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Human-Centred Manned-Unmanned Teaming: Lessons From Global Developments and Implications For India's Land Warfare Capability

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Abstract

The development of MUM-T systems globally is rapidly progressing and is a major area of investment and innovation in the defence sector. It is also one of the focus areas for the Indian Army's efforts at transformation. While aerial teaming efforts attract more attention due to obvious technological sophistication, however, the question is that: are land based systems more suitable for MUM-T development? The United States of America is the global leader in implementation of MUM-T and a host of projects are under progress in other countries too including India. Niche technological advances in fields like Artificial Intelligence, drones, secure cyber and communication protocols etc. are further influencing its growth trajectory. But are these sophistications leading to increased complexity at the expense of platform effectiveness and operational efficiency? What is its effect on crew cognitive workload and situation awareness? How do Indian efforts fare on comparison with global ventures? What are the challenges in the trajectory of MUM-T development and how can Human Centered Design considerations assist in resolving them? Attempt has been made to find answers to these questions and more.

Keywords: Manned Unmanned Teaming, MUM-T, Defence Technology, Human Centered Design, Land Warfare

Introduction

Indian Army's (IA) Trishakti Corps, in April 2025 conducted Ex- SARVSHAKTI in Eastern India, involving synergistic employment of manned and unmanned systems to "work together as a team". This, as per reports, was said to herald employment of Manned Unmanned Teaming (MUM-T) in operations by IA. It highlighted field level validation of MUM-T for ISR and Target acquisition, integrating unmanned systems with traditional manned combat platforms and facilitated enhanced situational awareness (SA) and faster decision making by commanders (ANI, 2025).

The development of MUM-T systems globally is rapidly progressing and is a major area of investment and innovation in the defence sector. Driven by Industry 4.0, in the next 20 years, military systems are expected to be increasingly defined by the I2D2 (Intelligent, Interconnected, Digital, and Distributed) conceptual framework. These four characteristics are likely to shape the near future as highlighted by the NATO Science and Technology Organisation (NATO, OTAN, 2023). MUM-T is also one of the focus areas for the IA's efforts at transformation through induction of niche and disruptive technologies into its functioning.

The MUM-T concept is a natural progression and an extension of the I2D2 theory. However, globally and closer home, MUM-T is under various stages of development mainly for integration with air-based platforms like fighter aircrafts and helicopters. But can adding a Drone and its operator as part of manned platform crew be termed as MUM-T or is a more fundamental integration desired? Will MUM-T assist the 'men behind the machine' or lead to increasing the crew and their workload? Are we promoting and leveraging the entire ecosystem in attempting integration of this concept? Or are our efforts disjointed, merely going for the low hanging fruit of patching together evolving unmanned platforms with traditional manned ones? However, to start with, let us delve into the opportunities that MUM-T offers and reasons as to why land-based platforms may be more suitable for implementation of MUM-T systems.

MUM-T for Land Based Platforms

United States Army Aviation Center (USAACE) defined MUM-T as ''synchronized employment of soldier, manned and unmanned air and ground vehicles, robotics, and sensors to achieve enhanced situational understanding, greater lethality, and improved survivability". Initial development of this concept started for integration between manned aerial platforms (fixed and rotary wing) and Unmanned Aerial Vehicles (UAVs). Hence, this initial definition emanating from Aviation field became most widely accepted and laid grounds for leveraging of MUM-T for aerial platforms predominantly (Pandey, D.K. 2024).

However, MUM-T is easier to study and refine in land systems due to lower technology barriers, increased human control and easier scalability as compared to high-speed aviation. While aerial systems are primarily challenged due to increased speed leading to lesser reaction time, land-based systems have to deal with obstructions and clutter. While navigating and path planning, follow me feature etc., are easier for aerial based assets, the risk of crashing and stalling is lesser for ground-based assets. A clear line of sight and communication (more bandwidth due to reduced clutter) is better in the air while chances of detection from longer ranges are reduced closer to ground (Yadav, B. 2026). In a dense 'signal unfriendly' environment such as a battle zone, latency tolerance on ground is high and consequences of failures (crash risk) are manageable. As regards cognitive load, a pilot is already '100% hands full' due to flying which itself is a very high mental load while a ground based manned platform crew has relatively more cognitive 'think-space' available (Curras, M. 2024).

Table 1: Air and Land MUM-T Comparison

Factor	Air MUM-T	Land MUM-T
Speed	Extremely high	Moderate
Reaction Time	Seconds	Minutes
Operator Burden	Very high	Manageable
Communication Requirements	Stringent	Less demanding
Operating Environment	Minimum clutter	More obstacles
Development Risk	High	Moderate

Source: Author's Own

Therefore, although the air domain has exhibited maximum enthusiasm for incorporating MUM-T— the technology and capabilities offered by it can revolutionise the way land forces conduct warfare. MUM-T, in the ground domain, typically involves a 'mother-ship' or a manned platform like a Tank or an Infantry Combat Vehicle (ICV) operating in sync with one or more Drones/ UAVs or Unmanned Ground Vehicles (UGVs). This arrangement enhances battle situational awareness, force protection and firepower for the manned platform while reducing exposure to threats (Research and Markets, 2025). MUM-T is therefore leveraged either for extended vision (using tethered or other drones to see beyond the tanks line of sight) or integrated strike (using tanks to launch kamikaze drones and loiter munitions). Let us have a brief overview of the economic scope and status of MUM-T development world over for aerial as well as ground-based teaming.

Global Scan

Market Analysis. Global MUM-T market size is estimated at USD 5.66 billion in 2026 and is projected to grow with over 13% CAGR to reach USD 15.92 billion by 2034 (Bhilare, P. 2026). By platform, airborne systems lead with a 45.25% share of the defence MUM-T systems market while naval solutions recorded the fastest projected CAGR of nearly 16%. By application, ISR dominates with over 45% revenue share and combat operations are expected to advance at nearly 15% CAGR (Mordor Intelligence Research & Advisory, 2025). Driven by ample funding, advancements in AI (Artificial Intelligence), sensor technology and the need for force survivability, MUM-T is rapidly transforming from experimental concepts to deployable capabilities.

USA. The US is developing Collaborative Combat Aircraft (CCA) program or the Loyal Wingman envisioning autonomous drones supporting manned fighter jets (UAV Navigation, 2023). US Army Aviation has been a leader in implementing MUM-T for its Apache helicopter with UAVs. The US Navy and Marine Corps have plans to start their MUM-T journey based on the XQ-58A Valkyrie UAV (Menon, J. 2025). In the land domain, it is aggressively pursuing MUM-T with Next Generation Combat Vehicles cross functional team. AbramsX is a tech demonstrator for next generation MBT which boasts of reduced crew and enhanced AI for teaming capabilities (Larsen, C. 2022). Robotic Combat Vehicle (RCV) is the primary wingman project designed for control through Bradleys or future XM30 (next gen ICV formerly known as Optionally Manned Fighting Vehicle {OMFV}) (Ball, M. 2020). USA is currently the leader in integration of Loitering Munitions (LMs) directly into turret structure of next generation tanks like AbramaX technology demonstrator paired with four Switchblade 300 LMs (Newdick, T. Rogoway T. 2025) or Griffin III with Shrike 2 VTOL drone for surveillance (Eshel, T. 2018).

Russia. Russia has tested MUM-T in active combat and is integrating with newest platforms like T-14 Armata which has a digital backbone for teaming with UGVs like Uran-9 which is heavily armed with 30mm canon and anti-tank missiles for fire support. The Marker UGV is an experimental robotic platform for testing swarm intelligence and teaming concepts (Saha, T. 2023) while BMP-3 Sinista is equivalent of the US OMFV allowing to act as robotic wingman for other ICVs (Defense Express, 2023). Russia also has a unique approach of tethering drones to tanks for unlimited flight time and surveillance like T-14 Armata & Pterodactyl drone (Deagel, 2020), (Carlin, M. 2024). The recent adaptation in Ukraine theatre has RD-8 drone mother-ship which can carry and act as repeater for First Person View (FPV) drones, thus allowing control from inside ICVs (Khomenko, I. 2025). Russia is also integrating S-70

Okhotnik Drones with SU-57s to significantly upgrade its surveillance, EW and strike capabilities (Indian Defence Times, 2025).

China. China is focusing on developing an ultramodern air combat environment augmented by AI driven swarming and agile networks. Recent inputs suggest integrating stealth drones like the GJ-11 Sharp Sword with manned fighters like J-20S and KJ-500 (Honrada, G. 2025). In the land domain, it has converted legacy Type 59 MBT for operation via remote control for use as breaching or fire support vehicle (Mizokami, K. 2018). The Norinco VU-T10 is a heavy combat vehicle specifically designed for teaming with manned armoured units (Mandal, S. 2025). They also recently debuted Type 100 MBT or beyond visual range tank which boasts of high degree of intelligence and strong collaborative ability (Xuanzun, L. 2025). The VT-4A1 upgraded tank has drone integration as a crucial addition to the tank's capabilities for surveillance beyond the line of sight (Army Recognition Group, 2025).

Europe. The Future Combat Air System (FCAS) is a European initiative led by France, Germany and Spain to integrate the sixth-generation stealth fighter jets with UAVs (remote carriers) using MUM-T (Swan, J. 2025). Another European Union funded project, MUSHER (Manned Unmanned System for HElicopteR), recently demonstrated generic MUM-T development with helicopters and UAVs from different manufacturers. The demonstrated missions were based on concept of operations defined by France, Italy and Spain's Defence Ministries (Mobility Engineering, 2024). In the land domain, a joint Franco- German project is the Main Ground Combat System (MGCS) which is not just a tank but team of Combat Vehicles carrying sensors, missiles or lasers (Bub, G. 2025). Rhinemetal is developing KF41 Lynx ICV as a command hub for Mission Master UGV family (Joint Forces, 2018). Germany has focused on integrating Israeli LMs like HERO 120 on KF51 Panther tanks which gives it almost 60km non-line of sight strike capability (Defence Redefined, 2022).

Israel. Israel is focusing on AI and see-through armour via sensors to facilitate UGV control. The Carmel program demonstrated by Elbit, Rafael and IAI is under development, featuring a 2-man crew relying on sensors and AI for vehicle driving, hence, freeing the crew for control of UGVs and drones (Lappin, Y. 2019). Elbit and UVision are working on the 'Legion-

X' which is a swarm management system allowing armoured vehicles like Merkava to command multiple drones and ground robots (Hambling, D. 2022).

Australia. Boeing Australia has developed the MQ-28 'Ghost-bat' UAV as uncrewed CCA for teaming with existing military aircrafts. Boeing and Royal Australian Air Force (RAAF) are partnering to establish an environment facilitating CCA operational systems with interoperable and interchangeable capabilities. (Boeing, 2026). It has also converted M113 APCs into M113 Optionally Crewed Combat Vehicle which acts as the wingmen (BAE Systems, 2026).

South Korea. The Low Observable Wingman UAV System (LOWUS) is being developed for MUM-T roles by South Korea. The program began in 2021 and is aimed to be completed by 2027 (Kadidal, A. 2025). For the land domain, its Hanwa Arion- SMET is a 6x6 multi-purpose UGV optimised for MUM-T operations (Felstead, P. 2024).

Approach to Integration. The above projects clearly highlight the diverse range and depth for MUM-T integration by various nations. While the USA has numerous cases for development of both air and ground MUM-T, it also has a dedicated project Convergence, which is not a platform but a large-scale experimentation effort for testing such concepts. It is a recurring campaign of learning and adapting aimed at ever evolving data fusion, networking and synthesis of a cohesive picture across manned and unmanned platforms (Feickert, A. 2022) (Army Futures Command, 2022). NATO and European projects focus on 'system of systems' approach wherein the tank is just one node in the connected network (STO NATO, 2021). Russia is integrating MUM-T in its newest platforms while actively testing them in live combat (Syria & Ukraine). They are also focusing on tethered drones connected to tanks thus providing unlimited flight time. The Chinese believes in MUM-T to be the decisive feature in future combat and accordingly is developing operational concepts to integrate it into the existing doctrine. They are focusing more on developing software & algorithms to enable unmanned systems to augment manned platforms (Mei, S. 2025). Israel is focusing on 'closed-hatch' operations leveraging AI, where the crew can see through from inside the cockpit/ platform, thus facilitating UGV and drone operations from safely inside the armour.

Indian Landscape

Aerial Manned Platforms. The Indian Air Force sees MUM-T as a critical and transformative technology aligned with the 'Atmanirbhar Bharat' initiative to promote indigenisation of defence equipment development and manufacturing (Indian Airforce, 2025). The Hindustan Aeronautics Limited (HAL) is teaming with private industry on project CATS or the Combat Air Teaming Systems, akin to the US 'Loyal Wingman' which aims for fighter aircrafts like Light Combat Aircraft (LCA), SU-30, Jaguar etc., to control UAVs and Drones (Indian Defence News, 2025). The landmark maritime trial of this saw a LCA teaming with UAVs off the Konkan coast recently thus signaling transition from conceptual design to real world simulated demonstration (Indian Masterminds Bureau, 2025). The UAVs which include standalone as well as collaborative swarms will be used for forward scouting, as decoys or for precision strike missions.

Ground Based Manned Platforms. The Indian Army's MUM-T efforts focus on retrofitting legacy platforms (T-90 & BMP II) with drone capabilities. Plus, tank development program like the Future Ready Combat Vehicle (FRCV) and Light Tanks are looking at integrating native MUM-T features. According to the RFI for FRCV issued by MoD, it should be integrated with LMs for striking targets beyond line of sight and capable of carrying Tethered Drones for prolonged surveillance (Kumar, B. 2025). The Light Tanks, being developed under the Make I category, should also be capable of carrying drones for immediate surveillance (Larsen & Toubro, 2026). The ICV BMP II, held with the Mechanised Infantry, is to receive an upgrade for carrying LMs thus enhancing its combat capabilities (News Bharati, 2023). The T-90s are to receive specialised Surveillance Drones for enhancing situational awareness (Mukherjee, P. 2025). An iDEX ADITI 4.0 challenge has been launched to enable remote control operation of T-72 tanks for use in MUM-T role (Mohan, V. 2026).

Approach to Integration. The legacy platforms are being enabled to carry drones and LMs by retrofitting of launch canisters outside the turret instead of integrating them within (Kajal, K. 2024). Alternatively, the Drone/ LMs may be carried on separate vehicles with additional personnel for its launch and recovery. Control is likely to be exercised through a separate Tablet or portable ruggedized ground control station (GCS) (IDRW, 2025). Handling the GCS is likely to entail increased workload for the crew consisting of Driver, Gunner and Commander. Interestingly, the FRCV is to have an additional fourth person onboard for control and operation of LMs/ UAVs (AVNL, 2025). Even the DRDOs initiatives like MUNTRA (Mission Unmanned Tracked) are also mostly limited by platform centricity rather than an integrated systems approach (Firstpost, 2017).

As seen above, MUM-T development globally has shifted from the conceptualising and experimentation phase to being adopted as a core pillar for combat strategy (Binnendijk A et. al., 2020). It is intended to graduate the MUM-T platforms from being remotely controlled tools to semi-autonomous AI driven partners or team members. Let us try to understand the future trajectory of its development.

Trajectory of Development

Most of the global programs focus on standardized frameworks, plug and play architecture, Modular Open Systems Approach (MOSA) which is essential to rapidly field new MUM-T capabilities without massive, time-consuming integration efforts later (Warfighting Acquisition University, 2026). This also prevents vendor lock-in, drives affordability, accelerates innovation and enhances interoperability (ELMA, 2025). As seen earlier, the European MUM-T efforts involve not only multiple vendors but also multiple countries attempting to bring the best from everyone to the table!! The US Air Force recently has awarded a major CCA program production contract to multiple agencies. This was after learning from the single vendor driven development of F-35 Joint Strike Fighter contract in 2001 which created a perpetual monopoly of the contractor. It saw a 44 percent increase in sustainment costs apart from major issues and litigation for full access or rights to the software updates and upgrades. Hence, this dual 'split-buy' decision is a carefully nuanced shift to follow distributed responsibility approach rather than building overtly complex system (Ahlawat, S. 2026).

Also, there is a strong emphasis on human factors along with concurrent R&D into the fields of Human Centered Design (HCD), HSI (Human Systems Integration) and implementation of HRL (Human Readiness Level) scales akin to TRL (Technology Readiness Level) scales. This facilitates projects to be both technologically as well as 'human' ready (CII, 2024). Ensuring priority consideration of the human element avoids constant redesigns, prevents subsequent delays and additional costs (Tharrett DL et. Al., 2020).

However, most of the Indian MUM-T projects in land domain are centered on linking manned platforms with some unmanned assets, often without defining standards for architecture or protocol for communication or cyber security or HCD considerations. Lack of a single coherent policy also leads to silos within which each service or developer continues to work (Bhattacharya A, 2024). These development projects silently morph into attempts at mere connected presence of manned and unmanned systems, more akin to platform aggregation or at best unmanned supported manned operations. They are unlikely to achieve true MUM-T unless it provides shared SA, collaborative decision-making, adaptive task allocation, reduced human cognitive burden leading to improved combat effectiveness.

In the Indian defence ecosystem, the general principle has always been for humans to adapt to technology rather than tailoring technology to human requirements. The designing part of creation is seen as obvious, at best covered under aesthetics or ergonomics. (Kant V, 2024). This causes the end user i.e. the soldier, to bear the burden of lack of human factors, often compensating for design shortfalls through individual ingenuity. Training of the Indian soldier ensures that he will never complain and continue to make best use of the given resources. However, if a better product is made available, the same energy can be focused on the battle instead of being spent on compensating for technology!!

Despite the rapid progress and scale of developmental projects as seen till now, several hurdles still remain for meaningful deployment of MUM-T. Let us briefly look into these.

Major Challenges

The challenges to widespread implementation of MUM-T on the battlefield mainly includes technical factors like interoperability, communication and cyber vulnerability resilience as well as human factors like crew workload, trust, regulations and ethical uses. While technical hurdles are significant, many experts agree that non-technical issues like crew workload, regulations and ethics are the most demanding and slowest to resolve. That is because these require changes in human behaviour, ethics, policy, psychological engineering etc. making them stubborn to solve. Apparently, technology-based solutions and advanced engineering may be able to make systems talk to each other (interoperability) and build resilience (cyber security and seamless communication) but getting a human operator to trust and work alongside a machine cannot be forced, especially when its failure could endanger life and the entire mission itself.

Crew Workload and Trust. Adding a sophisticated and autonomous team member can increase the operator's cognitive load. The operator must monitor the unmanned platform and continue to keep an eye on the surrounding situation while performing his primary role in the manned platform. Further, trust is the single biggest factor which, if missing, will cause the operator to override the AI's decision while over trust may lead to complacency and possible catastrophe. Trust is situation dependent and requires the AI system to clearly communicate why a particular decision was made. Hence, designing effective HMI (Human-Machine Interface) that manage the added workload on human operators and build trust in the AI's decisions are essential for adoption (Rehder, VS. et. Al., 2024).

Regulation and Ethics. Lack of clear regulatory frameworks, especially concerning autonomous lethal functions, is slowing acceptability and investment (Sharma, A. 2024). Ethical concerns about human-in-the-loop control are prominent. Who is responsible for consequence of errors of the unmanned platform — is it the operator or the software developer or the manufacturer? More clarity has to emerge on this aspect before any serious and meaningful employment of MUM-T happening on the battlefield.

It is also widely understood that Functionality and Interface are two main elements to be considered in design of any human centered automation (Parasuraman, R. et. al., 2008). Consider the MUM-T on board the US AH-64E Apache helicopter, which has moved form Level of Interoperability (LOI) 3 to 4. But operators rarely utilise this feature as it leads to a large cognitive workload increase caused by a cumbersome HMI which requires the operator to memorise dozens of bezel button menus with three level deep hierarchies. Additionally, the link-up procedure is very complex and there is no visual feedback on the areas searched (Alicia, T. et al, 2020). One report mentions that it reduces combat power from the fight since the operator-gunner has to abandon his weapon/ sights for controlling the unmanned platform (Jaksha, C. 2022).

Having understood the challenges, let us now consider how adoption of HCD may be greatly impactful and critical for future development of MUM-T systems in India.

Recommended Blueprint for Human Focused MUM-T

It is amply evident from leading global and indigenous MUM-T use cases and programs that the Indian approach is sub-optimal at best. Apart from initiating direct implementation of MUM-T features into various platforms, there is greater requirement to concurrently synthesise these efforts so as to cultivate an environment first. This would then form the support structure for an ecosystem based on enhanced synergy aimed at improving SA while reducing crew workload. After all, increased workload of crew has been correlated with reduced SA as per one study in the land-based platforms environment.

Indian MUM-T efforts need to integrate adaptive HMI, cognitive workload reduction along with explainable AI at a more fundamental level which seems to be lacking as of now. Towards this end, the succeeding paragraphs enumerate key steps in formulating a strategy for development, design imperatives and HMI usefulness.

Strategy for Development. Without a guiding policy or strategy for development, all efforts will continue to be dis-jointed. An overarching plan must consider the following aspects: -

- ***MUM-T Doctrine***. A MUM-T doctrine must be developed for guiding all MUM-T projects within the IA. It must be based on the current technological state of art and look to cover the next 15-year period. The doctrine may be revised every 5 years thus maintaining its currency regularly. It should look at capability evaluation of projects by suitably incorporating 'human' metrics like crew cognitive workload, effectiveness of HMI, crew SA etc. instead of presently used 'technology' ones like range, payload, performance etc. This will encourage adoption of human factors over technology parameters in the procurement process. The measure of successful MUM-T should not be autonomy level but workload reduction per operator, improved decision quality, enhanced SA and faster kill chain.
- ***Defining the Role***. It is important to define the role of the MUM-T system within the operational environment. This, in turn, will lead to defining the level of shared autonomy and the HMI to achieve it. For example, roles like recce and surveillance or recce, surveillance and strike or target designation or IED and mine detection or Electronic Warfare etc., will influence the design and implementation differently.

- ***Employment Concepts***. It is imperative that employment concepts for MUM-T in operations must be developed first. A detailed crew workload analysis of the intended environment must be included as the start point. That should help define the immediate and essential requirements followed by possible supporting utilities. Thereafter, the development should be in phases starting with the most essential. This will ensure MUM-T adoption meaningfully at the core of operational requirements rather than going for the low hanging fruit by patching what is easily achievable or readily available.
- ***Dedicated Experimentation Cells***. There is a need to create dedicated MUM-T experimentation cells within few armoured, mechanised, infantry, and artillery formations or training establishments with a direct connect to the Army Design Bureau (ADB). This will help to develop operational test environments wherein soldiers, engineers, startups, and researchers can co-develop MUM-T concepts. Unlike most current development happening in technological silos, MUM-T requires continuous user feedback, iterative experimentation and tactical validation.
- ***Build Indigenous MUM-T Ecosystem***. Rather than relying on platform centric development, there is a need to build a complete MUM-T ecosystem. Effective MUM-T requires the integration of capabilities spanning AI, robotics, secure communications, human-factors engineering, cognitive psychology, user-interface design, and operational doctrine—expertise that is distributed across start-ups, MSMEs, universities, defence laboratories, and private industry. A consortium of multiple stakeholders must be encouraged rather than development by individual vendors. Apart from the advantages seen earlier, challenge based innovations approach encompassing all these stakeholders will not only strengthen long term technological self-reliance but also foster indigenous competencies in the critical technologies that underpins future multi- domain warfare.

Design Considerations. MUM-T system design must be based on modular and open systems approach keeping the following aspects in mind: -

- ***Common Architecture and Standard Protocols***. Architectural commonality leads to resilience and scalability of systems and networks necessary for coordinated operations in contested environments. Apart from enabling multiple and diverse systems performing as a cohesive team, it also prevents being locked into a single supplier, which significantly lowers long-term maintenance costs and supply chain risks. It facilitates rapid integration of technological insertion like new AI, sensor, or communication breakthroughs into existing fleets through modular updates rather than requiring costly, full-system redesigns.

- ***Automation Transparency***. This entails providing accurate perception of the system's intent and performance. It is mainly related to constraints that may prohibit accomplishment of the task e.g. inability of unarmed platform from engaging the target or inability to track the target etc. If the system is able to explain the rationale for a decision with transparency, the operators trust in the system will increase leading to better teaming.
- ***Supervised Autonomy.*** This capability frees the operator from requirement of micromanaging the unmanned platform. Once a higher task like 'recce an area or route' or 'search an area' is given to the unmanned platform, it should be able to plan and execute implied tasks like movement from present location to the target location and perform the recce or search without the operator controlling the platform or its sensor payload. The operator shifts from being a remote pilot to a task manager and the unmanned platform becomes an active ally rather than an expensive accessory.
- ***Cooperative Engagement***. Using the unmanned platform to designate the target while other manned/ unmanned platform engages the target. This increases the unmanned platforms utility even when not carrying any weapons at the same time keeps the manned platform out of vulnerable range.
- ***Contingencies***. In case of emergency situations, the unmanned platform should enable immediate direct control availability for critical tasks. It should also have a high level of ability to quickly react to threats.

Adaptive HMI. In the land platform domain, the tasks most critical to successful mission performance were reconnaissance and target engagement. Hence, in a high cognitive load situation, the HMI design must prune the interface and actively reduce unnecessary inputs. It may hide fuel levels or secondary drone telemetry, showing only the target lock and threat alerts to keep the commander focused on survival. Features which may be more useful are: -

- ***Information at Point of Need***. MUM-T system designers should strive to incorporate decision aids within the area of decision maker focus at that moment and location of need. Presenting relevant information wherein the operator needs it for example, latitude, longitude, or Military Grid Reference System (MGRS) displayed on a map, or a compass displayed in sensor view etc.
- ***Task Progress***. In a multi-tasking environment, the operator must get notification of task completion without active monitoring. For example, sensor scan history and current scan status as in visual feedback on the areas yet to be scanned and the ones already scanned including how much earlier. This will notify the operator of system readiness for next task and prevent idle time.
- ***Aided Target Detection***. Once a target is decided, the operator must be alerted through an icon on the display by locking and tracking or red flagging it. This will reduce the operator's workload considerably as he will not require to focus on the sensor feed screen of the unmanned platform and continue to perform his primary role in the manned one.

Table 2: Traditional Vs HCD Comparison

Feature	Traditional Design	Human-Centered Design
Control	Tele-operation (Joystick)	Supervised Autonomy (Mission intent)
Data Flow	Constant Video Stream	Exception-based Alerting
Pilot Role	Operator / Pilot	Tactical Mission Commander
Environment	General Purpose	Altitude and Terrain-Adaptive

Source: Author's Own

Conclusion

Incorporating use of robotic assets that can lighten the physical workload acts as a force multiplier on the battlefield. Every component of MUM-T planned integration should account for this element to ensure reduction of stress on the warfighter, which will increase lethality on the battlefield in return (Cover, M. 2017). The primary challenge is to provide increased amount of information and control to an operator without overloading or distracting them from their already incredibly demanding job on the battlefield. The MUM-T on board AH64E Apache helicopter is an apt example although of 'what not to do'!! With proper design founded on solid human factors and human systems integration principles, an integrated MUM-T capability can increase SA and mission effectiveness while decreasing risk to human lives.

Since MUM-T is an evolving technology, land systems domain provides a safer and more efficient environment for its implementation. There are also a host of other advantages as discussed in the previous sections. The global MUM-T sector is poised for exponential growth in the coming years ensuring availability of necessary funds for more projects. Due to its evolving nature, MUM-T projects are limited only by imagination and contemporary technological capabilities. The range and depth of projects on the global and domestic scenes confirms the same. However, all indigenous development efforts must be synergised and focused more towards human factors rather than technology consideration alone.

Experts believe that the ability to leverage MUM-T to own advantage on the battlefield is likely to depend more on crew capabilities and cognitive limitations rather than the number of additional competencies offered by this technology (Rossetti, L. 2020). Towards this end, prioritising efforts for solving human related challenges like crew workload, trust and ethical issues is desired since solutions to technical challenges will follow suit eventually. In doing so. we must capitalise on the entire ecosystem rather than specific products or developers. After all, effective MUM-T requires simultaneous development of technology, human factors, operational doctrine, training philosophy, life cycle support etc.

Indian MUM-T initiatives need to evolve from platform-level integration to human-centered teaming that enhances combat effectiveness while reducing operator workload. While all above discussed MUM-T integration efforts must continue in the Indian ecosystem, a more streamlined approach is desirable. Individual services and system developers must continue the current efforts and more, albeit under an overarching guidance framework. It is imperative that the higher defence organisations, either the MoD or CDS should take initiative for such a policy framework.

The future success of MUM-T will not be determined by the number of unmanned autonomous platforms fielded, but by how effectively human operators can understand, trust, supervise, and collaborate with them. For India, a land-centric and human-centered approach may provide a more practical bridge towards the broader vision of autonomous warfare than attempting to replicate air-centric models developed elsewhere. After all, the true measure of 'team' success is not the sophistication of the machine, but the effectiveness of the soldier working alongside it.

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