

NAVIGATING AI HALLUCINATIONS AND REGULATIONS: THE INDIAN CHALLENGE IN AIR COMBAT

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I don't see human fighter pilots being phased out. I see their effectiveness being enhanced by cooperation with artificial intelligence systems.

– Dr. Mark J. Lewis, US Department of Defence

INTRODUCTION

India stands at the crossroads where the Artificial Intelligence (AI) revolution has taken the world by surprise in the past half decade and every nation is attempting to infuse AI into its weapon systems. India is still in the design phase of its first 5th Generation aircraft, the Advanced Medium Combat Aircraft (AMCA), which must infuse the 5th Generation technologies, especially leveraging AI, and be a stepping stone for the development of the 6th Generation platform. Yet the path is filled with challenges like 'hallucinations' within the AI systems which need to be mitigated through thorough testing and evaluation by the formulation of a regulatory framework for the combat systems.

The war in AI assisted systems would be at machine speed with systems utilising AI working inside the Observe, Orient, Decide, Act (OODA) loop of the others and, thus, snatching victory from the start. However, hastened

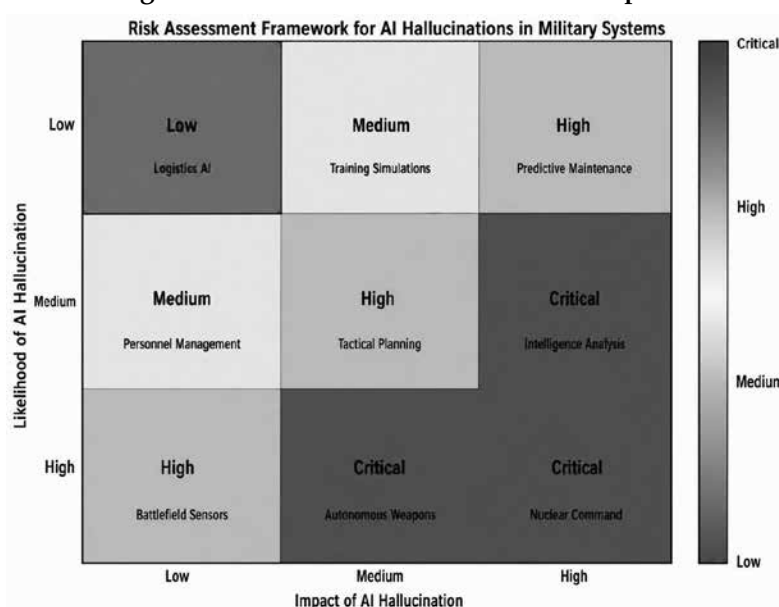
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implementation of AI in combat systems can lead to fratricide through data poisoning or through hallucinations, thus, the regulatory framework and indigenous data centres for data security are a must.

THE NATURE OF AI HALLUCINATIONS

AI hallucinations represent a challenge which must be overcome to ensure operational utilisation of AI technology. AI can hallucinate and if the human is out of the loop or has over-trust in the system generated solutions, it can lead to catastrophic results. The solutions may appear to be correct while being absolutely incorrect or entirely fabricated with incorrect information. Though the Retrieval Augmented Generation Verification (RAG-V) is a process which significantly reduces AI hallucinations, there still exists a possibility about the same in operational scenarios.

Fig 1. AI Hallucination Likelihood vs Impact¹



1. Source of image from Teodor Frunzeti, "Effects of AI Hallucinations on Military Systems," Annals of the Academy of Romanian Scientists: Series on Military Sciences, vol. 17, no. 2, 2025, p. 15, <https://aos.ro/doi/military-2025-2-13-effects-of-ai-hallucinations-on-military-systems>. Accessed on December 26, 2025.

Military-Specific Hallucination Risks

The consequences of AI hallucinations in military aviation differ significantly from civilian flight applications. Unlike commercial flight AI systems wherein errors may result in inconvenience, delays or misinformation which can be corrected with the human on the loop due to the requirements of the tasks or through sensitisation to pilots about the trust levels of AI, hallucinations in military AI can lead to much more adverse scenarios:

- **Target Misidentification:** AI systems might incorrectly classify civilian aircraft as hostile threats, thus, potentially leading to tragic incidents of fratricide or civilian casualties². The consequences of such errors extend beyond immediate loss of life and may include diplomatic crises and unintended conflict escalation when it could have been avoided.
- **Tactical Decision Errors:** In combat scenarios, AI might recommend inappropriate tactical solutions based on misinterpreted sensor data or flawed situational analysis based on an incorrect dataset. These errors could compromise mission objectives and endanger personnel, both on the ground and in the air.
- **Sensor Fusion Failures:** Data from multiple sensors is being fused and tactical action taken by the electronic pilot based on this operational picture. An incorrect picture due to a false target or incorrect fusion can lead to a poor/wrong tactical decision, thereby affecting safety.
- **Autonomous System Malfunction:** Though robust autonomous systems already exist in the present day scenario (Tomahawk missile/Harpy), AI may still hallucinate when in a scenario not having been trained for, leading to a hazardous flight condition.

Regulatory Framework Challenges for Military AI

India's existing legal and regulatory frameworks need to evolve at a rapid pace towards military-grade AI technologies. Traditional certification bodies

2. Paul Robertson, "Artificial Intelligence in the Cockpit: New Systems Could Help Prevent Aviation Accidents," *Scientia Global*, February 20, 2025, para 14, <https://www.scientia.global/dr-paul-robertson-artificial-intelligence-in-the-cockpit-new-systems-could-help-prevent-aviation-accidents/>. Accessed on February 12, 2026.

When an AI system makes a critical error, determining liability becomes complex and mostly untraceable, especially when the system has learned over a period of time and adapted beyond its original programming, depending on the dataset and environment.

like the Regional Centre for Military Airworthiness (RCMA) and Centre for Military Airworthiness and Certification (CEMILAC) have historically focussed on certifying physical platforms such as aircraft, missiles, software and weapon systems for safety³.

However, the autonomous decision-making capabilities which we aspire for through amalgamation of AI in air combat aircraft present entirely new categories of

risk that existing frameworks may struggle to address. Though the software of the current weapon systems which are autonomous at certain stages have certain conditions being certified, the complete autonomous platform poses its own challenges. The Information Technology Act and Arms Act and relevant Military Standard (MIL STDs) of the West can be used as guiding factors yet they lack specific provisions for AI driven military systems⁴.

This Regulatory Vacuum Creates Several Challenges

- **Accountability Issues:** When an AI system makes a critical error, determining liability becomes complex and mostly untraceable, especially when the system has learned over a period of time and adapted beyond its original programming, depending on the dataset and environment.
- **Certification Standards:** Traditional testing methods are inadequate for AI systems that can modify their behaviour through continuous machine learning, thus, the need to improve the certification process. The US Department of Defence (DoD) has revised the MIL STD-882F which supersedes the existing MIL STD-882E and includes separate chapters for

3. Defence Research and Development Organisation (DRDO), "Certification Services – CEMILAC Functions," Government of India, <https://www.drdo.gov.in/drdo/en/offerings/schemes-and-services/certification-services>. Accessed on January 20, 2026.

4. Bhatt & Joshi Associates, "Legal Aspects of Artificial Intelligence in Defence," March 11, 2025, para 11, <https://bhattandjoshiassociates.com/legal-aspects-of-artificial-intelligence-in-defence/>. Accessed on December 18, 2025.

AI and Machine Learning (ML) to cater for current requirements while setting minimum benchmarks to ensure safety. The same can be taken as a guiding factor towards the design and development of AI systems by India.

- **Ethical Compliance:** Current frameworks lack mechanisms to ensure that AI systems comply with international humanitarian law and ethical warfare principles as no AI model has yet been deployed without the human in the loop or over the loop, which has lethal consequences. Therefore, factors to measure trust and ethical compliance must be quantified and tested before employment.

Ensuring AI systems perform consistently and predictably would be a challenge under various operational conditions, including adversarial attacks, degraded environments and in situations not encountered during the training of the AI model.

Recognising these challenges, the Indian Ministry of Defence (MoD) launched the Evaluating Trustworthy Artificial Intelligence (ETAI) Framework and Guidelines in October 2024⁵. This landmark initiative represents the first comprehensive attempt to establish standards for military AI in India.

The ETAI Framework is Built on Five Fundamental Principles⁶

- **Reliability and Robustness:** Ensuring AI systems perform consistently and predictably would be a challenge under various operational conditions, including adversarial attacks, degraded environments and in situations not encountered during the training of the AI model.
- **Safety and Security:** Cyber attacks on the data centres of the AI training facility and operational data centres for reinforced learning need to be safeguarded against in the cyber domain. Data poisoning may lead to

5. Press Information Bureau, Government of India, "Framework & Guidelines to Integrate Trustworthy AI into Defence Operations," October 17, 2024, para 1, <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2065847®=3&lang=2>. Accessed on December 26, 2025.

6. Ibid., para 5.

negative outcomes of using AI in lethal systems, leading to fratricide or unfavourable outcomes.

- **Transparency:** The requirement of explainable AI that allows human operators to understand the system generated output in time sensitive situations and yet allows the human to verify the AI decision-making process before implementation is crucial.
- **Fairness:** Ensuring AI systems do not exhibit bias that could lead to discriminatory targeting in operational scenarios. Though these biases can be guarded against till a human is on the loop or in the loop, the final aim of an autonomous system is to ensure that there are no biases with continuous training.
- **Privacy:** Protecting sensitive data and maintaining security on military platforms with AI onboard to enhance effectiveness would be a key requirement to be met.

Chief of Defence Staff General Anil Chauhan emphasised the urgent need for trustworthy AI, noting that recent global conflicts have demonstrated how AI is revolutionising modern warfare while highlighting the essential requirement that these systems be resilient to adversary attacks⁷.

Global Context and Competitive Dynamics

Leading military powers are rapidly advancing their AI capabilities, creating both competitive pressure and opportunities for collaboration.

- **United States:** The US Air Force's Next Generation Air Dominance (NGAD) programme aims to develop a 6th Generation fighter with sophisticated AI systems. The successful flight of the AI controlled X-62A VISTA aircraft completing autonomous flight testing demonstrated the advanced capabilities in AI fighter aircraft flight controls attained through AlphaDog trials⁸.

7. Ibid., para 2.

8. Lockheed Martin, "VISTA X-62A Advancing Autonomy and Changing the Face of Air Power," February 13, 2023, para 3, <https://news.lockheedmartin.com/2023-02-13-VISTA-X-62-Advancing-Autonomy-and-Changing-the-Face-of-Air-Power>. Accessed on February 20, 2026.

- **European Initiatives:** The Future Combat Air System (FCAS) developed by France, Germany and Spain emphasises networked AI capabilities and collaborative combat operations⁹. Saab's successful integration of the AI agent 'Centaur' into Gripen E fighters marks significant progress in European AI aviation¹⁰.
- **Chinese Development:** China's state driven approach to military AI has resulted in rapid advancement across multiple domains; though specific details of fighter aircraft AI integration remain limited, the recent flight of the 6th Generation J-36 and J-50 have left the world needing to catch up¹¹.

International Regulatory Context

India's approach to military AI regulation should be derived from other nations' framework as guidelines to leapfrog timelines. The United States had released a Doctrinal Note on AI, thereby ensuring a roadmap and vision for the USAF towards futuristic warfare as the Air Force Doctrine Note 25-1¹². Every warfighter knows for a fact that a warfighting army needs to have a vision before it can employ any technology, otherwise it would be repetition of history, by following the mistakes of the past, just like the example of utilisation of tanks by the Allied forces vs Germany. Even with similar capabilities, by ensuring a roadmap, the Germans were able to employ their tanks in a different way to achieve victory (Operation Blitzkrieg). Similarly, having set the roadmap and through the institutionalised framework of Defence Advanced Research Projects Agency (DARPA) (to redefine a possible) an innovative approach like the Alpha Dog Fight trials was fruitful wherein private players accelerated the Design and Development (D&D)

9. European Commission, "Future Combat Air System (FCAS)," June 22, 2021, para 2, at <https://www.airbus.com/en/products-services/defence/future-combat-air-system-fcas>. Accessed on February 12, 2026.

10. Saab AB, "Saab Successfully Tests AI 'Centaur' in Gripen E Fighter," May 28, 2024, para 1, at <https://www.saab.com/newsroom/press-releases/2025/saab-achieves-ai-milestone-with-gripen-e>. Accessed on January 16, 2026.

11. Brian Moscioni, "Autonomous Drones Will Not Replace Fighter Pilots, They Will Be Their Wingmen," Harvard Kennedy School, June 2025, p. 13.

12. United States Air Force, *Air Force Doctrine Note 25-1: Artificial Intelligence*, April 8, 2025.

cycles to infuse AI in combat aircraft¹³. These initiatives have provided a structured testing environment, identified possible roadblocks to the project and devised mitigation strategies, thereby paving a pathway to evaluate AI reliability while ensuring ethical compliance and human-AI trust in military applications.

The European Union's approach towards infusing AI in combat aircraft was by establishing a rapid kill chain with the Future Combat Air System (FCAS) emphasising on networked capabilities and collaborative AI systems (system of system approach) while maintaining ethical oversight¹⁴. On the other hand, China has adopted a state driven approach with tight control over military AI applications and declared a 6th Generation aircraft (J-50 and J-36) in the era of 5th Generation aircraft but its AI applications onboard remain a closely guarded secret. Though the capabilities envisaged from a 6th Generation aircraft are still hazy, it would be safe to understand that AI would be a part of every 5th+ Generation aircraft to capitalise on the compute capability and big data.

The United Nations frameworks, particularly the Convention on Certain Conventional Weapons (CCW) continue to grapple with the problems of regulation and implementation of Lethal Autonomous Weapon Systems (LAWS)¹⁵. While some nations advocate for a complete ban on autonomous weapons, India and a few others emphasise the importance of responsible use while maintaining human oversight, in order to not lag behind in future warfare. The competitiveness in warfare, the changing character of war and the rapidity in technological advancement have raised questions on policies at the world level, with institutions like the United Nations being undermined for being outdated or outpaced.

13. DARPA, "AlphaDogfight Trials and AI in Air Combat," August 26, 2020, para 2, at <https://www.darpa.mil/news/2020/alphadogfight-trial>. Accessed on December 28, 2025.

14. Futura D'Aprile, et al., "Europe's Military Programmes: Strategies, Costs and Trade-offs," Institute of Economics, Scuola Superiore Sant'Anna, July 25, 2025, p. 3.

15. United Nations Office for Disarmament Affairs, "Convention on Certain Conventional Weapons (CCW) and Lethal Autonomous Weapons Systems (LAWS)," CCW/GGE.1/2023/2, May 24, 2023, para 21.

Implementation Challenges and Requirements

- **Technical Capacity Building:** Military regulators must rapidly develop expertise in AI specific issues beyond traditional hardware certification. This requires a government-led approach to ensure investment in training and recruitment of both military and civil personnel with AI expertise.
- **Scenario-Based Testing:** Unlike traditional systems, AI requires testing across a vast range of scenarios that cannot be fully predicted in advance. Adequate infrastructure is required to ensure that all scenarios is being tested in a dense Electronic Warfare (EW) environment or a Global Positioning System (GPS)/communication denied environment, thereby reducing the plausibility of hallucinations. This would require facilities like large (two football stadium size) anechoic chambers to ensure secrecy of the electromagnetic spectrum while ensuring end-to-end testing.
- **Adaptive Regulatory Models:** Traditional certification approaches are hardware-centric and would have to be revamped to ensure regular updates being transferred at the earliest to the platform yet ensuring accountability. This would require targeted testing or round the clock testing of the software versions to be uploaded onto field aircraft.
- **International Cooperation:** AI systems would take on a greater role in ensuring mission objective achievements with every update and application. Thus, to avoid strategic surprises, international cooperation with friendly foreign countries must be considered. It would also enable India to leapfrog in the niche technologies to truly build an indigenous 5th Generation aircraft.

AMCA: India's AI Integration Challenge

India's AMCA is a culmination of all niche technologies (quantum navigation and sensing, artificial intelligence, directed energy weapons, adaptive engines, edge computing, hypersonic technology, broadband stealth) which would give India a definitive edge, with indigenous production capability towards platforms as well as weapons. It should feature an 'electronic pilot' which would carry out the tasks like navigation, evasive manoeuvres for

The risk appetite of the higher defence organisation and testing fraternity must be increased to accept failures and yet not allow the programme to get rolled back. This approach would ensure that the failure reasons are addressed without compromising on safety yet keeping up with the timeline.

survivability and sensor fusion for a comprehensive operational picture. The level of autonomy should be increased based on the results and reinforced learning and maturing of the indigenous Large Language Model (LLM).

That would represent a significant advancement in combat aircraft capabilities, thereby easing the cockpit workload to manipulate or employ all sensors individually, but it would also create new vulnerabilities like AI hallucinations that could affect critical

mission functions through misinformation or incorrect dataflow which may paint a completely different air situation as compared to an actual air situation.

The risks are even higher for the AMCA programme, as any reliability issue leading to an accident/incident, due to AI systems, may push the programme further behind in the timeline and cause mistrust in the entire programme affecting India's *Atmanirbhar Bharat* dream in the defence sector and lead to continued reliance on foreign countries for niche technology in combat aircraft. The risk appetite of the higher defence organisation and testing fraternity must be increased to accept failures and yet not allow the programme to get rolled back. This approach would ensure that the failure reasons are addressed without compromising on safety yet keeping up with the timeline. This would require a whole of nation approach, with the industry and developers working hand-in-hand.

Timeline and Development Milestones

Shown below is the timeline of the AMCA project, as per open sources. It indicates the careful and weighed methodology being followed by

designers while incorporating a disruptive technology like AI, thereby ensuring ethical implementation:

- **2025:** Raksha Mantri approves AMCA model execution through the industry partnership model¹⁶.
- **2027-2028:** Expected timeline for first prototype post design refinements and first flight of the AMCA.
- **2034-2035:** Expected completion of testing and release of the platform to production partners post all capabilities integration, including AI.

The success of AI in air combat aircraft depends significantly on India's ability to develop indigenous AI technologies along with the relevant infrastructure, thus, reducing dependence on foreign countries/ companies and ensuring strategic autonomy.

These timelines, though appearing to be long drawn, are a must to ensure a reliable platform being produced. Simultaneous development of the platform as well as niche technologies like AI in fighter aircraft would be required to meet even these timelines.

Building Indigenous AI Capabilities

The success of AI in air combat aircraft depends significantly on India's ability to develop indigenous AI technologies along with the relevant infrastructure, thus, reducing dependence on foreign countries/companies and ensuring strategic autonomy.

- **Current Achievements:** India has already been developing indigenous AI applications and products for military use with public sectors institutions like the Aeronautical Development Agency (ADA), Defence Research and Development Organisation (DRDO) and Hindustan Aeronautics Limited (HAL) as well as collaborating with academia [Indian Institutes of Technology (IITs)] and start-ups with the Department of Defence

16. Press Information Bureau, Government of India, "Aatmanirbhar Bharat: Approval of Advanced Medium Combat Aircraft Programme Execution Model," May 27, 2025, <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2131528®=3&lang=2>. Accessed on January 6, 2026.

Production releasing a list of 75 projects enabled by AI under the recent initiative by the Government of India¹⁷.

- **Remaining Challenges:** Despite this progress, India still lacks critical infrastructure and technologies like advanced AI chips, data centres and proprietary large language models. Investment in Research and Development (R&D) needs to be further increased as technology and infrastructure development are essential for leapfrogging and achieving AI prowess like the leading nations in AI.
- **Strategic Initiatives:** To achieve this, there must a goal-based approach with a structured framework along with multiple redundancy for the programme. The IAF's Meher Baba innovative approach for fast tracking Unmanned Aerial Vehicle (UAV) development must be followed even in AI development to invite competition and rapid progress. Direct collaboration towards the 6th Generation fighter with friendly foreign countries must be done to gauge our own technology development pace.

Risk Mitigation Strategies

Successfully integrating AI into the AMCA programme would require comprehensive risk mitigation strategies which address both technical and operational challenges along the development cycle:

- **Redundant Systems Architecture:** Critical AI functions must have high trust levels and also back-up/redundant systems, along with human override capabilities to prevent single points of failure.
- **Continuous Monitoring:** AI systems require real-time monitoring for anomalous behaviour with automated shutdown procedures for detected malfunctions as a safety feature.
- **Graduated Autonomy:** Rather than immediately deploying fully autonomous systems, a graduated approach allows for incremental increases in AI authority as reliability is demonstrated by the model, thereby following during the Design and Development (D&D) phase a

17. Ministry of Defence (Department of Defence Production), "The New Age of Defence," July 17, 2022, p. 12, <https://www.ddpmod.gov.in/sites/default/files/2023-11/ai.pdf>. Accessed on January 16, 2026.

step-wise methodology of human in the loop, human on the loop and then human out of the loop.

- **Human – AI Teaming:** The most effective approach is to ensure human operators in critical decision-making roles while leveraging AI for data processing and recommendations generation capacity, based on the scenario.

Explainable AI: A Recommended Way Ahead

India must adopt a prudent approach by placing explainability at the centre of its AI development process. The Explainable AI (XAI) would ensure that every decision made by AI systems can be traced, verified and understood by the human operator at the earliest through the fastest possible means (audio/visual/brain interface)¹⁸. Accelerating the OODA cycles in contested environments creates the fundamental strategic opportunity by XAI integration.

- **Ground-Based Learning:** Large language models and machine learning algorithms are extensively tested on in-ground simulations for strategy development and tactical planning. However, their outputs undergo rigorous validation before any deployment on in-flight systems.
- **Frozen In-Flight Learning:** During live missions, AI systems cannot alter their behaviour based on mission data, thus, preventing unexpected behaviours that could compromise safety or mission success. All upgrades would be through the software version rollovers post mission debrief analysis.
- **Simulation Verified Deployment:** Every AI module must pass extensive testing in high fidelity simulators before integration onto operational aircraft, thus, reducing the risks of hallucinations. In any in-flight scenario being encountered by the model for the first time, its confidence level on the decision generated must be indicated to the pilot.

18. P. Jonathon Phillips, "Four Principles of Explainable Artificial Intelligence," National Institute of Standards and Technology, September 2021, p. 2.

The architectural approach must emphasise augmentation rather than replacement, with AI handling information intensive computational tasks while humans retain authority over decisions requiring judgment, contextual understanding and moral responsibility.

The architectural framework for XAI integration in combat aircraft comprises **five integrated functional layers**, each serving distinct purposes within the overall system¹⁹.

- The *Perception Layer* which fuses the information from varied sensors while ensuring that the authenticity of the data must have a matrix for its reliability to be shown to the pilot.
- The *Cognitive Layer* processes the data from the previous step to draw possible tactical decisions based on the identified threat scenario. This too should have a layered decision based on a score available to the pilot for informed decision-making.
- The *Reasoning Layer* processes the data to a humanly understandable representation of data from the previous two steps to reduce the time taken by the pilot to understand and then make the decision in a tactical scenario.
- The *Interface Layer* represents information intuitively to the pilots, either visual or aural, for human operators to rapidly comprehend and act.
- The *Action Layer* executes decisions automatically for non-lethal/non-critical tasks (like an auto pilot) or executes the pilot's decision post confirmation in lethal/critical tasks.

Though the path may look difficult, it is an essential requirement of the current geopolitical scenario. The ongoing conflicts in the world are at all time high post World War II. As the USA was forced to leapfrog to attain these technologies and militarise them based on its appreciation of China's growing capabilities, its approach to intelligentised warfare, and restructuring of its military, along with impetus on civil-military fusion.

19. J. M. Schraagen, "Bounded Autonomy," in J. M. Schraagen, ed., *Responsible Use of AI in Military Systems* (2024), pp. 350–358.

The same urgency should be shown by India. As Christian Brose argues in *The Kill Chain*, modern warfare increasingly centres around organisational speed and sensor-to-shooter cycles rather than individual platform capability²⁰.

Given below are documented timelines of AI development by the USA in an air combat aircraft, with varying stepping stones and following a whole of nation approach by utilising the armed forces' assets, academia and private players while involving the industry.

- **2016:** DARPA launched an XAI military programme leading to the ACE trial and coliseum testing environment²¹.
- **2018:** Practical implementations of the XAI systems, leading to visual-based Human Machine Interface (HMI) explanations for better human assimilation.
- **2025:** Shield AI (a private industry company) utilised the VISTA and Alpha dog trial AI matured technology to make the X-BAT prototype model in October 2025 and released possible production by 2028²². The extent of their feasibility in an air-to-air engagement is still unknown, with an unclear idea of the Combat Collaborative Aircraft (CCA) and mother aircraft HMI, as per open sources.

XAI: Practical Implementation

Practical implementation of the XAI in Beyond Visual Range (BVR) and Within Visual Range (WVR) combat scenarios would give a feel of the capabilities that XAI has to offer. BVR engagements represent the ideal application for initial XAI integration, given that these scenarios feature intense data requirements and extremely compressed decision timelines that naturally exceed the human cognitive processing capacity.

20. Christian Brose, *The Kill Chain: Defending America in the Future of High-Tech Warfare* (New York: Hachette/Houghton Mifflin Harcourt, 2020), pp. 15–55.

21. Christopher R. DeMay, et al., "AlphaDogfight Trials: Bringing Autonomy to Air Combat," *Johns Hopkins APL Technical Digest*, vol. 36, no. 2, 2022, pp. 154–163.

22. Shield AI, "X-BAT Autonomous Aircraft," <https://shield.ai/x-bat/>. Accessed on February 12, 2026.

Missile employment optimisation involves calculating firing solutions that maximise hit probability while considering remaining fuel, self-defence options (chaffs and flares) and weapon type as well as the position of other members on the network and their weapon states.

In BVR engagement scenarios, pilots face multiple contacts simultaneously appearing on radar displays at ranges exceeding visual detection capability. AI systems can rapidly analyse the radar returns to prioritise contacts by threats level, distinguish friendly from hostile aircraft based on identification of friend or foe information and other sensor signature analysis [Infrared/Ultraviolet (IR/UV)] to recommend the optimal sequence for engaging targets while minimising risk exposure. Missile employment optimisation

involves calculating firing solutions that maximise hit probability while considering remaining fuel, self-defence options (chaffs and flares) and weapon type as well as the position of other members on the network and their weapon states.

Defensive manoeuvre and programme selection for chaffs and flares or jamming techniques becomes computationally intensive in scenarios involving multiple threats from different directions and altitudes, where AI analysis can identify manoeuvre options that evade threats while maintaining the capability to engage targets.

Formation coordination ensuring that multiple aircraft within an airspace can maintain mutual support and integrate defence benefits significantly from AI coordination that maintains awareness of each aircraft's position, fuel state, weapon status and assigned roles.

WVR combat demands fast decision-making in extreme scenarios of high-G manoeuvres, with limited situational awareness due to human physiological limits. XAI in WVR would assist the pilot in ensuring that the defensive actions are automated, thereby ensuring survivability against an unknown or pop-up threat while manoeuvring effectively against an engaged threat by optimising energy management, power management

and predicting the most optimal path for a missile/gun solution.

XAI: Automation Paradox and Trust Calibration

Automation bias occurs when operators develop excessive reliance on automated system recommendations, while under-trust manifests when operators inappropriately disregard valid AI recommendations despite evidence supporting the AI analysis. Singer's longitudinal observation of military personnel operating alongside robotic systems reveals consistent patterns which are that operators' developmental models of machine behaviour are based on repeated interaction experiences and when machines behave unpredictably, operators experience trust deterioration, sometimes over-correcting toward excessive distrust of automated systems²³. Example of over-trust and under-trust are amply quoted by Paul Scharre through examples of fratricide in the Gulf War by Patriot operators and operation of the Aegis system by the US Navy²⁴.

Trust calibration represents the critical interface design objective of ensuring that operator confidence in AI systems matches the actual reliability and capability of those systems. Appropriately calibrated trust develops when operators understand both the strengths and limitations of AI systems sufficiently to discriminate between situations where AI recommendations should be accepted and situations where human judgment should override AI analysis.

Trust calibration represents the critical interface design objective of ensuring that operator confidence in AI systems matches the actual reliability and capability of those systems.

23. P. W. Singer, *Wired for War: The Robotics Revolution and Conflict in the Twenty-First Century* (New York: Penguin/Brookings, 2009), pp. 200–250.

24. Paul Scharre, *Army of None: Autonomous Weapons and the Future of War* (New York: W. W. Norton & Company, 2018), pp. 159–163.

XAI: Interface Design Principles for Combat Effectiveness and Safety

Transparency and explainability represent foundational principles enabling appropriate operator judgment over autonomous systems. The interface should communicate what the system does through clear descriptions of system function and authority level, why the system selected specific actions through transparent explanation of decision reasoning, what alternative courses of action exist and why they were rejected, confidence levels for recommendations providing a quantitative assessment of recommendation reliability and system limitations delineating operating parameters and conditions where the system was not trained. Such communication enables operators to understand system recommendations sufficiently to accept recommendations with confidence in system capability and override recommendations when tactical judgment suggests superior alternatives²⁵. Effective interface design leverages these comparative advantages by allocating information intensive computational tasks to AI systems while reserving judgement intensive tasks requiring contextual understanding to human operators.

XAI: Implementing Transparency in Combat-Critical Interfaces

Transparency would be ensured through careful design of the HMI thereby ensuring the visualisation of data which is meaningful to the pilot for decision-making instead of just data. The need for HMI to be human-centric is absolutely essential, thereby emphasising on visual depiction of the threat assessment and displaying of threats in spatial orientation along with the confidence level of the decision cycle followed by the XAI system. It should also recommend the possible alternatives and their success rates with the time available to approve the decision being taken.

Authority allocation is another aspect which must be designed with utmost care. There must be a clear visual or aural indication of control authority. Functions which are totally autonomous, and which are totally

25. M. L. Cummings, "Automation and Accountability in Decision Support System Interface Design," *The Journal of Technology Studies*, vol. 32, no. 1, 2006, pp. 4–13.

under human control must be colour coded, while the functions which can be interchanged must have a clear indication of the control authority between AI or human, depending on the tactical situation. There must be a manual override available for all the decisions, thus, allowing the human to take over the aircraft in the case of complete XAI failure or partial degradation in the combat scenario.

Multi-agent control would be possible only by implementation of XAI into the manned system, thus, making it the command and control centre in the air for these agents. The HMI must be designed to ensure minimal pilot workload and the majority of actions being automated based on the payload and mission requirement. The ability to access their individual states (weapon and fuel) would be crucial to allot the tasks in flight dynamically. Technologies like Brain Computer Interface (BCI) would enable control of multiple autonomous agents without increasing the pilot workload but has its own limitations of unwarranted commands being captured, which is a problem statement which needs to be resolved, as the technology is in the nascent stage.

CONCLUSION

The degree of autonomy in the combat situations perceived can be varied only if the trust between AI and humans is established right from the development stage. It would be the biggest challenge for the Indian R&D industry to achieve this through collaboration and steadfast progress. Examples from other R&D projects around the world also indicate that it is inevitable to integrate AI into air combat systems in the near future. China has declared that the 6th Generation fighter (J-36/J-50) aircraft will be in production by 2035, while the USA has given 2030 as timeline for the first flight of the NGAD. India would be one complete generation behind the rest of the world if we do not perceive the future combat systems in time and include its features in our CCA aircraft which would have much shorter development cycles.

Future air combat will be determined not merely by aircraft speed and weapons capability but by decision speed and networks. The ability to perceive threats, understand them and respond appropriately within compressed time scales demanded by increasingly complex contested environments would determine the victor. This decision-centric paradigm reflects emerging recognition that information dominance ultimately rests on decisional superiority rather than technical superiority alone. We, as a nation, should be ready for the next war at machine speeds.