed. Cabinet Committee on Security (CCS) met on April 23 and was briefed in detail on the terrorist attack in Pahalgam.

The CCS condemned the attack in the strongest terms and expressed its deepest condolences to the families of the victims and hoped for the early recovery of the injured. In the briefing to the CCS, the cross-border linkages of the terrorist attack were brought out. It was noted that this attack came in the wake of the successful holding of elections in the Union Territory and its steady progress towards economic growth and development.

The government has said that the terrorists responsible for the attack and the conspirators behind it will face severe punishment The government has announced a series of measures, including putting the Indus Water Treaty in abeyance, to send a strong message to Pakistan for its support to cross-border terrorism.

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India Deploys Advanced Jamming Systems On Western Border To Disrupt Satellite Navigation Used By Pakistani Military Aircraft: Report

Source: Swarajya, Dt. 01 May 2025,
URL: https://swarajyamag.com/news-brief/india-deploys-advanced-jamming-systems-on-western-border-to-disrupt-satellite-navigation-used-by-pakistani-military-aircraft-report

In a bid to degrade the navigational and strike effectiveness of Pakistan air force, India has deployed advanced jamming systems near its western border to interfere with Global Navigation Satellite System (GNSS) signals used by Pakistani military aircraft, India Today reported citing sources.

This deployment follows India's decision to close its airspace to all Pakistani owned and operated flights, a ban effective from 30 April to 23 May.

Indian jamming systems are capable of disrupting the multiple satellite-based navigation platforms — GPS, GLONASS and Beidou — which are used by Pakistani military aircraft, according to the sources cited in the India Today report.

The intended outcome, they said, is to cripple Pakistan's situational awareness targeting accuracy, and the effectiveness of its precision-guided munitions during any potential conflict or incursion.

Tensions have escalated between the two nations after the 22 April terror strike in Pahalgam in which 26 people were killed.

India on Wednesday issued a NOTAM (Notice to Airmen) restricting its airspace, effective from 30 April to 23 May, to all aircraft registered, operated, or leased by Pakistan - including commercial airlines and military flights.

The tit-for-tat move came nearly a week after Pakistan barred Indian flights from its airspace.

Officials noted that Pakistan-based carriers had already started rerouting to avoid Indian airspace due to concerns over potential Indian retaliation.

With the ban now in effect, Pakistani airlines will now have to traverse longer, more expensive routes over Chinese or Sri Lankan airspace to access Southeast Asian cities such as Kuala Lumpur.

The airspace ban joins a suite of Indian responses after Pahalgam terror attack, including suspending the Indus Waters Treaty and cancelling visas granted to Pakistani citizens.

The brunt of the disruption is expected to fall on Pakistan International Airlines (PIA), which operates a modest fleet of 32 aircraft.

Flight times from Pakistan to Southeast Asia and East Asia are likely to increase by 60 to 120 minutes.

These extended routes will mean higher fuel consumption, stretched crew duty hours, and could prompt flight cancellations or reduced frequency.

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Army, IAF Dhruv choppers cleared for flying

Source: Hindustan Times, Dt. 02 May 2025,
URL: https://www.hindustantimes.com/india-news/army-iaf-dhruv-choppers-cleared-for-flying-101746126065103.html

The army and the air force's Dhruv advanced light helicopter (ALH) fleets, grounded nearly four months ago following a fatal coast guard crash in Gujarat, have been declared airworthy, Hindustan Aeronautics Limited (HAL) said on Thursday.

The development comes at a critical moment as the Indian military readies plans to respond to Pakistan in the aftermath of the Pahalgam terror attack.

The navy and coast guard's ALHs are still grounded. The development comes at a critical moment as the Indian military readies plans to respond to Pakistan in the aftermath of the Pahalgam terror attack.

"The Dhruv ALH army and IAF versions are cleared for operations based on the recommendations of the defect investigation committee recommendations," the state-run plane maker said.

A time-bound plan for the resumption of operations has been worked out with the users, it added.

Before the clearance came, the army had already begun flying its ALHs in Jammu and Kashmir to address urgent operational needs a day after the April 22 Pahalgam terror attack that killed 26 people.

HT had reported on April 2 that investigators were struggling to determine the root cause of the January 5 accident in which two coast guard pilots and an aircrew diver were killed.

A high-powered panel earlier found that a swashplate fracture caused the coast guard ALH crash at Porbandar in Gujarat on January 5. The reason for the breakdown of the critical component, which compromised the ability of the pilots to control the helicopter's motion, was not immediately known.

Earlier HAL, which has designed and developed the ALH, involved Bengaluru-based Indian Institute of Science (IISc) to perform fatigue testing of a critical part in the twin-engine helicopter's transmission system to get to the bottom of the matter.

The prolonged grounding of the workhorse fleet was a setback for the three services and the coast guard, which together operate around 330 ALHs.

A fleet-wide inspection conducted after the January 5 crash revealed that some navy and coast guard ALHs were facing the same problem --- cracks in the swashplate assembly --- and this could be linked to sustained operations in a saline environment.

HT was the first to report on February 4 that a detailed analysis by the Council of Scientific and Industrial Research-National Aerospace Laboratories (CSIR-NAL), Bengaluru, pointed to a swashplate assembly failure.

The ALH underwent a design review followed by a replacement of a defective control system only in 2023-24.

The helicopter has been involved in around 15 accidents during the last five years, putting the spotlight on its safety record.

The coast guard suspended ALH operations following an accident last September when a helicopter crashed into the Arabian Sea near Porbandar.

Then too, two pilots and an aircrew diver were killed. The grounding was for a one-time check. The three services did not ground their fleets then.

Last September's accident, too, came after the design review that culminated in a critical safety upgrade on the ALH fleet, initiated by HAL. It involved installing upgraded control systems on the helicopters to improve their airworthiness. The comprehensive design review came after the ALH fleet was grounded several times in 2023 too after a raft of accidents called into question its flight safety record.

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राफेल में लगेगी BrahMos-NG मिसाइल, फाइटर जेट की मारक क्षमता और बढ़ेगी

Source: Aaj Tak, Dt. 01 May 2025,
URL: https://www.aajtak.in/defence-news/story/pakistan-trembles-as-rafale-jets-armed-with-brahmos-ng-missiles-gain-devastating-strike-power-dskc-2230319-2025-05-01

पाकिस्तान का खौफ बढ़ने वाला है. पहले राफेल फाइटर जेट की वजह से. अब उसमें खतरनाक ब्रह्मोस-एनजी (नेक्स्ट जेनरेशन) लगने वाली है. भारतीय वायुसेना (IAF) और नौसेना अपने राफेल विमानों में स्वदेशी ब्रह्मोस-एनजी (नेक्स्ट जेनरेशन) सुपरसोनिक क्रूज मिसाइल लगाने जा रही है.

राफेल बनाने वाली कंपनी डैसो एविएशन ने भारत की स्वदेशी हथियार प्रणालियों के एकीकरण की मांग को स्वीकार कर लिया है, जो राफेल की भारत में भूमिका को और मजबूत करेगा. 2026 में ब्रह्मोस-एनजी के परीक्षण और लखनऊ में नई उत्पादन सेंटर के साथ शुरू होगा. यह मिसाइल राफेल, सुखोई-30 MKI और तेजस Mk1A के लिए भारत की हवाई ताकत का आधार बनेगी.

ब्रह्मोस-एनजी: हल्का, तेज, और घातक

ब्रह्मोस-एनजी, ब्रह्मोस सुपरसोनिक क्रूज मिसाइल का हल्का और कॉम्पैक्ट संस्करण है. इस मिसाइल की प्रमुख विशेषताएं हैं...

वजन और आकार: 1.3-1.4 टन वजन, 6 मीटर लंबाई, और 50 सेमी व्यास—यह अपने पूर्ववर्ती से 50% हल्की और 3 मीटर छोटी है.

रेंज और गति: 290 किमी की रेंज और 3.5 मैक (4170 km/hr) की गति, जो इसे घातक बनाती है.

बहु-मंच उपयोग: हवा, जमीन, समुद्र और पनडुब्बी से लॉन्च करने की क्षमता.

उन्नत तकनीक: कम रडार क्रॉस-सेक्शन (RCS) और AESA रडार के साथ उन्नत सीकर, जो इसे स्टील्थ और सटीक बनाता है.

भारतीय वायुसेना ने 8,000 करोड़ रुपये की लागत से 400 ब्रह्मोस-एनजी मिसाइलों को खरीदने की योजना बनाई है. जिनकी डिलीवरी उत्पादन शुरू होने के पांच साल के भीतर होगी.

राफेल में स्वदेशी एकीकरण: एक रणनीतिक कदम

डैसो एविएशन का स्वदेशी हथियार प्रणालियों को राफेल-M (नौसेना) और राफेल C (वायुसेना) में लगाने का समझौता भारत की लंबे समय से चली आ रही चिंताओं को दूर करता है. पहले राफेल फ्रांसीसी हथियार जैसे 70 किमी रेंज वाली एक्सोसेट मिसाइल पर निर्भर था. ब्रह्मोस-एनजी की 290 किमी रेंज और सुपरसोनिक गति राफेल को दुश्मन के जहाजों और जमीन पर लक्ष्यों को सुरक्षित दूरी से निशाना बनाने की क्षमता देगी, जो अधिकांश वायु रक्षा प्रणालियों की पहुंच से बाहर है.

यह कदम भारत की रणनीति के अनुरूप है, जो राफेल बेड़े और घातक बनाएगी. नौसेना के 26 राफेल-M विमान INS विक्रमादित्य और INS विक्रांत से संचालित होंगे, जबकि वायुसेना के 36 राफेल C विमान अंबाला और हाशिमारा हवाई अड्डों पर तैनात हैं.

एकीकरण की प्रक्रिया और समयसीमा

ब्रह्मोस–एनजी का एकीकरण सबसे पहले सुखोई–30 MKI पर होगा, जिसके लिए 2025 के अंत या 2026 की शुरुआत में परीक्षण निर्धारित हैं. सुखोई–30 MKI अपनी भारी पेलोड क्षमता के कारण, तीन ब्रह्मोस–एनजी मिसाइलें ले जा सकता है. यह हवा से लॉन्च होने वाली मिसाइल का टेस्टबेड होगा.

सफल परीक्षणों के बाद इसे तेजस Mk1A और राफेल बेड़े में लगाया जाएगा. तेजस Mk1A जिसके 83 विमानों की डिलीवरी 2025 से शुरू होगी, एक ब्रह्मोस–एनजी ले जाएगा. राफेल शुरू में एक मिसाइल ले जाएगा, जिसे भविष्य में दो मिसाइलों तक बढ़ाया जा सकता है.

लखनऊ में उत्पादन सुविधा

ब्रह्मोस–एनजी का उत्पादन उत्तर प्रदेश के लखनऊ में 200 एकड़ में बन रही नई सुविधा में होगा. 2026 में चालू होने वाली यह फैक्ट्री सालाना 80–100 मिसाइलों का उत्पादन करेगी, जो घरेलू जरूरतों और निर्यात प्रतिबद्धताओं जैसे कि फिलीपींस को हालिया डिलीवरी को पूरा करेगी.

चुनौतियां और समाधान

राफेल में ब्रह्मोस–एनजी का एकीकरण तकनीकी रूप से जटिल हो सकता है. सुखोई–30 MKI में ब्रह्मोस–A का एकीकरण 2017 में पूरा हुआ. मैकेनिकल, इलेक्ट्रिकल और सॉफ्टवेयर संशोधनों के कारण देरी का शिकार हुआ था. राफेल के फ्रांसीसी सिस्टम और इंडो–रूसी मिसाइल के बीच संचार प्रोटोकॉल में अंतर एक चुनौती हो सकता है. इसके समाधान के लिए मध्यस्थ हार्डवेयर विकसित करने का प्रस्ताव है, जो डेटा संचार को सुगम बनाएगा.

रणनीतिक महत्व

ब्रह्मोस–एनजी का राफेल में एकीकरण भारत की रक्षा रणनीति में एक गेम–चेंजर साबित होगा. यह न केवल राफेल की मारक क्षमता को बढ़ाएगा, बल्कि भारत को क्षेत्रीय खतरों, विशेष रूप से हिंद महासागर और दक्षिण चीन सागर में चीन और पाकिस्तान की आक्रामकता का जवाब देने में सक्षम बनाएगा.

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Science & Technology News

IIA researchers chart Sun’s subsurface weather

Source: The Hindu, Dt. 01 May 2025,
URL: https://www.thehindu.com/sci-tech/science/iia-researchers-chart-the-suns-subsurface-weather/article69522295.ece

An international team of solar physicists led by the Indian Institute of Astrophysics (IIA) have traced giant tides of plasma beneath the Sun’s surface at a region called near-surface shear layer (NSSL).

According to a study published in the Astrophysical Journal Letters, the plasma’s currents shift with the Sun’s magnetic heartbeat and could have a far-reaching influence on space weather and earth.

"The near-surface shear layer (NSSL) extending to about 35,000 km in depth is a critical region beneath the Sun's surface. It is marked by distinct rotational behaviours that vary with depth and changes, over space and time, that relate to active region magnetic fields and the solar cycle," said the Department of Science and Technology.

It added that astronomers have probed the dynamic inner weather of the Sun — plasma currents just beneath its surface at the NSSL, that pulse in step with its 11-year sunspot cycle.Apart from IIA, researchers from Stanford University (USA), and the National Solar Observatory (NSO, USA) have traced how these hidden flows shift over time, potentially reshaping our understanding of solar dynamics in general and how the Sun's interior connects to its outer magnetic behaviour in particular.

Employing helioseismology — an advanced technique that tracks sound waves as they travel through the Sun — the team observed changes in the movement of solar material using more than a decade of data from NASA's Solar Dynamics Observatory/Helioseismic and Magnetic Imager (SDO/HMI) and the ground-based Global Oscillations Network Group (GONG) of National Solar Observatory (NSO), USA.

Fascinating patterns

The analysis led by Professor S.P. Rajaguru and PhD student Anisha Sen from IIA revealed fascinating patterns — surface plasma flows converge toward active sunspot latitudes, but reverse direction midway through the NSSL, flowing outward to form circulation cells.

"These flows are strongly influenced by the Sun's rotation and the Coriolis force — the same force responsible for the spin of hurricanes on earth," the department said.

"To validate our findings, we zoomed in on a massive sunspot region using 3D velocity maps. The localised flow patterns we observed matched the global trends — confirming both surface inflows and deeper outflows," said lead author Anisha Sen.

These findings give us a better understanding of how the Sun's magnetic activity is linked to its internal flows and hint that we might still be missing something lurking in deeper layers that truly drives its global dynamics.

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The science of AI and the AI of science

Source: The Hindu, Dt. 01 May 2025,
URL: https://www.thehindu.com/sci-tech/science/the-science-of-ai-and-the-ai-of-science/article69520957.ece

The fundamental idea behind artificial intelligence (AI) stems from the British mathematician Alan Turing, who in the 1950s defined the idea of intelligence in a machine. During World War II, when attempting to break encryption code the Nazis used to transmit secret messages, he wondered whether machines would be able to find patterns in large amounts of data that humans couldn't. He speculated machines could learn from experience instead of being taught to work from the first

principles. Computer scientist John McCarthy coined the term “artificial intelligence” in a summer workshop in 1955 that many leading computer scientists attended.

While the idea enjoyed enough attention in the subsequent decade — enough for the first chatbot, ELIZA, to be created in 1966 — funding dipped in the 1970s before rebounding after. By 1997, IBM’s Deep Blue defeated chess champion Gary Kasparov, around the same time researchers were starting to build sophisticated artificial neural networks that supercharged machine learning. Soon, the idea emerged that these neural networks, which are computers that process information like networks of neurons in animal brains, could solve most scientific problems.

From ANNs to GPUs

Artificial neural networks, or ANNs, could learn to solve each problem by digesting large amounts of data, mapping the relationships between various problem statements and their respective solutions, and finally recreating these relationships for unsolved problems. This paradigm is called unsupervised learning. In supervised learning, humans label the data with tags the machine picks up on. For example, humans can create a database of images of cats and dogs and label them accordingly. The ANN that ‘trains’ with the database then ‘learns’ what ‘cat’ and ‘dog’ stand for.

In another type of learning, called reinforcement learning, humans go through the results of what a machine has learnt and provide feedback for the machine to improve.

Every ANN consists of nodes, small computers that accept input signals and provide an output. The nodes are divided into groups called layers. The layers are connected to each other like neurons in the brain: each node in one layer connects to a single other node in the next layer. It’s a sandwich: the layers are the two slices of bread and in between are all the connections between the nodes.

Not all connections are equal, some are more important than others. These relationships are adjusted by giving each connection a weight. The greater the weight, the more important the signal passing along that connection. By adjusting the weights, arrangement of nodes, and number of layers, then, the ANN can be adjusted to learn and process data in different ways.

Machine-learning models that use such ANN architecture are capable of processing in a few hours databases that might take humans several months — as long as they have the requisite computing. This power comes from graphics processing units (GPUs), an advanced version of the central processing units (CPUs) that power home computers. GPUs are specialised to solve multiple mathematical problems simultaneously, speeding up the ANN’s learning process.

Machine learning v. artificial intelligence

Recognising patterns in any form of data is in the domain of machine-learning (ML). It has applications in many fields. For example, ML models installed on self-driving cars are trained to check the condition of the cars’ various components and if possible perform repairs. In the clinical realm, ML models can learn to find patterns in disorders that lead to new forms of treatment or read test reports to identify the risk of specific diseases.

AI, on the other hand, is broader. It is based on more recent advances in ML that mimic human intelligence in problem-solving — like completing an unfinished sentence the way Arthur Clarke

might or create an image in the style of Vincent van Gogh. Such AI models are being rapidly adapted for various applications.

For example, researchers can build ML algorithms that digest the average behaviour of a user's financial accounts, like transaction frequency, spending limits, login times, and device use, according to Jia Zhai, senior associate professor in the Department of Finance at the Xi'an Jiaotong-Liverpool University in Suzhou, China. "If a fraudster gains valid credentials but logs in via an unrecognised device at 3 am and initiates rapid microtransactions, clustering algorithms detect this as an outlier compared to the user's historical behaviour," she said.

Then, more specialised networks called convolutional neural networks look for complex patterns in transactions; recurrent neural networks identify deviations from average spending behaviour; and graph neural networks examine the connections between accounts, merchants, and IP addresses to uncover hidden money-laundering networks, said Shimeng Shi, assistant professor in the same department and institute.

The capabilities of AI surged from around 2017, when researchers began using ML to process large amounts of data simultaneously using multiple GPUs. A major advance that resulted was the large language model. As private sector enterprises figured out how to apply this and other models to solve different but specific problems, manufacturers and vendors rushed to meet the demand for the underlying hardware. This in turn led to more computing power and faster chips entering the market. Another equally important and roughly simultaneous development was the availability of large datasets on which the new batch of AL/ML models could be trained.

All together, the next major advance took shape: generative AI, where an AI model didn't just analyse what was in front of it but also put existing information together in new ways, e.g. creating an image based on a user's text instructions. Perhaps the most well-known products that make such capabilities available to users are ChatGPT and DALL-E, both made by US-based company OpenAI. Shimeng Shi also said financial firms have been trying to "help their clients to generate real-time trade ideas" using "AI-empowered tools" that are out of view.

The technology isn't a silver bullet, of course. Completely autonomous AI agents are not yet a reality because of their tendency to "hallucinate", i.e. invent information that doesn't exist in the real world. This happens when an AI model is confronted with a particular kind of data it hasn't been trained on, causing it to mix them up with data it is familiar with.Does AI still hallucinate or is it becoming more reliable?

Precision, speed, structure

"Your model is as good as your data," Aditi Shanmugam, a research associate of analytics and databases at Bengaluru-based startup Ultrahuman who uses AI models to draw inferences in health data, said. "For any good model, you need lots of data with good diversity," Debnath Pal, professor in the Department of Computational and Data Sciences at the Indian Institute of Science (IISc), Bengaluru, added.

The next thing a good model needs after training data is hardware resources. "Each data centre — especially a large one with AI GPUs — can consume as much power as a whole nuclear power plant will produce," Akash Pradhan, a member of the technical staff at chip-maker AMD, said. The

machines also generate a large amount of heat of their own, which means they need to be cooled, which requires even more power.

If the machines are performing a particularly complex task, the data they are manipulating need to be stored in high-speed hard drives.

Given all these requirements, most of the better AI research today — especially of the cutting edge variety — is led by big corporations with deep pockets.

But it may not always be this way. Many computer scientists are working on techniques to lower the power and hardware requirements for specific models without also compromising the latter's problem-solving ability.

For example, Rakesh Sengupta, director of the Centre for Creative Cognition at S.R. University in Warangal is working on a technique called pruning. In a recent paper, he proposed a method in which some connections in a neural network are cut while the most important ones are preserved, then retraining the model to work with the smaller set of connections. He expressed belief that we can "trim" existing models without sacrificing their reliability. "I feel customising small language models for specialised tasks in healthcare or robotics will be most" improved, he added.

The faster and more precise AI models become, the more precise application they will find — "whether it's neural prosthetics or brain-computer interfaces or some [other] technologies that can interface seamlessly with the brain," Sengupta said.Most AI researchers use the most accessible model and data to achieve specific goals. In their absence, researchers draw up datasets from first principles and mix them with available ones to create more complete, yet also more reliable, datasets.

For example, Pal said, material science researchers integrate experimental data of the properties of materials with synthetic data of the presence of other materials to create synthetic datasets that are complete and contain more information for the models to search for. "After doing all these experiments, you may be able to figure out that, 'oh, if I dope with this material, then I would get that property'. Such experiments are being done and then it is kind of reducing the time to realise those compositions," Pal said.

But defining the problems and arriving at solutions is not always straightforward, and often depends on factors that require researchers to dig deep into the specific peculiarities in the data and the models.

For example, Adway Mitra, an assistant professor in the Centre of Excellence in Artificial Intelligence at IIT-Kharagpur, expressed belief that there is considerable scope to use AI models to improve weather and seasonal predictions, especially of Indian monsoons. This is what he does. Often, weather data exists as a combination of textual, visual, and numerical data "We first condense the space of all weather patterns to a small number (about 10) of 'typical' patterns, and our claim is that every day's weather pattern is an approximate or noisy version of any one of these 'typical' patterns," Mitra explained. Generative AI models train on these datasets and create new data from them that are easier to analyse and represent as mathematical structures.

But real-world weather data is often noisy and difficult to interpret, and weather is a complex system with lots of parameters across various locations and times. “The key technical challenge is the availability of weather data,” Mitra said.

Weather data has structures that an ML model must be able to work with. Mitra’s research focuses on what kind of algorithms or models scientists can use to best utilise that structure. Thus, researchers like Mitra are turning the idea of AI back to where it started from: while machines are good at understanding patterns, at the end of the day, the patterns must be supported by physics because weather patterns are created by physical processes. The question researchers are thus asking is: “How can we constrain machine learning so that it provides us values which are consistent with the different laws of physics?” This exercise, Mitra said, will bring down the number of computations the AI models will need to perform to make accurate weather predictions and thus demand less power and data storage infrastructure.

Towards AI agents

Sandeep Juneja, a professor of computer science and director of Safexpress Centre for Data, Learning and Decision Sciences at Ashoka University, said corporations like Google have large data-driven AI models that are already doing this at scale — but that they may be running out of data to train with. On the other hand, he added, academicians in India and even worldwide don’t have the computational capacity to develop such large models to develop nuanced weather predictions. He said models like DeepSeek provide hope as they have been able to use “clever” tricks to use small amounts of data to train the models efficiently.

But Chiranjib Bhattacharyya, a professor in the Department of Computer Science and Automation at IISc, said that even DeepSeek’s model is large compared to what academics can presently access.

Lixian Qian, an associate dean for research and professor in the Department of Intelligent Operations and Marketing at from Xi’an Jiaotong-Liverpool University, works on autonomous vehicles that use AI algorithms to model their complex environment, predict the movement of objects on the road, and decide how the vehicle moves to avoid accidents. While there has been significant integration of AI into autonomous vehicles, he said practical challenges remain — and AI has the ability to address them. “AI algorithms can increase the number of tests on autonomous driving systems in diverse driving environments, so that the potential problems could be uncovered and diagnosed in advance.”

In a sense, then, we are slowly transitioning from a world of generative AI to agentic AI. AI agents are more powerful than the present versions of AI which still specify on particular tasks. They integrate the power of different functionalities into an ecosystem that can be empowered to make particular decisions.

For example, AI assistants may one day be able to parse data about a person’s life, including their hobbies, expenses, health conditions, work, and life priorities, and help them with tasks like booking appointments or filling out forms. However, how much of such a technology will be accessible and usable to people at large will depend on data privacy protections and technological

literacy. Bhattacharya said social scientists and law scholars will play an important role in shaping how such systems fit into our lives.

Sohini Majumdar, a software engineering manager at Salesforce, agreed the time for agentic AI was near. Many business platforms are increasingly using agentic AI instead of simple chatbots to integrate their business and increase their impact. However, she added, fundamental challenges remain in using generative AI models too. The principal challenge is understanding why an AI model outputs one specific business decision rather than another — especially if the output deviates from a human understanding of the business. So she and her colleagues use yet other AI models to validate the decisions suggested by generative AI. Their aim is to understand what a model is doing and how to tweak various inputs so that the model does what she wants it to. In this way, her team will be able to make automated decisions and trust them as well.

According to Bhattacharyya, the fundamental problem boils down to AI models currently lacking the ability to reason. Pal agreed: “What is the path that [a model] follows? Is it following the same path that as a human I would want it to follow to do this inference? That we don’t know.” Mathematicians, computer scientists, and physicists are currently trying to untangle this Gordian knot.

Pradhan of AMD said these challenges are fundamental: despite neural networks being based on the human brain, the way the machines learn and the way the human brain functions are different. A fundamental difference is how the computational blocks in an artificial intelligence model — the GPUs — are different sites from where the parameters of the model are stored. In the brain, these two are stored at the same location. Second, chemical reactions run the brain whereas electricity runs digital machines. The challenges, Pradhan said, can be mitigated in neuromorphic computing, where the hardware more closely mimics how neural networks in our brain operate.

“Instead of you writing code to emulate a neural network, your hardware is the neural network,” he said. Functional neuromorphic computers of the future are expected to require less power and have the ability to update its model automatically when it encounters new data — just like our brain. But there are multiple hardware and software challenges to be surmounted before it can be realised, Pradhan said.

Sengupta is sceptical of how much AI will truly mimic us. While each generation of humans has been more comfortable with the increasing presence of smarter gadgets and software, and the tools have changed us too, there might be a natural barrier to how much AI might affect us. But it has also made us think deeply about our technologies. Just like how we constantly grapple with understanding our own existence, we might have to do the same when we invite AI into every aspect of our lives.Debdutta Paul is a freelance science journalist.

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