IoBT in India: A Race Towards Operational Supremacy

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INTRODUCTION

The Internet of Battlefield Things (IoBT) comprises a system of connected devices tailored for military use, facilitating instantaneous communication and synchronisation between diverse battlefield elements. It is a vast limitless concept ranging from simple Night Vision Goggles (NVG) projecting live coverage of a night recce to a highly sophisticated recce pod embedded into a fighter aircraft capable of exploiting the environment behind the enemy lines and generating a comparative report of infra-advancements for a defined period. The question is of the count of independent battlefield elements integrated, the accuracy of the battlefield assessment, and the latency in the decision-making. As a concept, IoBT has proven to be the next revolution. Extensive Research and Development (R&D) in the field has led to the

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creation of the ONYX exoskeleton and Human Universal Load Carrier (HULC) bringing Iron Man to reality.[1] The technology is slowly gaining both respect as well as huge funding in the developed nations.

CONVENTIONAL WARFARE TO THE INTERNET OF BATTLEFIELD THINGS

The Internet of Things, or IoT, is a network of physical devices. These devices can transfer data to one another without human intervention. IoT devices are not limited to computers or machinery. The IoT architecture mainly consists of four layers, that is, the sensing layer, the network layer, the processing layer, and the application layer.[2] The sensing layer collects data via the Radio Frequency Identification (RFID), camera, 2-D code, and other advanced sensors. The network layer fetches this data and sends it to the processing layer. In the processing layer, complex algorithms process the data and, finally, the application layer provides access services for IoT users. History is a testament to the strong foundation of IoBT. Traditional military systems relied on independent technologies for communication, navigation, and intelligence collection. Systems like radar, Global Positioning System (GPS), and satellite communications laid the groundwork for future connectivity. The broad acceptance of consumer IoT devices in the early 2000s demonstrated the potential of interconnected technologies. This included smart home devices,

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1. M. Iriarte, "AI to Augment Soldier's Strength, Endurance via New Exoskeleton Contract with Lockheed Martin," November 2018. [Online]. https://militaryembedded.com/ai/machine-learning/artificial-intelligence-to-augment-soldiers-strength-endurance-via-new-exoskeleton-contract-with-lockheed- martin. Accessed on January 5, 2025.
2. N. Luong, D. Hoang, P. Wang, D. Niyato, D. Kim, and Z. Han, "Data Collection and Wireless Communication in Internet of Things (IoT) Using Economic Analysis and Pricing Models: A Survey," IEEE Commun. Surveys Tuts., vol. 18, no. 4, pp. 2546–2590, 4th Quart., 2016.

wearables, and industrial IoT applications. Military organisations began to recognise the potential benefits of these technologies for improving operational capabilities. Military applications began incorporating advanced sensors into various platforms such as drones, vehicles, and soldiers' gear. These sensors could provide real-time data on environmental conditions, troop movements, and potential threats. The advent of secure communication networks, including 4G and, more recently, 5G, facilitated real-time data exchange between field units. This connectivity is crucial for situational awareness and coordinated response. The advancement of big data analytics and Artificial Intelligence (AI) has transformed how military organisations interpret and use the vast amounts of data generated by IoBT devices. AI driven insights help commanders make quick, informed decisions. IoBT is characterised by its focus on interconnected military devices that offer a comprehensive battlefield perspective. This involves integrating various platforms such as Unmanned Aerial Vehicles (UAVs), smart weapon systems, and ground troops into a unified operational network.

IOBT TECHNOLOGY IN INDIA

As discussed, India is in a No War No Peace (NWNP) state and is continuously in a state of war not necessarily kinetic. The following are some practical examples of armouring India's military fabric using IoBT.

1. India has one of the largest set-ups of military installations deploying human resources at entry/exit points. The system for authenticating the legitimacy of a person entering the facility is outdated, relying on manual inspection of identification documents. Not limiting just to the perimeter security of military installations, let us have a broader outlook. Spanning approximately 15,100 km, India's land border is shared with seven neighbouring countries. The boundary with Pakistan extends for about 3,323 km, while the

border shared with China measures roughly 3,488 km in length. Moreover, India has a long coastline of 7,516.6 km, including the Arabian Sea to the west and the Bay of Bengal to the east.[3] To effectively guard such vast and diverse terrain borders, we need an extensive use of technology.

The US-Mexico border has implemented extensive technological measures to curb unauthorised immigration, including the deployment of AI-driven surveillance towers. These structures, available in both fixed and mobile configurations, are equipped with a comprehensive array of monitoring devices. The towers utilise cameras, heat-detecting sensors, motion-tracking equipment, and radar systems to provide continuous, real-time border surveillance. These towers can autonomously focus on areas of activity without human assistance. Moreover, there is extensive use of drones capable of scanning large areas and detecting human presence using high-definition thermal imaging cameras.[4] For an even broader coverage, aerostat balloons are deployed. Along the border highways and roads, remote licence plate readers are installed that autonomously scan through the licence plates and generate alarms based on run-through checks continuously being carried out at the backend server. In addition, the facial recognition systems exercising convolutional neural networks and feature extraction algorithms at the backend fetching high-definition imagery input using 3D sensors, and thermal cameras are deployed at border crossings. This can

3. R. Uppal, "India's Smart and Comprehensive Integrated Border Management (CIBMS) to Guard its Long, Difficult and Porous Borders," June 11, 2023. [Online]. https://idstch.com/security/indias-smart-and-comprehensive-integrated-border-management-cibms-to-guard-its-long-difficult-and-porous- borders/.
4. P. Molnar, "The Grim High-Tech Dystopia on the US-Mexico Border," May 21, 2024. [Online]. https://jacobin.com/2024/05/high-tech-ai-mexico-border. Accessed on January 5, 2025.

drastically improve the accuracy of credibility checks at guard posts where only Identification (ID) checks are carried out.

Additionally, fibre optic sensor networks have been implemented to identify vibrations remotely and notify the relevant authorities as needed. In highly sensitive points, quadruped robots are deployed utilising thermal cameras for detecting heat signatures, Light Detection and Ranging (LiDAR) and laser range finders for accurate environment mapping, gas sensors for detecting environmental hazards, and adaptive central pattern generators control algorithms for seamless transitions between different gaits based on sensory feedback such as gyroscope signals for body orientation. Advanced mapping systems like the Displacement Tracking Matrix (DTM) have also been deployed to study detailed migration patterns and accordingly set the alert status at border crossings.[5]

Along similar lines, various projects have been inaugurated in India but the scale of implementation needs a major boost. The Pathankot attack was an eye-opener and an extensive perimeter security solution was formalised at various frontline bases. The solution has been highly effective and it needs to be extended to all the crucial military stations. Even in the existing security solution, focussed Research and Development (R&D) can fetch hefty and promising outputs. Integrating all the existing Closed Circuit Television (CCTV) endpoints and weaving the set-up into a dense fabric with a backend local server that continuously leverages the technology of facial recognition and remote licence plate readers can be a game-changer as it will exploit existing hardware to fetch output ensuring 24-hour autonomous identity check of personnel and vehicles inside the base. One of the major takeaways from the US-Mexico border security has been the extensive use of drones.

Again, considering the large maritime coastline, the 2008 Mumbai attack was a major wake-up call. The Integrated Coastal

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5. Ibid.

Surveillance System (ICSS) is an effort to secure the maritime borders. The project was planned to be executed in two stages and aimed at installing a total of 84 radar stations across the Indian coastline. These stations will feed data into the Information Fusion Centre for the Indian Ocean Region (IFC-IOR), allowing for real-time analysis and situational awareness among the maritime security agencies. The project employs L/S band radars capable of detecting small vessels, including fishing boats and dinghies, with a detection range of approximately 30 km in the worst weather conditions possible. Apart from high-resolution day/ night cameras and thermal imaging systems, every registered shipping vessel has been tagged with automatic identification system transponders allowing real-time tracking. Surveillance receivers monitor unauthorised communication and, finally, post data fusion at the IFC-IOR, a Common Operational Picture (COP) is generated, enabling a unified view. The project is a perfect example of IoBT and under the Security and Growth for All in the Region (SAGAR) doctrine, India has been extending its coastal surveillance capabilities to neighbouring countries in the Indian Ocean Region (IOR).[6]

2. India is a country of diverse landforms and we have the great Himalayas towards the north that protect us from adversaries like China and Pakistan. There is a huge chunk of human resources deployed in these challenging contours of Ladakh and Jammu and Kashmir (J&K). The Indian Air Force is the major lifeline for the region, airlifting the necessary victuals and supplies to Leh and Thoise, which are further conveyed via convoy movement to even higher sectors. Let us take a look at a survey. The operating cost of a C-17 Globemaster III is approximately US$ 23,811 per

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6. Levina, "Tightening the Noose Around Chinese Ships: India's Coastal Surveillance System & SAGAR Policy," *RESONANT NEWS*, December 14, 2022. [Online]. https://resonantnews.com/2022/12/14/5573/. Accessed on December 29, 2024.

flight hour. This figure encompasses various expenses associated with the aircraft's operation, including fuel, maintenance, and crew costs.[7] Considering an approximately one-hour flight from Chandigarh to Leh, a single one-way operation will cost around INR 20 lakh. Considering the return operational costs, a single focussed operation without any major unserviceability costs INR 40 lakh. In a week, just five such operations will cost around INR 2 crore. In a year, the cost goes to US$ 12 million. Apart from this, we have other tactical airlift giants flying in the region. The cost will increase if we consider further conveyance charges from Leh to the upper sectors. The crux of the matter is that the cost is gigantic and we need to revert to smarter solutions.

Hydroponic and aeroponic farming is the solution. Hydroponics is the method of growing plants in a nutrient solution without soil. The term has been coined out of two Greek words "hydros" (water) and "ponos" (labour), indicating a water-based cultivation system. In the solution, the soil is absent and the plant is supported using gravel, coconut coir, and rock wool. A water-based nutrient-rich solution is fed that includes macronutrients (like nitrogen, potassium, and phosphorus) and micronutrients (such as magnesium and calcium). Some of the common hydroponic systems are the Nutrient Film Technique, Ebb and Flow, and Deep-Water Culture. Some of the key features of such farming include reduced pathogen risk, water efficiency, and space utilisation. The solution is being continuously experimented with, and the results are promising. With the integration of moisture and crop health sensors automating irrigating actuators and physical surveillance by swarm drones on an alarming input, although the initial cost of set-up has risen, on a longer scale, the Return on Investment (ROI) is exponential. The cost of setting up a hydroponic farm on one

7. C. Ritsick, "C-17 Facts: Everything You Need To Know," January 15, 2020. [Online]. https://militarymachine.com/c-17-facts/. Accessed on December 31, 2024.

acre of land will range roughly between $145,000 and $197,000, excluding the land cost.[8] Hydroponics allows for continuous crop production throughout the year. Unlike traditional farming, which is often constrained by seasonal changes, hydroponic systems can be adjusted to grow various crops irrespective of the season.[9] Some of the key vegetables can be grown throughout the year on the same set-up, ensuring continuous supply.

Another promising solution for regions like Leh and further north is aeroponic farming which comprises growing plants in an air or mist environment without using soil or an aggregate medium. The roots are freely hung in the air while being misted with a nutrient solution, allowing for maximum oxygen exposure. Unlike hydroponics, aeroponics does not require any solid medium to support the plant roots. Some of the notable start-ups integrating high-end sensors and exploiting IoT to revolutionise farming are CropIn, AgNext Technologies, etc. The solution can be very helpful in high altitudes in India as it will ensure self-sufficiency in the region and adequate supplies during a war. The results are extremely promising after integrating data analytics, AI, drone surveillance, and high-end sensors, especially in water-scarce environments, thus, saving 90 per cent of water.[10] It will further boost the employment graph in the region and attract foreign investors directly into the region, thus, facilitating better connectivity. It will further ensure the modernisation of these

8. Bhawana, "How Expensive Is Hydroponic Farming: Set Up Cost + Profit," July 1, 2023. [Online]. Available: https://gardeninglovy.com/how-expensive-is-hydroponic-farming/. Accessed on December 31, 2024.
9. "Seasonal Hydroponics: Best Practices for Every Season, November 12, 2024. [Online]. https://www.hydroponicsfarming.in/blog/seasonal-hydroponics-best-practices-for-every-season/. Accessed on December 31, 2024.
10. S. Gupta, "Farmer Earns 5 Times More with Hydroponics and Saves 80% on Electricity Bills; Helps Others Switch," July 15, 2024. [Online]. https://thebetterindia.com/356971/hydroponics-farming-without-soil-sustainable-agriculture-farmer-increases-income-solar-energy/. Accessed on December 31, 2024.

remote places and will, in turn, help in faster deployment of other things connected to the Internet and, finally, help in extending the fabric of the IoBT.

3. Military convoys play a crucial part in battle dynamics, however, no solid solution to fetch convoy vitals, including vehicle position, velocity, tyre pressure, fuel usage, and braking has been accepted. The paper titled "Design and Implementation of a Vehicle Tracking System Using GPS/GSM/GPRS technology and Smartphone Application" employs GPS for location coordinates and Global System for Mobile Communication/General Packet Radio Service (GSM/GPRS) to update vehicle positions in a database, supplemented by a mobile app for ongoing monitoring.[11] Another paper titled "Accurate Vehicle Location System Using RFID, an Internet of Things Approach" combines RFID technology with GPS and GSM to provide precise vehicle tracking, even in areas with poor GPS reception.[12] Another paper highlights an IoT-based system utilising Bluetooth to transmit traffic conditions and density, employing data analysis for dynamic traffic monitoring.[13] A 5G-based intelligent logistics traceability system integrates IoT and AI for fully automated transportation, advancing smart logistics capabilities.[14] The EURIDICE solution adopts an IoT approach for distributed intelligence, allowing mobile devices

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11. S. Lee, G. Tewolde, and J. Kwon, "Design and Implementation of Vehicle Tracking System Using GPS/GSM/GPRS Technology and Smartphone Application," in Proc. IEEE World Forum Internet Things (WF-IoT), Seoul, South Korea, March 2014, pp. 353–358.
12. J. Prinsloo and R. Malekian, "Accurate Vehicle Location System Using RFID, an Internet of Things Approach," *Sensors*, June 2016, vol. 16, no. 6, p. 825.
13. S. Sukode and S. Gite, "Vehicle Traffic Congestion Control and Monitoring System in IoT," Int. J. Appl. Eng. Res., vol. 10, no. 8, pp. 19513–19523, October 2015.
14. L. Zhou and C. Lou, "Intelligent Cargo Tracking System Based on the Internet of Things," in Proc. 15th Int. Conf. Netw. Based Inf. Syst., Melbourne, VIC, Australia, September 2012, pp. 489–493.

to interact with a central platform, enabling services like cargo localisation, rerouting, and condition monitoring autonomously.[15]

IoT technology can also be utilised in driver monitoring to assess driver health and conduct. Research explores the use of wearable sensor networks for efficient, real-time healthcare processing, which can transmit physiological data wirelessly to remote locations, aiding in the prevention of road accidents.[16] The study in the paper titled "Fog Assisted Driver Behavior Monitoring for Intelligent Transportation System," presents an architecture based on IoT and fog computing that observes driver behaviour through multiple sensors and various communication technologies (RFID, Bluetooth, WiFi, 4G-LTE), with fog computing addressing time-critical data.[17] In the paper titled "Service Architecture for Driver Behavior Analysis in an IoT Vehicular Environment,", the authors suggest an IoT-based system for analysing driver behaviour using mobile technologies in embedded devices and smartphones, with data mining services performed in the Cloud.[18] A driving style assessment system using IoT-based embedded technology can examine vehicle speed, acceleration, jerk, engine speed, and driving duration.[19] The IoT-based Intelligent Transportation Systems (ITSs) in logistics transportation require data collection

15. M. Forcolin, E. Fracasso, F. Tumanischvili, and P. Lupieri, "EURIDICE—IoT Applied to Logistics Using the Intelligent Cargo Concept," in Proc. 17th Int. Conf. Concurrent Enterprising, Aachen, Germany, June 2011, pp. 1–9.

16. S. Choudhari and V. Giripunje, "Remote Healthcare Monitoring System for Drivers Community Based on IoT," Int. J. Emerg. Technol. Eng. Res., vol. 4, no. 7, pp. 118–121, July 2016.

17. M. Aazam and X. Fernando, "Fog Assisted Driver Behavior Monitoring for Intelligent Transportation System," in Proc. IEEE 86th Veh. Technol. Conf. (VTC-Fall), Toronto, ON, Canada, September 2017, pp. 1–5.

18. C. Boja, P. Paul, and I. Bogdan, "Service Architecture for Driver Behavior Analysis in an IoT Vehicular Environment," in Proc. 15th Int. Conf. Informat. Econ. (IE), March 2018, pp. 114–119.

19. B. Jachimczyk, D. Dziak, J. Czapla, P. Damps, and W. Kulesza, "IoT On-board System for Driving Style Assessment," *Sensors*, vol. 18, no. 4, pp. 1–22, April 2018.

from multiple sensors, local preprocessing, and transmission of information to logistics centres for analysis and prediction. These systems demand high real-time performance and stability from wireless communication networks.[20, 21]

4. Server rooms are vulnerable points in an era that breathes effective communication for its sustenance. IoBT plays a crucial role in its security. Monitoring the server room environment encompasses the management of temperature, humidity, and power distribution. A smart warehouse control system utilising the ZigBee Wireless Sensor Network (WSN) and network nodes is introduced in the paper titled "Design of Intelligent Warehouse Measure and Control System Based on ZigBee WSN".[22] An IoT-based automated monitoring system can address issues of monitoring delays and lack of intelligence, and is capable of tracking temperature, humidity, and fire.[23] IoBT can also be exploited to detect real-time intrusions, reducing the need for deploying human resources.[24]

5. Loading and unloading of armament stores requires speed, precision, and accuracy, all at the same time. All three forces engage in peace-time exercises to gain excellence in these three pillars. The processes of loading and unloading encompass various activities such as stacking, storage, and outbound transport. These

20. L. Liu, C. Chen, Q. Pei, S. Maharjan, and Y. Zhang, "Vehicular Edge Computing and Networking: A Survey," *Mobile Netw*. Appl.

21. Y. Song, Y. Fu, F. R. Yu, and L. Zhou, "Blockchain-enabled Internet of Vehicles with Cooperative Positioning: A Deep Neural Network Approach," IEEE Internet Things J., vol. 7, no. 4, pp. 3485–3498, April 2020.

22. T. Liu, J. Liu, and B. Liu, "Design of Intelligent Warehouse Measure and Control System Based on Zigbee WSN," in Proc. IEEE Int. Conf. Mechatronics Autom., Xi'an, China, August 2010, pp. 888–893.

23. X. Yu, M. Zhang, M. Zhu, K. Xu, and Q. Xiang, "Design and Implementation of Automated Warehouse Monitoring System Based on the Internet of Things," Appl. Mech. Mater., vol. 543–547, pp. 1099–1102, March 2014.

24. S. Chihana, J. Phiri, and D. Kunda, "An IoT Based Warehouse Intrusion Detection (E-Perimeter) and Grain Tracking Model for Food Reserve Agency," Int. J. Adv. Comput. Sci. Appl., vol. 9, no. 9, pp. 214–223, 2018.

operations are fundamental to transportation and storage, and their repetitive nature significantly impacts logistics speed and expenses. The IoBT enabled machinery, particularly forklifts, enhances logistical efficiency through automation, precise positioning, condition monitoring, and strategic dispatching. Implementing automated loading and unloading machinery reduces costs and boosts productivity. Research describes a Data Collection Unit (DCU) equipped with sensors that integrate various interfaces like the Controller Area Network (CAN), Universal Asynchronous Receiver Transmitter (UART), and Recommended Standard 232 (RS232), enabling forklifts to autonomously locate and transport goods.[25] An IoT-based forklift robot utilises multiple sensors and Wi-Fi for remote communication.[26] Another study details an application that automates industrial forklifts using sensors and wireless communication for remote operation and data monitoring.[27]

Monitoring the position and status of equipment facilitates effective dispatching. Studies have introduced a system allowing human supervisors to interact with self-operating forklifts through voice commands, simplifying cargo handling instructions.[28] In the paper titled "A Novel Wireless Forklift Positioning System for Indoor and Outdoor Use," a 5.8-GHz wireless system for forklift

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25. Y. Lee, J. Kim, H. Lee, and K. Moon, "IoT-based Data Transmitting System Using a UWB and RFID System in Smart Warehouse," in Proc. 9th Int. Conf. Ubiquitous Future Netw. (ICUFN), Milan, Italy, July 2017, pp. 545–547.
26. R. Khan, A. Bhujbal, and M. Goudar, "IoT Enabled Automated Robotic Service for Warehouses," Int. J. Eng. Technol. Sci. Res., vol. 4, no. 5, pp. 588–592, May 2017.
27. L. Armesto, M. Mora, H. Ávaro, and T. Josep, "A Client/Server Tele Operation Application of Industrial Forklifts," in Proc. 7th IFAC Symp. Robot Control (SYROCO), vol. 2, September 2003, pp. 515–520.
28. M. Walter, et al., "A Situationally Aware Voice-Commandable Robotic Forklift Working Alongside People in Unstructured Outdoor Environments," *J. Field Robot*, vol. 32, no. 4, pp. 590–628, May 2015.

positioning employs an optimised heuristic localisation method, reducing the complexity of the infrastructure.[29]

6. Military depots hold highly sophisticated, sensitive, and hazardous units that require disciplined monitoring and smart management. The solution for effective environment monitoring has been discussed in point No. 4. Military depots need to be transformed into intelligent distribution centres utilising intelligent handling, automatic sorting equipment, and information processing systems for smart management. The paper titled "An Intelligent Model for Assuring Food Quality in Managing a Multi-Temperature Food Distribution Center" proposes an IoT-based Route Planning System (IRPS) that integrates IoT, the Taguchi experimental design, and genetic algorithms for optimal delivery routes in multi-temperature food distribution.[30] Another research developed a model for intelligent distribution centres, utilising IoT for cargo identification, information storage and collection, intelligent warehouse management, and automatic vehicle dispatching.[31]

Traditional delivery lacks precise timing and real-time monitoring of the status of the goods. To address these issues, new logistics delivery methods, such as intelligent containers, Autonomous Vehicles (AVs), and Unmanned Aerial Vehicles (UAVs), have emerged.[32] An intelligent container system using

29. J. Michel, H. Millner, and M. Vossiek, "A Novell Wireless Forklift Positioning System for Indoor and Outdoor Use," in Proc. 5th Workshop Position. Navig. Commun., Hannover, Germany, Mar. 2008, pp. 219–227.
30. Y. Tsang, K. Choy, C. Wu, G. Ho, H. Lam, and V. Tang, "An Intelligent Model for Assuring Food Quality in Managing a Multi-Temperature Food Distribution Centre," *Food Control*, vol. 90, pp. 81–97, August 2018.
31. J. Gao and Y. Tang, "Intelligent Distribution System Based on IoT Technology," in Proc. 3rd Int. Conf. Transp. Eng. (ICTE), 2011, pp. 2211–2216.
32. F. Wang, F. Wang, X. Ma, and J. Liu, "Demystifying the Crowd Intelligence in Last Mile Parcel Delivery for Smart Cities," IEEE Netw., vol. 19, no. 2, pp. 23–29, March/April 2019.

WSN and wireless communication technologies monitors internal and external parameters, enhancing the supervision of goods.[33, 34]

Autonomous Vehicles (AVs) show significant potential in logistics. The paper titled "Autonomous Vehicle Logistic System: Joint Routing and Charging Strategy," introduces an Autonomous Vehicles Logistics System (AVLS) using Vehicular ad hoc Networks (VANETs) and Dedicated Short-Range Communications (DSRC) for smart cities, optimising routes based on logistic needs. UAVs can alleviate urban congestion and improve rural accessibility by shifting deliveries to the air. The same concept can be stretched to gaining access to inaccessible parts, probably behind the enemy lines.[35] Using diverse communication technologies, smart distribution integrates IoT technologies, involving multi-sensory acquisition, dynamic positioning, multi-source information fusion, and decision-making optimisation.

REVOLUTIONARY ADVANCEMENTS IN IOBT

Lockheed Martin has developed wearable military technology, including the ONYX exoskeleton and the HULC (Human Universal Load Carrier), to enhance soldiers' physical capabilities and health monitoring. The HULC is a hydraulic-powered external frame designed to boost strength and endurance, featuring biosensors for vital sign monitoring. It tracks heart rate, respiration, and other vital signs. It enables soldiers to carry up

33. W. Lang, R. Jedermann, D. Mrugala, A. Jabbari, B. Krieg-Brückner, and K. Schill, "The 'Intelligent Container'—A Cognitive Sensor Network for Transport Management," IEEE Sensors J., vol. 11, no. 3, pp. 688–698, March 2011.

34. P. Dittmer, M. Veigt, B. Scholz-Reiter, N. Heidmann, and S. Paul, "The Intelligent Container as a Part of the Internet of Things," in Proc. IEEE Int. Conf. Cyber Technol. Autom. Control Intell. Syst. (CYBER), Bangkok, Thailand, May 2012, pp. 209–214.

35. N. Motlagh, T. Taleb, and O. Arouk, "Low-Altitude Unmanned Aerial Vehicles-based Internet of Things Services: Comprehensive Survey and Future Perspectives," IEEE Internet Thing J., vol. 3, no. 6, pp. 899–922, December 2016.

to 200 pounds (90 kg) of equipment, reducing fatigue and injury risk.[36] Lockheed Martin envisions these systems as part of an integrated battlefield environment, enabling continuous health and performance monitoring for better tactical decision-making and rapid medical response. Although HULC and ONYX are not yet fully operational in combat, they represent progress towards a future soldier system that combines physical enhancement and health monitoring, in collaboration with military initiatives like the U.S. Army's Warrior Integration Programme. Elon Musk's company, Neuralink, is in charge of Brain-Computer Interface (BCI) technology development. Its primary objective is to create high- bandwidth, implantable neural interfaces that connect human thought processes with digital systems. Neuralink has made several significant strides in BCI technology and aims for instant communication between the brain and linked devices using Bluetooth or similar technologies.[37] Neuralink obtained Food and Drug Administration (FDA) approval for preliminary human trials to evaluate the safety and effectiveness of its implants, with a focus on conditions like paralysis and neural signal restoration. Project Maven is a U.S. Department of Defence (DoD) endeavour centred on employing Artificial Intelligence (AI) and Machine Learning (ML) to boost the military's capacity to handle extensive visual data (e.g., from surveillance drones, satellites, and reconnaissance systems). The initiative, officially titled the Algorithmic Warfare Cross-Functional Team, was launched in 2017 to expedite the application of AI for enhancing

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36. "Human Universal Load Carrier (HULC)," October 26, 2020. [Online]. Available: Lockheed Martin has developed wearable military technology, including the ONYX exoskeleton and the HULC, to enhance soldiers' physical capabilities and health monitoring. Accessed on January 5, 2025.
37. V. Neuro, "Understanding the Neuralink Brain Chip – A Brain-Computer Interface," February 21, 2024. [Online]. https://veritaneuro.com/news/understanding-the-neuralink-brain-chip-a-brain-computer-interface/. Accessed on January 5, 2025.

the efficiency and rapidity of data analysis in military operations. Maven aims to utilise AI algorithms for automatic analysis of vast video and image datasets, enabling swifter and more precise identification of objects, individuals, and potential hazards automating data identification and categorisation. Maven allows military analysts and decision-makers to concentrate on higher-level strategic planning.[38] The Joint All-Domain Command and Control (JADC2) is a crucial element of the Pentagon's future warfare strategy, wherein various military units (including aircraft, ground forces, cyber teams, and satellites) can effortlessly exchange information and operate collaboratively in a connected and adaptable manner. The main aim is to connect diverse military assets and command centres from the different branches (army, navy, air force, marines) into a single network. This facilitates swift information exchange, enhanced decision-making, and a more responsive military force.

JADC2 strives to deliver real-time, actionable intelligence to commanders, ensuring that military units in various domains can collaborate efficiently and quickly, regardless of their location or operational sphere. JADC2 incorporates artificial intelligence and data analytics to process and examine information instantaneously, aiding commanders in making quicker, more informed decisions in dynamic and complex scenarios.[39] JADC2 signifies a significant advancement in military command and control capabilities for multi-domain warfare. It envisions near-perfect integration of all military assets, enabling them to function as a unified entity,

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38. N. Strout, "Intelligence Agency Takes Over Project Maven, the Pentagon's Signature AI Scheme," [Online]. https://www.c4isrnet.com/intel-geoint/2022/04/27/intelligence-agency-takes-over-project-maven-the-pentagons-signature-ai-scheme/. Accessed on January 5, 2025.
39. T. Hitchens, "Pentagon's JADC2 Strategy: More Questions Than Answers," March 17, 2022. [Online]. https://breakingdefense.com/2022/03/pentagons-jadc2-strategy-more-questions-than- answers/. Accessed on January 5, 2025.

rather than in isolated segments. The system will heavily rely on sensors, satellite imagery, unmanned aerial vehicles, and other intelligence-gathering technologies that provide an instantaneous, comprehensive view of the battlefield across all domains. JADC2 plans to utilise edge computing to process data locally on devices and systems, allowing for faster analysis and decision-making without relying on centralised processing. JADC2 promises to give the U.S. military a significant advantage in the increasingly complex and rapid nature of modern warfare, particularly in contested environments where multiple domains (cyber, space, air, etc.) are simultaneously involved.[40] Other nations are likely to pursue similar initiatives to create more integrated and agile military forces, and the success of JADC2 could establish new benchmarks for joint operations and interoperability worldwide. The concept of a fully integrated, real-time command and control system could alter how militaries across the globe approach strategic operations, compelling nations to invest in advanced communications, artificial intelligence, and sensor systems

CONCLUSION

Today, there is a huge thrust on the formation of Theatre Commands integrating land, air, and naval warfare.[41] Most of the combat elements work disjointed as of today and there is critical human involvement in integration nodes, leading to latency in decision-making. Today is the best time to invest in IoBT. Although many military establishments around the globe hesitate to invest

40. L. Perez, "Edge Computing Keys DoD's JADC2 Strategy, Experts Say," December 16, 2022. [Online]. https://www.meritalk.com/articles/edge-computing-keys-dods-jadc2-strategy-experts-say/. Accessed on January 5, 2025.
41. N. A. Gokhale, "After Consensus Building, Theatre Commands To Be A Reality In 2025?," December 31, 2024. [Online]. https://bharatshakti.in/after-consensus-building-theatre-commands-to-be-a-reality-in-2025/. Accessed on January 5, 2025.

in the same due to the huge initial cost, and budget limitations, however, the technology offers huge cost savings in a long-term engagement.

The potential of IoBT is vast, with current research concentrating on developing advanced battlefield analytics and resilient edge architectures. As the U.S. DoD continues to make significant investments in IoBT, issues like cyber security and data handling will become increasingly crucial. The incorporation of IoBT into military operations is anticipated to transform combat tactics, providing unparalleled benefits in tactical surveillance, resource allocation, and logistical assistance. A change in mindset is necessary, viewing IoBT as a significant force multiplier capable of handling vast amounts of data from numerous sensors in resource-constrained environments at speeds beyond human capacity. India needs this mindset shift.