

TRIVENI BULLETIN
FOR THE FUTURE
BY THE FUTURE



TRIVENI BULLETIN

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1. Maritime and Aviation technologies have really come of age this century. Unfolding against the backdrop of the two World Wars, these technologies have matured over the years. Interplay of various factors as in sea-lanes of communication, AI, Robotics, EW, Unmanned platforms, Space etc have seen vast research and development efforts being poured into these domains. This edition aptly focusses on the theme of Combat Maritime and Aviation Technologies.
2. As with other domains and systems, maritime and aviation domains have started to embrace the unmanned and autonomous environment to enhance operational efficiency and cause technological disruption in the field of warfare. This edition brings out developments in the fields of Unmanned Underwater Vehicles (UUVs), High Altitude Pseudo Satellites (HAPS), Blue Force UAVs and the like as the harbinger of tomorrow's war. The same are being dovetailed into modern era tactics and warfighting doctrines to achieve out of proportion gains as being witnessed in the recent conflicts in Europe & West Asia.
3. As always, it is heartening to note that bulk of our contributions come from the training institutes of DSSC and CDM. Equally appreciative is the fact that the scholar warriors have not only brought out the nuances of the modern technologies but have dwelt upon their applicability in warfighting as evident in articles such as Integrated Aerial Destruction Teams, Revolutionising the Kill Chain and more. The period has also witnessed significant Defence expositions and Technological forums, the gist of which has been covered in our Technomics section.
4. As we wind up the year, we hope that the bulletin is enriching the technical knowhow of the readers, as also bringing to the fore own perspective of emerging combat technologies and their employment in the Indian context.

' Happy Reading '

Unmanned Underwater Vehicles (UUVs)

1. **Introduction.** In the dynamic landscape of modern Naval warfare, Unmanned Underwater Vehicles (UUVs) have emerged as pivotal assets reshaping operational strategies and capabilities across the high seas. These advanced technologies represent a significant leap forward, offering unparalleled versatility, stealth, and endurance in underwater environments. This article aims to provide a broad overview of UUA's evolution, capabilities, global developments, technological advancements, challenges, and outlook of UUVs in military applications.

2. **Global Military Developments.** Countries around the globe have recognized the strategic importance of UUVs and have made significant advancement in their development and deployment. Some notable developments in UUV technology by nations are enumerated below:-

(a) **United States.** The United States Navy has been at the forefront of UUV development, investing in large-displacement UUVs such as the Orca. Designed for extended autonomous operations and strategic missions, these platforms enhance undersea surveillance and reconnaissance capabilities, contributing to broader maritime security objectives. The U.S. Navy's strategic initiatives include extensive research and development efforts, operational deployments, and the integration of UUVs into combined Naval operations.

(b) **Russia.** Russia's advancements in UUV technology include autonomous nuclear-powered drones like the Poseidon. These platforms represent a significant leap in undersea strategic deterrence capabilities, capable of carrying nuclear payloads and conducting autonomous operations in deep waters. Russia's UUV development programs focus on enhancing its strategic deterrence and expanding its undersea operational capabilities.

(c) **China.** China has rapidly expanded its UUV capabilities with platforms such as the Haiyan series and Haidou autonomous underwater vehicles. These advancements strengthen China's anti-submarine warfare capabilities, enhance undersea surveillance capabilities, and augment its presence in contested maritime regions. China's UUV development strategies are aimed at asserting its maritime claims and increasing its influence in regional and global maritime security.

Unmanned Underwater Vehicles (UUVs)

3. **Advancements Driving UUV Capabilities.** Technological advancements in autonomous navigation, sensor fusion, machine learning algorithms, and underwater communication systems are pivotal in enhancing UUV capabilities. These advancements enable UUVs to navigate complex underwater environments, detect and classify objects with precision, and transmit real-time data seamlessly. Cutting-edge technologies such as advanced sonar, high-resolution imaging systems, and AI-driven decision-making processes are driving the evolution of UUV capabilities in military applications. Research breakthroughs in these areas are continually expanding the operational potential and versatility of UUVs, making them indispensable assets in modern Naval warfare.

4. **Challenges and Future Trends.** Despite technological progress, UUV deployment and operations present significant challenges, including power management for extended endurance, cyber security vulnerabilities, and integration with existing Naval platforms. Addressing these challenges is crucial to ensuring the reliability, security, and operational effectiveness of UUVs in diverse maritime environments. Ongoing research efforts focus on developing more efficient energy storage solutions, enhancing cyber security measures, and improving the interoperability of UUVs with other Naval systems. Future trends in UUV development are likely to emphasize increased autonomy, enhanced AI integration, and greater operational flexibility to meet evolving mission requirements and threats.

5. **Future Outlook.** UUVs are increasingly integrated into combined Naval operations, working alongside manned submarines, surface vessels, and aerial platforms. This integration forms interconnected networks that enhance operational flexibility, efficiency, and responsiveness across diverse maritime missions. The strategic implications of UUV integration include improved situational awareness, more effective mission execution, and greater operational resilience in contested environments. Collaborative operational scenarios involving UUVs and manned platforms are expected to become more common, leveraging the unique strengths of each to achieve strategic objectives.

6. **Global Adoption and Strategic Implications.** As UUV technology matures, more nations are expected to incorporate these capabilities into their Naval arsenals. This global adoption will not only bolster maritime defense strategies but also contribute to maintaining Naval superiority in an increasingly

Unmanned Underwater Vehicles (UUVs)

complex and competitive global security landscape. Global trends in UUV procurement reflect a growing recognition of their strategic value and the need to enhance undersea operational capabilities. International collaborations in UUV development are likely to increase, fostering innovation and accelerating the deployment of advanced UUV systems. The strategic implications for regional and global maritime security dynamics include shifts in Naval power balances, new forms of underwater conflict, and the need for updated doctrines and strategies to address the evolving maritime threat environment.

7. **Conclusion.** In conclusion, Unmanned Underwater Vehicles represent a transformative leap in maritime military capabilities, offering Navies worldwide unprecedented advantages in undersea operations. As technological advancements continue and global adoption expands, UUVs are poised to redefine the future of undersea warfare, ensuring Naval superiority and enhancing maritime security in an evolving global security environment. By harnessing the full potential of UUVs, nations can effectively address maritime challenges, strengthen defense capabilities, and maintain strategic dominance in critical maritime regions.

Artificial Intelligence & Its Impact on Conventional Warfare

1. **Introduction.** Decision-making is a critical process in the Indian Army, as it can significantly impact the success or failure of any military operation. The Indian Army is responsible for ensuring national security and must make informed decisions quickly and accurately to achieve this goal. This article explores the various factors that influence decision-making in the Indian Army and the tools and techniques that can be used to improve this process.

2. AI and DSS technologies are used together to create more sophisticated decision-making systems. For example, AI can be used to analyze large datasets and extract insights, which can then be used by a DSS to generate recommendations or predictions. Conversely, a DSS can provide the context and constraints needed for an AI system to make informed decisions. However, the use of AI and DSS also raises ethical and social issues, such as concerns around data privacy, bias, and transparency. It is important to ensure that these technologies are developed and used in a responsible and ethical manner.

3. Military decision making often involves high costs, both in terms of financial resources and human lives. Here are some examples of these costs:
 - (a) **Financial Costs.** Military decision making often involves the use of expensive equipment, such as aircraft, tanks, and missiles, which can cost millions or even billions of dollars. Additionally, the training and support of military personnel, as well as the costs associated with maintaining bases and other facilities can be substantial.

 - (b) **Human Costs.** Military decision making often results in the loss of human lives, both among military personnel and civilians. The physical and emotional toll on individuals involved in military operations can also be significant, with many soldiers experiencing post-traumatic stress disorder (PTSD) or other mental health issues as a result of their experiences.

 - (c) **Political Costs.** Military decisions can also have political costs, both domestically and internationally. These decisions can lead to disagreements between political leaders, protests and public outcry from citizens, and strained diplomatic relations with other countries.

(d) **Strategic Costs.** Military decisions can also have strategic costs, such as the loss of territory, the weakening of alliances, and the damage to a country's reputation and influence in the international community.

4. **Data Analysis & Interpretation.** Data analysis and interpretation are critical components of AI, as they enable algorithms to learn from data and make predictions or decisions based on that data. In AI, data analysis involves the use of statistical methods and algorithms to identify patterns, relationships, and other insights in large data sets. The interpretation of this analysis involves understanding the meaning of the patterns and insights and making informed decisions or predictions based on this understanding.

5. **Conclusion.** Decision-making is a critical process in the Indian Army, and it is essential to make informed decisions quickly and accurately to achieve mission objectives. The factors that influence decision-making in the Indian Army include mission objectives, situational awareness, available resources, and time constraints. To improve decision-making, tools and techniques such as ISR, AI, DSS, and simulation and training can be used. By leveraging these tools and techniques, the Indian Army can enhance its decision-making abilities and improve the chances of success in any military operation.

1. **Introduction.** Naval communications are vital for modern maritime operations. They ensure situational awareness, coordination, and safety. Situational awareness for effective communication keeps Naval forces informed about threats, weather conditions, and friendly units, coordination communication enables joint operations, tactical manoeuvres, and synchronized movements. Quick and accurate communication enhances safety during navigation, combat, and emergencies. Technology, including satellite systems and radio frequencies, facilitates seamless communication across vast ocean expanses. Automation and encryption further enhance Naval communication towards COMSEC.

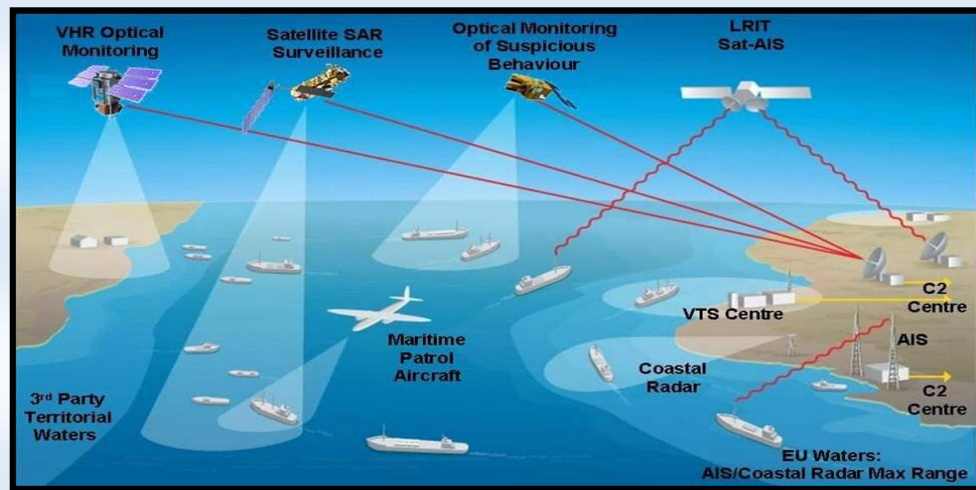


Fig 1 : Naval Communication Technologies

2. **Emerging Technologies for Naval Communication.**

(a) **5G and Beyond.** 5G networks promise ultra-low latency, critical for real-time communication faster data transfer, enabling high-definition video streaming and sensor data exchange. 5G's reliability ensures consistent connectivity even in challenging maritime environments. 5G networks comes with its own challenges which includes Installing 5G infrastructure on ships and coastal bases requires careful planning, Interference of radio waves at higher frequencies (millimetre waves) face obstacles like rain and buildings and ensuring security of IP based secure network over 5G.

(b) **Quantum Communication.** Quantum Key Distribution (QKD) leverages quantum properties (entanglement) to distribute encryption keys securely. It prevents eavesdropping by detecting any interception

attempt. QKD has direct implications for Naval Security with its unbreakable encryption. It ensures information confidentiality, critical for naval intelligence. Quantum-Resistant algorithms are necessary preparation for future quantum computers that could break classical encryption. Labs worldwide have demonstrated QKD over fibre optics and even satellite links. Even with promising applications, deploying QKD on Naval vessels remains a challenge due to stability requirements.

(c) **AI and Automation.** AI in communication systems assists in analysis of vast data streams, improving decision-making and threat detection. AI based application in natural language processing and aids communication between crewmembers with automated systems. Artificial Intelligence has its own shortcomings like ethical considerations, which require AI algorithms must be fair and unbiased and will require sufficient human oversight for balancing automation to prevent errors. Strict policy guidelines require protecting sensitive data while using AI for communication.

3. **Mobile User Objective System (MUOS).** The US Navy's next-generation narrowband satellite communications system, MUOS, completed critical testing and evaluation. The system was assessed as operationally effective, suitable and cyber survivable. The system was capable of providing essential narrowband satellite communications for the Department of Defence & other U.S. government organizations. It enables secure communication beyond line of sight with improved quality of service. Even with such a potent system, it emerged that integration of commercial cellular technology (MUOS WCDMA) enhances capacity and reliability of system.

4. **Conclusion.** In the ever – evolving maritime landscape modern Naval communication plays a pivotal role in ensuring mission success and Naval dominance. Equipped with advance technologies such as AI, stealth, material, renewable energy sources and robust communication system, future Naval ships are well prepared to face the challenges of the open seas. Innovations in acoustics and optics are gradually overcoming these limitations, promising real- time undersea data transmission. Naval communications remain the vital connecting nerves among ships squadrons, and fleets ensuring seamless coordination in times of peace, crises, and war.

Victory Through Jointness

Impact of Niche Technologies on Joint Warfighting

1. **Introduction.** New technologies like autonomous systems and artificial intelligence will galvanize the very character of warfighting and shall also impact the other aspects of warfighting to include long range precision weapon system, robotics, C4I2SR, real time uninterrupted communications, sustenance and survivability. The technology has affected all facets of warfare and is going to influence not only kinetic operations, but also non-kinetic operations to include Psychological W, Cyber W, Eco W, EW, Legal W etc. These non-kinetic aspects will be holding a great relevance in the future battlefields, which will be fought in multi-dimensions physically and digitally.

2. **Evolving Contours of Conflict.** Technological and sociological changes have brought about a paradigm shift in the understanding of war, battlefield and in fact victory and defeat. Warfare has transformed from just a classic military aggression to include a number of other domains such as political, military, economic, legal, diplomatic etc. This has led to a corresponding change in the weapons used- currency, water, markets, narratives, malware, debt, technology etc are the new weapons. The next generation of warfare is indeed about paralyzing a country by targeting their network based critical assets- banking, electricity, nuclear facilities etc along with threats of conventional escalation.

3. **Future Techno Battle Field.** The future battlefield will be dominated by technologies from diverse fields. Employing technology in kinetic and non-kinetic actions is all aimed towards crippling the will and relevance of the military might of the adversary will be the key objective. Irrespective of the nation's stature in the world arena, innovative use of technology and information to 'enforce nations will' on the adversary is the way future is likely to unfold. Some of the key aspects of future battlefield are enumerated below:-

(a) **Technology.**

(i) By 2040, a diverse range of actors will be able to access capability once restricted to just a few states. This can be seen in the present circumstances too. Turkey and Iran have made their name in development of drones, which are being sought after by various countries. These were extensively used by Russia and Ukraine in the ongoing conflict.

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- (ii) Automated systems including those that are armed will proliferate over next couple of years. It will enable swarm attacks and this may counter the advantage of high-end systems.
 - (iii) Additive manufacturing will allow producing large number of cheap, precision weapons and will make logistics chain lighter.
 - (iv) Physical and cognitive abilities will be artificially enhanced via biomechanical systems such as exo-skeletons or prosthetics, wearable devices and sensors and memory-enhancing drugs.
 - (v) The data storage servers in foreign lands will become a critical national infrastructure, but may not have the type of protection warranted.
 - (vi) Real-time multi sensor surveillance capability will be omnipresent, cheap and passive. This will have implications for operational security.
4. Cyberspace will be ubiquitous by 2040, pervading every aspect of physical environment to a far higher degree than today. Cyber activity will offer a credible way to provide deterrent effect that complies with the principle of distinction, threatening states critical infrastructure and rendering state open to coercion.
5. **Connectivity**. The future of warfare is likely to focus more on the power of info, rather than firepower, and the concepts C4I2SR. More than ever, the advantage will lie with the side, which can **collect** the most vital info, accurately and quickly **analyze** it, and then rapidly and securely **disseminate** the info and associated instructions to forces.
6. **Quantum Tech**. Quantum tech are likely to become a source of radical disruption in military affairs. Quantum communication technology enables un-hackable quantum networks. Likewise, quantum met, which measures small variations in physical parameters with unprecedented accuracy, will improve accuracy of fire, air & sea ops. Three well identified branches of quantum information science with some associated quantum emblematic technologies that can be explored as niche tech are illustrated as under:-

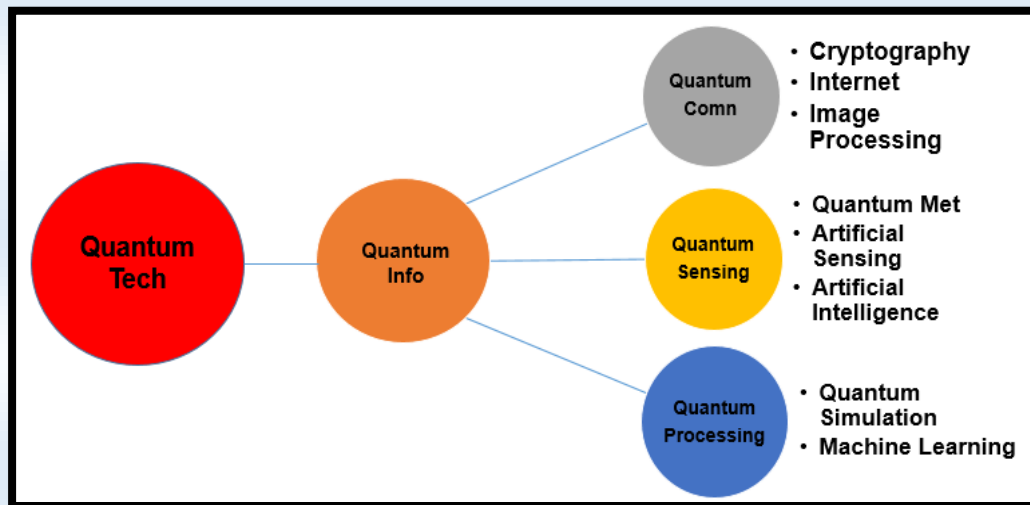


Fig 2 : Quantum Emblematic Technologies: Niche Tech

7. **Directed Energy Wpns.** DEWs offer the potential of enabling low cost, speed of light multi shots, thereby increasing the likelihood of destroying tactical and strategic targets. The challenge has always been how to deliver enough energy focused at the right spot on the target. Advances in solid and liquid state lasers have increased the prospects for practical weapon applications. DEWs could also be used to counter the high-speed and maneuverability of hypersonic weapons.

8. **Autonomy.** Autonomous and semi-autonomous systems have already revolutionised ISR. Underlying technologies that support autonomous systems, like robotics, AI, software and wireless systems are developing rapidly. The shift to unmanned system will get accelerated once the tag, track and target technologies further mature and get linked to other ISR developments.

9. **Challenges and Limitations.** While these technologies offer significant advantages, several challenges and limitations must be addressed in order to achieve success in present scenarios of war fighting:-

(a) **Adaptability & Flexibility.** Though there exists plethora of modern and niche technologies, yet it is imperative for own commanders and troops to adapt and assimilate these technologies quickly into use to enhance operational capabilities.

Impact of Niche Technologies on Joint Warfighting

(b) **Cyber Security Risks.** The utilization and integration of new technologies with the existing and traditional war fighting techniques increases the vulnerabilities in the systems which leads to increased risks of cyber-attacks substantially.

(c) **Training Requirements.** A number of technologies have been inducted into our armed forces in recent times. Due to frequent rotation of either the operators or the technical support provider, the system has not been optimally utilised. It is therefore imperative that significant training to a sizeable pool of persons is needed to ensure that personnel can effectively use these new technologies.

10. **Way Ahead.** A military tech revolution combining technological advancement in surveillance, C3I & precision munitions with new operational concepts, including IW, continuous and rapid joint operations is constantly emerging, posing a threat to enemy across frontage & depth of battlefield at all times. Integrating new and niche technologies into joint war fighting operations can significantly enhance military capabilities by improving situational awareness, decision-making and efficiency. However, addressing the associated challenges is crucial for successful implementation. By developing comprehensive strategies, robust training programs and strong cyber security protocols, military forces can effectively leverage these technologies to achieve their objectives and maintain a technological edge in modern warfare.

Latest Developments : Unmanned Underwater Vehicles (UUV)

1. **Introduction.** The explorations of the ocean's depths have undergone a revolutionary transformation. Underwater Unmanned Vehicles (UUVs) are the ones leading in this race with unimaginable margin. Underwater-unmanned vehicles, often referred to as UUVs or underwater drones, are autonomous or remotely operated vehicles designed to operate underwater without direct human intervention. These vehicles come in various shapes and sizes, each tailored to specific tasks and operational environments.



Fig 3 : Underwater Unmanned Vehicles Sys

2. **Technological Advancements.** Recent advancements in technology have significantly enhanced the capabilities of UUVs focusing on autonomy, endurance, and capabilities for various applications including defence, research, and commercial sectors. Militaries worldwide utilise UUVs for underwater surveillance, mine detection, and reconnaissance missions.

3. These vehicles enhance naval capabilities while reducing risks to human divers. Here are some notable advancements:-

(a) **Long-Endurance UUVs.** There has been significant progress in extending the endurance of UUVs, allowing them to operate autonomously for weeks or even months without needing human intervention. Lockheed Martin Corp. and Boeing Co. has received approx. \$20 million order from U.S. Naval Sea Systems Command in support of the Extra Large Unmanned Undersea Vehicle (XLUUV) programme last year.

Latest Developments : Unmanned Underwater Vehicles (UUV)

(b) **Navigation and Autonomy.** Advanced navigation systems, including GPS and inertial navigation, coupled with artificial intelligence, sonar, cameras, machine learning algorithms, enable UUVs to navigate autonomously through complex underwater environments.



Fig 4 : UUVs in Action

(c) **Communication Technologies.** Improved underwater communication technologies, such as acoustic modems and satellite links, enable UUVs to transmit data in real-time to operators on the surface. This enhances their operational flexibility and responsiveness.

(d) **Sensor Technology.** Sensor packages can include High-resolution Video or still cameras, sonar, magnetometers, fluorimeters (Chlorophyll sensors), dissolved oxygen sensors, conductivity, temperature, and depth sensors (CTDs), pH sensors and turbidity (Suspended sediment concentration) sensors.

(e) **Payload Capabilities.** UUVs are increasingly capable of carrying diverse payloads, including sensors for oceanographic measurements, cameras for underwater inspection, manipulators for

1. **Introduction.** SSBN is a ballistic missile submarine capable of deploying submarine-launched ballistic missiles (SLBMs) with nuclear warheads. These submarines became a major weapon system in the Cold War because of their nuclear deterrence capability. They can fire missiles thousands of kilometers from their targets, and acoustic quieting makes them difficult to detect, thus making them a survivable deterrent in the event of a first strike and a key element of the mutual assured destruction policy of nuclear deterrence. The deployment of ballistic missile submarines is dominated by the United States and Russia (following the collapse of the Soviet Union). Smaller numbers are in service with France, the United Kingdom, China and India. North Korea is also suspected to have an experimental submarine that is diesel-electric powered.

2. **Purpose.** Ballistic missile submarines differ in purpose from attack submarines and cruise missile submarines. Attack submarines specialize in combat with other vessels (including enemy submarines and merchant shipping), and cruise missile submarines are designed to attack large warships and tactical targets on land. However, *the primary mission of the ballistic missile boat is nuclear deterrence.* They serve as the third leg of the nuclear triad in countries that also operate nuclear-armed land based missiles and aircraft. Accordingly, the mission profile of a ballistic missile submarine concentrates on remaining undetected, rather than aggressively pursuing other vessels. Ballistic missile submarines are designed for stealth to avoid detection at all costs. The nuclear power allows almost the entire patrol to be conducted submerged. They also use sound-reducing design features, such as anechoic tiles on their hull surfaces, carefully designed propulsion systems, and machinery mounted on vibration-damping mounts.

3. **Armament.** Nuclear ballistic missile submarines generally resemble attack subs of the same generation, with extra length to accommodate SLBMs {(Russian R-29 (SS-N-23) or the NATO-fielded and American-manufactured Polaris, Poseidon, and Trident-II missiles)}. Some early models had to surface to launch their missiles but modern vessels typically launch while submerged at keel depths of usually less than 50 metres (160 ft). Missiles are launched upwards with an initial velocity sufficient for them to pop above the surface, at which point their rocket motors fire, beginning the characteristic parabolic climb-from-launch of a ballistic missile. Compressed air ejection, later replaced by gas-steam ejection was developed by Captain Harry Jackson. He also derived

of 16 missiles used in many SSBNs for the George Washington class in 1957, based on a compromise between firepower and hull integrity.

4. Nomenclature.

(a) **United States and United Kingdom.** In the US Navy, SSBNs are sometimes called Fleet Ballistic Missile submarines or FBMs. In US naval slang, ballistic missile submarines are called boomers.

(b) **France.** The French Navy commissioned its first ballistic missile submarines as SNLE {(*Sous-marin Nucléaire Lanceur d'Engins* (i.e "Nuclear-powered device-launching submarines"))}.

(c) **Soviet Union and Russian Federation.** The Soviets called this type of ship RPKSN (i.e "Strategic Purpose Underwater Missile Cruiser"). This designation was applied to the Typhoon class.

(d) India classifies this type of a submarine as a Strategic Strike Nuclear Submarine.

5. Status of SSBNs.

<u>Country</u>	<u>Active</u>	<u>Under Development/planned</u>
USA	Ohio class – 14	Columbia class - 12 planned
UK	Vanguard class – 4	Dreadnought class – 3 under construction, 4 planned
France	Triumphant class – 4	SNLE 3G – 4 planned
China	Type 092 – 1 Type 094 – 6	Type 096
India	Arihant class -2	Arihant class – 2 under construction S5 class – 3 planned
Russia	Borei class – 7 Delta class – 6	-

6. Latest Developments.

(a) **Life of Reactor Core.** The US Navy is accelerating the development and construction of its new Columbia class SSBNs to attain the goal of engineering the most lethal, high-tech and advanced SSBN the world has ever seen. These submarines will enter service by 2031 and serve well into the 2080s and beyond.

(b) **Underwater Detection Capabilities.** New detection techniques are emerging that do not rely on the noise a submarine makes and may make traditional manned submarine operations far more risky in the future. These include increased use of lower frequency active sonar and *non-acoustic* methods of detecting submarine wakes at short ranges.

(c) **Stealth, Sensors and “Acoustic Superiority”.** The innovations include quieting technologies for the engine room to make the submarine harder to detect, by using a new large vertical array and additional coating materials for the hull to attain what US Navy calls “Acoustic Superiority”.

(d) **Futuristic Hoistables.** The Columbia class will also use next-generation communications system, antenna and mast. The present day periscope is now replaced with a camera mast connected to fibre-optic cable, enabling crew members in the submarine to see images without needing to stand beneath the periscope.

(e) **Maintenance Free Shafts.** The shafts of the new submarines are being built to last up to 10 or 12 years in order to synchronise with the ships maintenance schedule. Existing shafts need inspection and refurbishment every six to eight years.

(f) **Silent Propulsion System.** China’s new submarine engine is poised to revolutionise underwater warfare. China’s new nuclear submarines will soon use a ‘*shaft-less*’ rim-driven pump-jet, a revolutionary and silent propulsion system. A rim driven pump-jet has a ring-shaped electrical motor inside the pump jet shroud, which turns the vane rotor (a vane rotor has the fan blades attached to a rotating band built on a cylindrical interior, as opposed to a propeller shaft) inside the pump jet cavity to create thrust.

(g) **Air Independent Propulsion.** Amongst the various type of air independent propulsion (AIP) systems in use on-board conventional submarines, the fuel cell (FC) based System is the most sought after and is also the preferred option for Indian MoD's Project P75(I).

7. **Conclusion.**

(a) The pace of submarine technological development globally, have made even the Moore's Law (the number of transistors per square inch on integrated circuits would double in the computer in approximately two years) redundant. The race for Indian Ocean Under-water *Supremacy* is on amongst the technology leaders in US, Europe and China. While India has the most ambitious submarine building programmes anywhere in the world today.

(b) In the backdrop of these developments, it is imperative for Indian Navy to keep abreast with the latest developments in the field of submarine technologies to be able to retain that critical technological edge.

Flying Torpedoes – A Force Multiplier

1. **Introduction.** A key component of naval combat, torpedoes combine devastating strength, stealth and accuracy. The contemporary torpedoes are formidable weapons for anti-submarine and anti-surface warfare because of their sophisticated counter-countermeasures, quiet propulsion technology, extended ranges and improved guidance capabilities. Torpedoes provide flexible and adaptable alternatives for maritime strategy since they can be launched from a range of platforms, such as aircraft, surface ships, and submarines.
2. Flying Torpedoes represent a significant advancement in naval warfare technology. Combining the stealth and precision of traditional Light Weight Torpedo (LWT) with the extended range and flexibility of missiles or glide bombs, the Flying Torpedoes offer enhanced capabilities for anti-submarine and anti-surface warfare. This paper provides an overview of Flying Torpedoes, covering their design, operational principles, strategic advantages and global scan of the technological advancements in this niche field.
3. **Structural Components.** The structural components of Flying Torpedoes are designed to maximise their range, accuracy, and lethality. Key elements of the torpedo include an aerodynamic glide body or canister based missile capable of housing a torpedo, which allows the torpedo to travel extended distances through the air before entering the water. This body is equipped with control surfaces that provide manoeuvrability and stability during the glide or cruise phase. The propulsion system typically consists of a solid rocket booster for the initial launch, which transitions to a glide mode. Upon nearing the target, the glide body detaches or the missile jettisons the torpedo, and the torpedo section enters the water, where it employs a conventional propulsion system, usually electric or thermal to close in on the target. Advanced guidance and control systems, incorporating GPS, inertial navigation systems (INS), and potentially satellite guidance, ensure precision targeting. In the underwater phase, acoustic homing systems guide the torpedo to its final target, making it a formidable weapon in both anti-submarine and anti-surface warfare.
4. **Operational Phases.** The operational phases of a Flying Torpedo can be broken down into three key stages:-

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(a) **Launch Phase.** During this initial phase, it is launched from its platform, which can be a surface ship, submarine, or aircraft. A solid rocket booster propels the torpedo into the air, providing the necessary thrust and altitude to transition into the glide phase. This phase is crucial for gaining the momentum and height required for the extended glide trajectory.

(b) **Glide or Cruise Phase.** In case of aerodynamic glide body, the torpedo travels through the air, utilising its aerodynamic design and control surfaces to maximise distance and accuracy. It is guided by advanced navigation systems, such as GPS and inertial navigation systems (INS), to maintain its trajectory towards the target area. In case of canister-based missile with torpedo, the torpedo is housed in the missile body and is jettisoned on reaching the probable target area. This phase allows the torpedo to cover a vast distance with minimal propulsion, reducing its acoustic signature and making it harder to detect by enemy defences.

(c) **Engagement Phase.** As the aerodynamic body nears its target, it transitions from the glide phase to the engagement phase. The glide body detaches, and the torpedo section enters the water. At this point, the torpedo's underwater propulsion system activates, propelling it towards the target. This phase leverages the torpedo's stealth and precision to deliver a devastating blow to the target, whether it be a submarine or surface vessel.

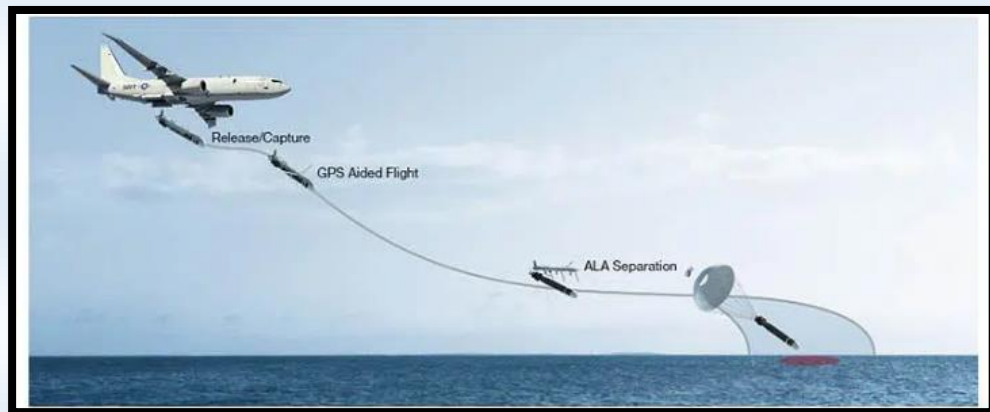


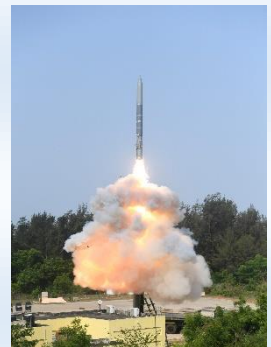
Fig 5 :Deployment of Light Weight Torpedo with Glide Kit

Flying Torpedoes – A Force Multiplier

5. **US Navy.** The United States Navy has been actively developing Flying Torpedoes to complement its existing arsenal of submarine and surface ship-launched torpedoes. The U.S. is focusing on integrating advanced guidance and propulsion systems to increase the range and accuracy of its torpedoes. Programs such as the High Altitude Anti-Submarine Warfare Weapon Capability (HAAWC) by Boeing, which converts the Mk 54 lightweight torpedo into a glide torpedo, are prime examples of these efforts. The HAAWC enables aircraft to launch torpedoes from high altitudes and long distances, enhancing the Navy's anti-submarine warfare (ASW) capabilities.



6. **Indian Navy.** DRDO is developing Supersonic Missile-Assisted Release of Torpedo (SMART) system, a next-generation missile-based lightweight torpedo delivery system to enhance the anti-submarine warfare capability of the Indian Navy far beyond the conventional range of lightweight torpedo. The SMART missile system comprises a long-range supersonic missile carrier that can travel up to 643 km, and a lightweight torpedo with a range of 20 km and a 50 kg high explosive warhead as the payload. It is a canister based missile system that consists several advanced sub-systems, namely two-stage solid propulsion system, electromechanical actuator system, precision inertial navigation system etc.



7. **Conclusion.** Flying torpedoes represent a transformative leap in naval warfare technology, offering unprecedented range, stealth, and versatility crucial for modern maritime operations. These advanced systems provide significant strategic advantages, such as the ability to engage targets from a safe distance, enhance operational flexibility, and serve as a force multiplier in diverse combat scenarios. For India, the DRDO stands at a pivotal juncture with potential to develop operational SMART system and its integration with the existing torpedoes in the Indian Navy inventory. By focusing on indigenous development, leveraging cutting-edge technologies, and fostering collaboration with private industry and academia, DRDO can position India as a key player in Flying Torpedo capabilities.

Resolution of 5G Interference in C Band Reception – Blind Source Separation

1. **Introduction.** The Government of India commenced auctioning of 5G spectrum from 26 Jun 22. The 5G bands supported in India can be classified into three categories based on carrier frequencies as follows:-

(a) **Low Band Frequencies.** The low band 5G uses a frequency less than 6 GHz with a much larger area coverage.

(b) **Mid Band Frequency.** This covers 3300 MHz frequency. This uses frequency of more than 6 GHz and less than 30 GHz. This band covers a lower range than low band frequencies. However, this mid band provides higher speed than low band 5G.

(c) **High Band.** High band comprises of frequency more than 30 GHz. This band covers area comparatively lesser than low and mid band 5G but has the ability to provide the fastest internet speed.

2. **Interference.** The C-band frequency range for SATCOM communication is from 3.6 – 4.2 GHz for reception and 5.8 - 6.4 GHz for transmission. The Ku band ranges from 10.9 – 12.7 GHz for receiving and 13.7 – 14.5 GHz for transmission. Thus it is evident that the reception of C band signals will be effected by the presence of n78 and n77 mid band frequencies of 5G. This paper intends to formulate a few techniques to obviate the presence of strong mid band frequencies from the weak C band receptions.

3. Dealing with strong 5G mid band interference signals is a challenging and highly specialised task. Blind Source Separation (BSS) is a powerful technique in digital signal processing that aims to separate a set of mixed signals into their individual source components without prior information about the source signals or the mixing process. It's particularly useful in scenarios where multiple signals are combined, that can be considered to filter out the effects of 5G interference and separate.

4. **Blind Source Separation (BSS).** Blind Source Separation refers to techniques that intends to separate a set of mixed signals into their original source signals without knowledge of the mixing process or the source signals. The common BSS techniques in application are enumerated below:-

Resolution of 5G Interference in C Band Reception – Blind Source Separation

(a) **Independent Component Analysis (ICA)**. ICA separate the mixed signals by assuming that the source signals are statistically independent and non-Gaussian. The steps involved in the same are as follows:-

(i) **Centering**. It is the process to subtract the mean from the observed signals to center them.

(ii) **Whitening**. Transform the signals to uncorrelated signals with unit variance.

(iii) **Maximizing Non-Gaussianity**. It is the use of measures like Kurtosis or Negentropy to maximize the non-Gaussianity of the separated signals.

(b) **Principal Component Analysis (PCA)**. PCA aims to reduce the dimensionality of the data by projecting it onto orthogonal principal components that maximize variance. PCA is not inherently designed for separation but can be used as a pre-processing step for ICA. The various steps involved in the same are as follows :-

(i) Computation of the covariance matrix of the centered data.

(ii) Performance of eigenvalue decomposition.

(iii) Selection of the top principal components based on the largest eigenvalues.

(c) **Non-negative Matrix Factorization (NMF)**. NMF factorizes a non-negative matrix into the product of two non-negative matrices, emphasizing the additive nature of the signals. The same is practically very useful and being extensively employed in audio processing, image processing, and spectral un-mixing.

(d) **Beamforming**. Beamforming uses an array of sensors to focus on signals coming from specific directions while nullifying others.

Victory Through Jointness

Resolution of 5G Interference in C Band Reception – Blind Source Separation

The use of adaptive algorithms. The use adaptive algorithms in conjunction with an array of sensors can dynamically adjust the beamforming weights to separate desired signals from strong interfering signals.

5. **Conclusion.** ICA can separate the mixed signals into their original components, even without prior knowledge of the mixing process. The effectiveness of this technique as enumerated above in resolution of 5G interference in C band interception depends on the specifics of the area and target VSAT links. The choice will also depend on the resources and capabilities of equipment available. This solution may be considered for resolution of 6G interference in C band reception through Blind Source Separation.

High Altitude Pseudo Satellites : Transforming Military Surveillance and Communication

1. **Introduction.** High Altitude Pseudo Satellites (HAPS) are advanced unmanned aerial platforms which ***operate in the stratosphere*** for extended period of time, between 18 and 22 km above earth surface. They combine the flexibility of aerial platforms with the extended endurance of satellites ***at much reduced cost***. Towards this, successful flight by Airbus Zephyr for 64 days made it one of the most advanced platforms. The Zephyr system was tested with high-resolution imagery and video with up to 15 cm resolution, 400 km sight horizon and a thousand square kilometres communication coverage.

2. **Overview.** HAPS are solar powered unmanned aerial platforms which fly above conventional air traffic in the stratosphere. While Aerostatic HAPS (balloons & airships) use the buoyancy to stay at the operational altitude, the aerodynamic HAPS (aircrafts) have fixed wings (solar panel) with large wingspan. Solar-powered HAPS leverage ***lightweight materials*** and ***vast solar panel arrays*** to efficiently harvest solar energy, while ***high-performance batteries*** ensure continuous operation at night. ***AI algorithms*** play crucial role in optimising power & heat management for adapting to dynamic weather conditions and ensuring efficient flight paths. Autonomous avionics powered by AI manage navigation, communication and undertake real-time decision-making for precise unmanned flight.

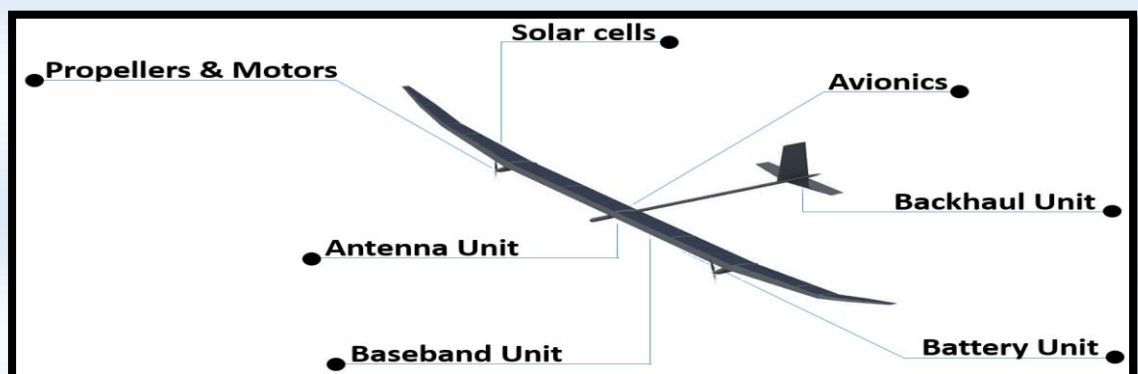


Fig 6 : HAPS System Architecture

3. **Capabilities.**
 - (a) **Unparalleled Persistence and Coverage.** Unlike traditional aerial platforms with limited flight endurance, HAPS can remain airborne for months, providing continuous surveillance and communication deep

Victory Through Jointness

High Altitude Pseudo Satellites : Transforming Military Surveillance and Communication

into enemy areas from own airspace. Additionally, their high- altitude position allows for a wider field of view, greater coverage, quick responsiveness, improved quality and security.

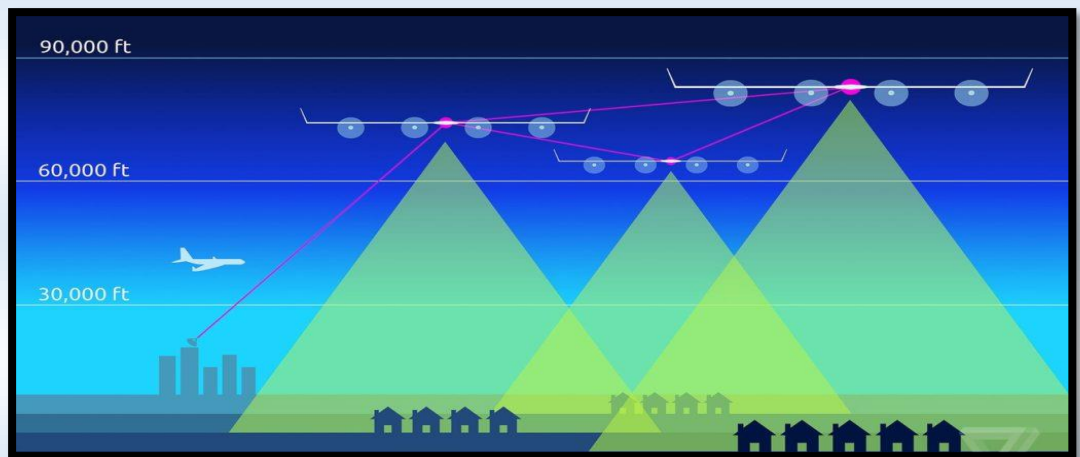


Fig 7: Altitude and Field of View of HAPS



Fig 8 : Comparison of Area Coverage – HAPS vs MALE UAV

(b) **Versatility and Flexibility.** The platform offers module-based integration of payloads thus providing versatility and flexibility.

(c) **AI Driven Real-Time Data Analysis.** AI driven analysis enables *automatic detection & tracking of objects, identification of patterns & generation of actionable intelligence* thereby enhancing situational awareness & better decision-making.

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High Altitude Pseudo Satellites : Transforming Military Surveillance and Communication

(d) The HAPS operates like a traditional UAV albeit with a much enhanced endurance of 30 to 60 days (unlike an UAV operating for 24 hours). Since it does not have to orbit like a satellite, it can maintain a constant surveillance over a specific area.

4. **HAPS Development: Global Trends.** HAPS market was valued at USD 0.76 billion in 2023 and is anticipated to reach USD 1.37 billion by 2028 (refer figure 5), registering CAGR of 12.44% during the forecast period. USA, UK, China, France, Germany, Czech Republic and India are focusing on development and acquisition of HAPS for civil and military applications. The Airbus (Zephyr), Boeing (Odysseus), Prismatic (PHASA-35), China's AVIS (Morning Star 50), Newspace Research & Technologies are few companies leading the R & D.

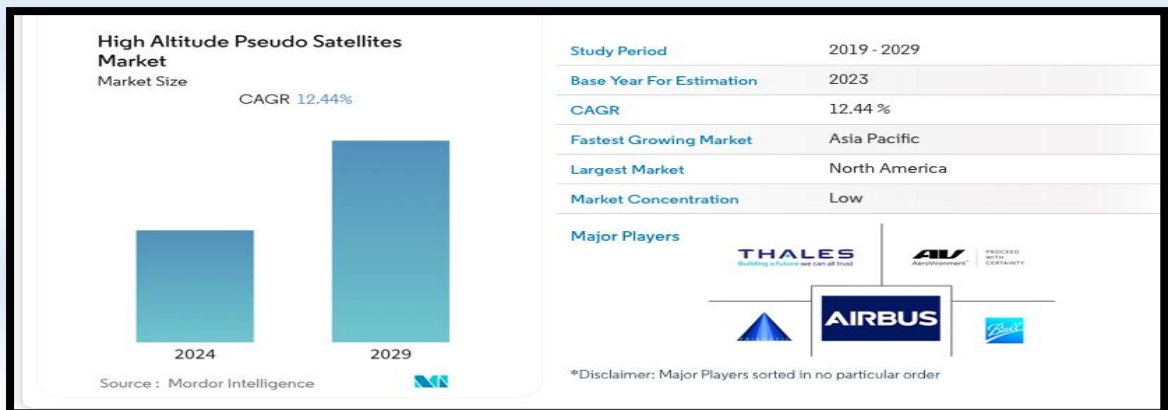


Fig 9 : HAPS Global Market

5. **Development in China.** Aviation Industry Corporation of China, in Sep 2022, carried out successful test flight (26 min) of its solar-powered HAPS, **the Morning Star 50** (refer figure 6). Similar to Airbus Zephyr, it has the ability for long term operation and is likely to be used for providing surveillance, communication and navigational relays for military operations. However, their use will likely be restricted to above tropic of cancer due to harsh stratospheric environment. These developments are part of China's broader strategy to bolster its capabilities in space and maritime domains and will supplement spy balloons programme.

High Altitude Pseudo Satellites : Transforming Military Surveillance and Communication

HAPS – Present Status in India

6. **Veda Aeronautics and Mira Aerospace**. This India-UAE collaboration is developing HAPS for the Indian Air Force under Make-1 project. The platform should be capable of carrying at least 35 kg payload and sustained operations at altitudes of 18,000 meters for 30-45 days. Their technology demonstrator has already conducted test flights over the Pokhran test Range at 40,000 feet.
7. **NewSpace Research & Technologies Pvt Ltd**. This start-up has secured a contract with the Ministry of Defence through the Innovation for Defence Excellence (iDEX) initiative. Their prototype has demonstrated capability of 27 hours flight time at 26,000 feet.
8. **Hindustan Aeronautics Limited (HAL)**. HAL and NewSpace Research are developing HAPS Infinity as part of the HAL CATS (Combined Air Teaming System).
9. **Way Ahead**. The emergence of HAPS signifies a transformative era in military surveillance and communication. Their unparalleled persistence, expansive coverage and AI-powered real time data analysis offers a significant advantage over traditional platforms. While technological challenges remain, ongoing research and development efforts are paving the way for the wider adoption in the future. Their ability makes them a valuable asset for adoption in the Indian armed forces as they hold the promise of reshaping the future of military operations and enhancing national security.

Integrated Aerial Destruction Teams

1. **Introduction.** Integrated Aerial Destruction Teams (IADT) are specialized units designed to coordinate and execute air and missile defense operations. These teams integrate various aerial assets and technologies to detect, track, and neutralize aerial threats, such as enemy aircraft, missiles, and drones. The concept is part of broader Integrated Air and Missile Defense (IAMD) strategies, which aim to create a cohesive defense network by leveraging multiple sensors, shooters, and command systems.

2. **Concept.** Integrated Aerial Destruction Teams are designed to capitalize on the unique strengths of both manned and unmanned aircraft as described below: -.

(a) **Autonomous Asset.** Unmanned systems, on the other hand, bring enhanced reconnaissance capabilities, increased firepower, and reduced risk to human lives. Drones and other unmanned aerial vehicles (UAVs) are equipped with sophisticated sensors and cameras that provide real-time intelligence and surveillance, offering a clear picture of enemy positions and movements, invaluable for planning and executing precise strikes on ground targets. Additionally, unmanned systems can carry a variety of weaponry, from small arms to standoff missiles, significantly boosting the firepower available to the team. Their ability to operate in high-risk environments without endangering human lives makes them ideal for missions that involve heavy enemy defenses or dangerous terrain.

(b) **Command and Control (C2) Element.** Manned platform play a critical role in these integrated teams, serving as the command and control centers of the operation. Pilots and crew members bring a wealth of experience and situational awareness to the battlefield, enabling them to make real-time decisions that are crucial for mission success. The human element ensures that precision targeting is executed with the utmost accuracy, leveraging advanced avionics and weapon systems to engage enemy forces effectively. Moreover, manned systems provide the strategic oversight needed to coordinate the various elements of an integrated team. They offer a broader view of the battlefield, enhancing the overall situational awareness and enabling seamless communication between all assets involved. This leadership role is vital in ensuring that all components of the team work in harmony to achieve their objectives.

Integrated Aerial Destruction Teams

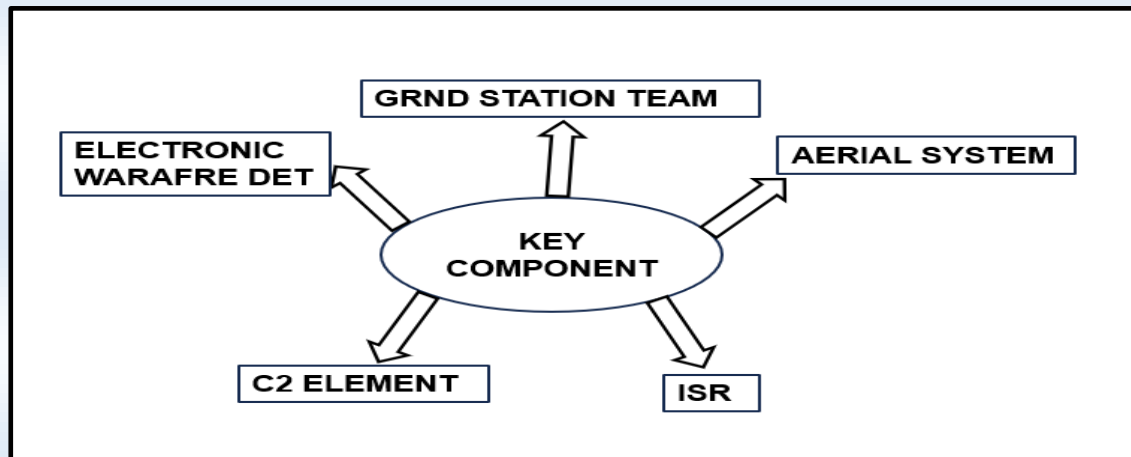


Fig 10 : Command and Control (C2) Element

3. Suggested Organisation.

(a) **Command & Control Element.** It will have a team leader, operation officer (for planning and coordination) and communication officer.

(b) **ISR Team.** It will have intelligence det and UAV for recce. Intelligence will analyse information and input received from integral resources and higher headquarters.

(c) **Aerial System.** It will have 1-2 Attack Helicopters / Fighter aircraft and a UAV/ UCAV.

(d) **Ground Station Team.** It will have Forward Air Controller (FAC) / Ground Station Controller and one to two persons for administrative duties.

(e) **Electronic Warfare Det.** This det will have 2-3 persons with EW equipment.

4. **Operational Capabilities.** During Air Interdiction (AI) / Battlefield Air Strikes (BAS), where resources may be limited but the objectives are critical, the autonomous systems can penetrate heavily defended areas to identify and neutralize air defense systems, paving the way for manned aerial / ground-based platforms (i.e, decision maker being a C2 element) to carry out subsequent missions with reduced risk. It extends their capabilities in air

Integrated Aerial Destruction Teams

operations, where the detection and neutralization of hostile aerial / ground-based Air Defence platform of enemy are paramount. UAVs can provide extensive aerial surveillance, while manned aircraft / helicopters / UCAV can execute strikes. The integration of standoff weapons with UAV capabilities allows for precise engagement of enemy targets from a safe distance. This reduces the risk to manned aircraft and ensures that critical targets are destroyed without exposing friendly forces to direct combat. These manned aerial / ground-based platforms act as the **nerve center** of Integrated Aerial Destruction Teams. Pilots and crew members, equipped with sophisticated avionics and communication systems, provide real-time command and control, ensuring seamless coordination between all team components. This real-time oversight allows for rapid decision-making and dynamic adjustments to mission parameters, which is crucial in fast-paced combat scenarios. IADTs provide robust close air support (CAS) to ground forces. UAVs can scout ahead, identify threats, and relay information to manned aircraft / ground control stations, which can then execute targeted strikes to support advancing troops. This close coordination enhances the overall combat effectiveness of ground operations, providing a significant tactical advantage. The various feasible models for IADTs are mentioned below: -

<u>Ser No</u>	<u>Model</u>	<u>Sensor Element</u>	<u>Decision Maker</u>	<u>Strike Element</u>
(a)	Model I	Scout Helicopter / Fighter Aircraft	Attack Helicopter / Fighter Aircraft	Attack Helicopter / Fighter Aircraft
(b)	Model II	UAV / UAS	Attack Helicopter / Fighter Aircraft	Attack Helicopter / Fighter Aircraft
(c)	Model III	UAV / UAS	Grnd Based Manned System (Ground control Station)	UCAV
(d)	Model IV	UAV / UAS	Grnd Based Manned System (Ground control Station)	PGM
(e)	Model V	UCAV	Grnd Based Manned System (Ground control Station)	UCAV

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Integrated Aerial Destruction Teams

5. **Types.** In view of above, integration of Unmanned Aerial System (UAS) being the Autonomous asset, Aerial / Ground Based Manned System (Ground control Station) as Decision maker and Attack helicopter / Fighter aircraft / UCAV / PGM being the Strike element, would be a game changer in the future battlefield. Suggested types of IADTs based on the above models for Indian Armed Forces are as mentioned below:-

- (a) Attack Helicopter IADT.
- (b) Fighter Aircraft IADT.
- (c) UCAV IADT.
- (d) PGM IADT.

6. **Conclusion.** While Integrated Aerial Destruction Teams represent a significant advancement in military aviation, they are not without limitations. Addressing these challenges requires continuous technological improvements, robust cyber security measures, comprehensive training programs, and careful consideration of ethical and legal implications. By acknowledging and mitigating these limitations, military forces can maximize the effectiveness of Integrated Aerial Destruction Teams in modern combat operations.

Revolutionizing the Kill Chain : How FPVs are Transforming Modern Warfare

1. **Introduction.** The term "kill chain" describes the process militaries use to attack targets in the battle space. This process can be broken down into specific steps—find, fix, track, target, engage, and assess—that enable planners to build and task forces for combat operations. This "kill chain" competition has been one of the foundational struggles underpinning military conflicts.

FPV Hunter-Killer Drones in the Russo-Ukraine Conflict

2. Small, affordable FPV drones are transforming the Kill Chain, as evidenced by the Ukraine conflict. These drones enable soldiers in the field to make decisions that previously required an elaborate process involving expensive hardware and senior commanders. This shift allows for quicker and more flexible responses on the battlefield. Reports of their significant battlefield influence highlight a fourfold increase in deployment due to their low cost (about \$400) and accessibility.

3. Ukrainian workshops produce up to 100,000 FPV drones monthly, usually equipped with one-pound grenades. While these drones have limitations, such as a six-mile range and lower-quality cameras affecting night or adverse condition operations, their strategic use has helped Ukraine offset Russia's numerical advantage and prompted other nations to reassess their military investments.

4. A case in point to highlight how FPV drones have revolutionized the Kill Chain is the vulnerability of Abrams tanks during the Russo-Ukraine conflict. In April 2024, Ukraine withdrew its Abrams tanks from frontline combat due to their vulnerability to inexpensive Russian drones. Despite their advanced features and high value of around \$10 million each, five Abrams tanks were destroyed by much cheaper drones. A significant event occurred on March 3, 2024, when a Russian Orlan-30 FPV-enabled drone, equipped with a laser designator, detected an M1 Abrams tank in Avdeyevka. The tank was destroyed by a Msta-S self-propelled howitzer using a Krasnopol smart munition, demonstrating the precision and cost-effectiveness of drone technology in the modern Kill Chain.

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Revolutionizing the Kill Chain : How FPVs are Transforming Modern Warfare



Fig 11 : Tanks & Armoured Vehicles Destroyed by Drones

5. **Kalashnikovs in the Sky for Ukraine's Defence.** A Ukrainian infantryman, Valentyn Ilchuk, leads a three-man 'hunter-killer crew' using FPV kamikaze drones to target Russian forces in the Zaporizhzhia region. His team, part of a mobile volunteer group, employs DJI Mavic drones as hunters and heavy-duty DJI Agras drones as bombers. They have also used modified fixed-wing UAVs such as the Skywalker X8 to deliver explosives behind enemy lines. Ilchuk emphasizes the cost-effectiveness and impact of drones in modern warfare, as inexpensive drones costing a few hundred dollars can inflict significant damage on high-value targets like tanks and missile launchers, thereby enhancing the Kill Chain.

6. **FPV Drone Technology.** FPV drone technology enables pilots to experience flight from the drone's perspective through a live video feed. Key components include an FPV camera that captures real-time video, a video transmitter (VTX) that sends the video to a ground-based video receiver (VRX), and FPV goggles for displaying the video feed. The drone's physical structure consists of a frame and motors, while an on board flight controller stabilizes and controls the flight. The pilot uses a radio transmitter and receiver to send control commands to the flight controller, guiding the drone's movements based on the live video feed.

Revolutionizing the Kill Chain : How FPVs are Transforming Modern Warfare

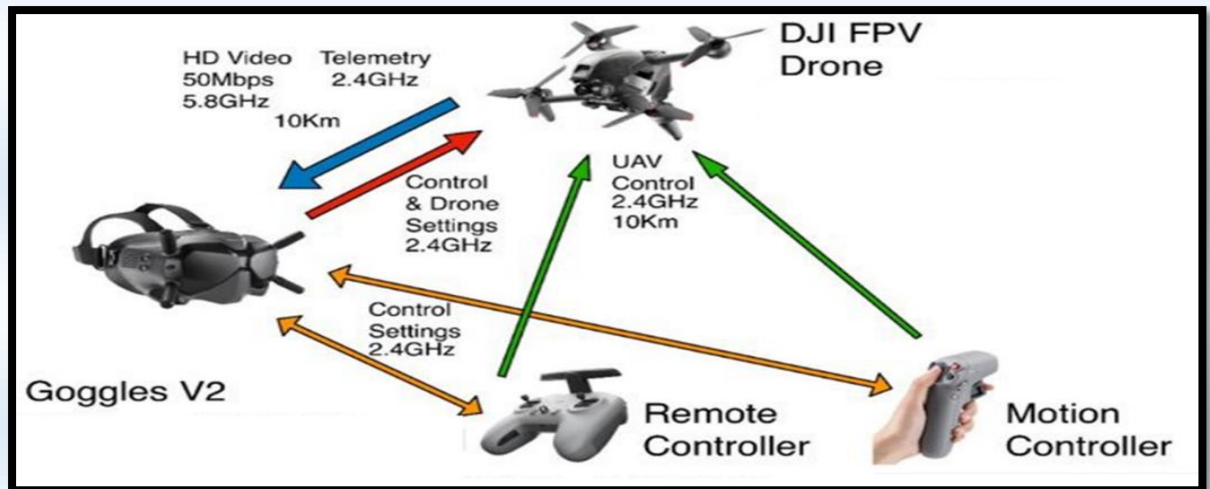


Fig 12 : FPV Technology

7. **The Indian Embrace for FPV.** India's drone development has faced significant hurdles due to bureaucratic delays, inconsistent policies, and technological limitations. Projects like the Nishant UAV, which suffered frequent crashes, and the stalled Rustom project highlight the country's struggles to meet operational needs. As a result, India relies heavily on imports such as Israel's Heron and Searcher drones and the U.S.'s MQ-9B drones. This dependency undermines strategic autonomy and increases costs, underscoring the need for a self-reliant drone ecosystem.

8. **Way Ahead.** In conclusion, integrating FPV drones into the kill chain has revolutionized modern warfare by enhancing situational awareness, speed, and cost-effectiveness. The experiences from the Russo-Ukraine conflict demonstrate the transformative impact of these drones, highlighting the need for strategic adoption. India faces significant challenges in developing its FPV drone capabilities due to technological gaps and reliance on imports. However, with increased government support, rigorous pilot training, and continuous innovation, India can build a self-reliant drone ecosystem. By learning from global conflicts and adopting best practices, India can enhance its strategic autonomy and operational efficiency in modern warfare.

Future Blue UAV

1. **Introduction.** The recent conflicts of **Armenia- Azerbaijan** and **Russia- Ukraine** have amply demonstrated the capability of **UAV platforms as technology disruptors** wherein the UAVs have completely changed the current landscape of war fighting. The proverbial truth of **change being the only constant** remains the cornerstone of all military planning. Having acknowledged the importance of aerial surveillance through UAVs, **the development of a Blue Unmanned Army**, with a technological focus of next 20 years, becomes an operational imperative.

2. The lack of **well-established ecosystem** for drone manufacturing including **suppliers, component manufacturers** and **skilled workforce**, limits realisation of full potential by the Indian drone industry. High end **miniaturised sensors, command and control systems**, advanced **navigation systems**, high performance **composite materials** and **specialised components** (propulsion system, landing gears) are certain areas that the manufacturing ecosystem in India is yet not able to design and develop indigenously.

Future UAV : What We Want Tomorrow?

3. Indian military is at the cusp of transformation and in order to be battle ready for future conflicts, the Indian drone industry has to step up to develop cutting edge UAV technology. Towards this an integrated approach between Military and Drone industry has to foster.

4. **Desired Capabilities of Future Blue UAV.**

(a) **Stealth.** Countries are increasingly focused on development of UAV systems **that are stealthy and have speeds of over Mach 1**. The Indian drone industry should focus on incorporation of nano particle technology wherein specialised radar absorbent coating can be used to reduce the radar cross section and electromagnetic radiations. 3D adaptive printing and streamlined structural design can further enhance stealth capability. For



Future Blue UAV

speed, modular design of propulsion system focusing on hydrogen powered scramjet/ pressurised air propulsion needs to be explored.

(b) **Payloads**. The future UAV should be capable of integrating and compact multi payload systems with the capability to switch sensors in real time while mission is under progress. Therefore, the focus now should be on **developing and integrating multi sensor payloads** including electro-optical sensors, high resolution visible-light cameras, SAR as well as **multispectral** and **hyperspectral** sensors.

(c) **AI Assisted Real Time Intelligence**. The future beholds the introduction of ***AI integrated with machine learning algorithms*** to collect and interpret data, enabling them to make informed decisions during flight under complex environment. AI algorithms, particularly machine learning and computer vision techniques integrated with UAV payloads will play a pivotal role in defining India's competitive edge. With **enhanced image processing algorithm** and **integrated sensors**, a single UAV while in flight will be capable of **acquiring, processing (Automatic Target Recognition** by comparing the acquired data with archival data stored on-board) and **interpreting** data and situations for improved and concurrent decision making by tactical and operational commanders.

(d) **Communication**. The need to develop **jam** and **spoof proof** communication systems providing **seamless communications** is an operational imperative. Certain innovative methods currently under research are **3D beamforming**, **Reconfigurable Intelligent Surface (RIS)**, **Multi-Path** and **multi frequency hopping** communication systems integrated with cipher algorithm.

(e) **Endurance**. **'Eyes in Air'**, and that too 24x7, 365 days a year, will be the need of future battlefield. While development of solar powered **High Altitude Pseudo Satellites (HAPS)** is a step in right direction, the industry should also explore development of **light weight systems powered by Hydrogen/ Nuclear energy that can power the UAV for weeks without requirement for refuelling**.

5. **Best Practices**. After being barred from purchasing American Reaper drones, the Turkish government invested heavily in indigenous research and development. Domestic defense companies, such as Baykar and Aselsan,

Victory Through Jointness

Future Blue UAV

played a pivotal role in advancing Turkish drone capabilities. In addition, Turkey collaborated with strategic allies, such as Ukraine and Qatar which enabled exchange of knowledge, expertise and resources, contributing to the rapid evolution of Turkish UAV capabilities. The development of TB2 by Turkish Aerospace Industries and Baykar has reduced import dependence and positioned Turkey as a key player in global politics. ***The Indian government and industry will do well to learn lessons from the Turkish story.***

6. **Way Forward.** The whole of nation approach to develop future UAVs, duly meeting operational requirement of Indian military, will not only contribute towards overcoming the extant challenges but will also foster self-reliance in unmanned technology. The raising of a future battle ready ***Blue Unmanned Army*** will enable military commanders with advanced situational awareness in diverse and challenging environments, including high-altitude border areas and remote regions.

The Application of Artificial Intelligence (AI) in Aerospace Engineering

1. **Introduction.** Aerospace engineering has witnessed large advancements recently, with a focus on enhancing safety, efficiency, and overall performance of aerospace systems. One area that has garnered considerable attention is the application of Artificial Intelligence (AI) techniques in aerospace engineering. AI has the potential to revolutionize the industry by enabling autonomous systems, optimizing operations and improving decision-making processes. The research significance of AI in aerospace engineering lies in its ability to address complex problems and improve system performance. AI algorithms can process large volumes of data, analyse complex patterns, and make intelligent decisions in real-time. This capability is particularly valuable in the context of autonomous navigation and flight control, where AI algorithms can enable aircraft to adapt to changing environments, optimize trajectories, and ensure safe and efficient operations. Despite the potential benefits of AI in aerospace engineering, the current state of research and applications in this field is not sufficiently comprehensive.

2. **Autonomous Navigation & Flight Control.** Recently, significant advancements have been made in the usage of AI techniques to address complex challenges encountered in autonomous navigation and flight control. By integrating advanced algorithms and sensor technologies, aircraft can perceive their environment, analyse data, and make precise decisions to achieve highly autonomous and efficient navigation and flight control. These techniques allow aircraft to adapt to varying environmental conditions, handle uncertainties, and optimize their trajectories in real-time. By leveraging AI technologies, autonomous navigation and flight control systems can enhance the overall safety, efficiency, and performance of aerospace operations.

3. The role of artificial intelligence in remote sensing mainly lies in its ability to efficiently and accurately process remote sensing data, automate object recognition and classification, and detect and predict environmental changes, providing support for environmental management and decision-making. In particular, Artificial intelligence has already been extensively utilized in the field of remote sensing for several purposes.

4. **Data Analysis and Prediction AI Techniques.** These techniques have transformed data analysis and prediction in the aerospace industry. In weather forecasting, machine learning algorithms analyse meteorological data, satellite imagery, and historical patterns to provide accurate predictions,

The Application of Artificial Intelligence (AI) in Aerospace Engineering

improving aviation safety and efficiency. Resource allocation problems benefit from AI techniques, optimizing aircraft routing, fuel consumption, and crew scheduling. By leveraging data analysis and predictive modelling, AI enhances decision-making, safety, and resource management. These advancements drive the aerospace industry forward, enabling more effective data-driven operations in aviation and space exploration.

5. **AI Techniques in Weather Forecasting.** Artificial Intelligence has experienced rapid development and has been extensively utilized across various domains in recent times. A commonly shared concern is how to effectively integrate AI, big data, and machine learning methodology in order to construct prediction models and enhance forecast precision.

6. **AI Techniques in Resource Allocation Problem.** The satellite communications sector has prioritized the automation of resource management strategies. With a significant increase in data demand and the introduction of adaptable communications payloads capable of operating and re-configuring numerous beams in orbit, the industry is poised for significant transformation. The growing complexity in dimensions and operations emphasizes the necessity for AI-driven dynamic algorithms that can make optimal decisions regarding resource allocation, replacing previous rigid policies. In the specific context of dynamic resource management in multi-beam High Throughput Satellites (HTS), the article presents a comparative analysis of various recently proposed algorithms under practical operating conditions for a specific problem.

7. **Conclusion.** The application of AI in autonomous navigation and flight control include enhanced safety through real-time data analysis and decision-making, adaptive trajectory optimization, and improved efficiency. However, challenges such as algorithm interpretability and certification processes need to be addressed to ensure the reliability and trustworthiness of AI-powered systems. AI technologies have greatly improved aerospace component quality inspection and remote sensing capabilities. These advancements have led to increased accuracy, efficiency, and reduced human error in these critical tasks.

1. **Promas Navigation System.** Naval vessels, such as Frigates and Corvettes, traditionally have rudders placed off-centre to the shaft line. This is to reduce cavitation issues on the rudder and allow the shafts to be pulled without removal of the rudder. Promas design allows the rudder to sit in-line with the shaft line. This reduces rudder cavitation and significantly improves the hydrodynamic performance compared to the traditional off-centre rudder. The results of the PROMAS system are increased propulsive efficiency of about 6-8% depending on the application, reducing fuel consumption and emissions as claimed by their company Kongsberg Maritime.
2. **BEL enters Nifty 50.** Bharat Electronics is all set to make its place in the benchmark Nifty 50 on September 27. The new Nifty 50 entrant along with Trent will be replacing pharma player Divi's Laboratories and IT major LTI Mindtree, which have been excluded. The Index Maintenance Sub-Committee (Equity) of NSE Indices has decided to make the changes in various Nifty equity indices as a part of the semi-annual review of broad market indices. The inclusion of Trent and BEL is expected to bring passive inflows of \$702 million and \$430 million into the headline Nifty 50 index. The counters will have a weight of 1.4 percent and 0.9 percent respectively, according to Nuvama Institutional Equities.
3. **ITU World Telecommunication Standardisation Assembly 2024.** Prime Minister Shri Narendra Modi will inaugurate the International Telecommunication Union – World Telecommunication Standardisation Assembly (WTSA) 2024 at Bharat Mandapam in New Delhi on 15th October 2024. WTSA is the governing conference for the standardisation work of International Telecommunication Union, the United Nations Agency for Digital Technologies, organised every four years. It is for the first time that the ITU-WTSA will be hosted in India and the Asia-Pacific. It is a pivotal global event that will bring together more than 3,000 industry leaders, policy-makers and tech experts from over 190 countries, representing telecom, digital, and ICT sectors. It will provide a platform for countries to discuss and decide the future of standards of next-generation critical technologies like 6G, AI, IoT, Big Data, Cybersecurity etc.
4. **Swarm : AI Driven Framework.** Open AI has released a new experimental framework called Swarm, aimed at advancing the interaction and collaboration of multiple AI agents. This initiative offers developers the tools to build networks of AI agents that can operate independently, tackling complex tasks with minimal human oversight. Swarm provides a glimpse of

Technomics

a future where AI systems can autonomously search across multiple sources, returning well-rounded answers. The framework could also enable AI to perform tasks across different websites or even act in real-world scenarios on behalf of users. However, its introduction has raised concerns about the impact of autonomous systems on employment and the reliability of AI-driven decisions.

5. **Tata Advance Systems Limited Deal with Morocco.** Indian company Tata Advanced Systems Limited (TASL) announced on 30 September that it has signed a deal with Morocco covering the local production of its 8x8 Wheeled Armoured Platform (WhAP). Morocco's official new agency Maghreb Arabe Presse (MAP) reported on 27 September that the kingdom's National Defense Administration and TASL had entered into a strategic partnership aimed at the local production of the WhAP at a plant that will be called the Tata Advanced Systems Maroc (TASM). The project is reportedly aimed to be carried out within three years and will initially have a local integration rate of 35% which will further increase to 90% creating jobs.

6. **Locally Developed K9 Engine by South Korea.** South Korea's Defense Acquisition Program Administration (DAPA) has announced the rollout of the first locally developed engine for the Hanwha K9 155 mm/52 calibre tracked self-propelled howitzer. The new engine – the name of which was not specified by DAPA – is being built by local company STX Engine, which DAPA said has won a contract to develop the power plant in 2021. Since its development the K9 has been powered by a German MTU diesel engine built under licence by STX Engine. DAPA said a roll-out ceremony for the new engine, which delivers 1,000 hp, was held on 27 September at STX Engine's manufacturing facility in the southern city of Changwon. DAPA claimed the engine has improved performance and efficiency compared with the MTU version but provided no details. DAPA also said the new engine would boost exports because South Korea did not require clearances from Germany to sell the power plant to third parties. STX Engine said that prototype production and performance testing of the engine was completed earlier in 2024.

7. **Land Forces 2024 Exhibition.** India's Defence Research and Development Organisation (DRDO) displayed a new Combat Free Fall (CFF) parachute system at the Land Forces 2024 exhibition in Melbourne held from 11 to 13 September. Speaking to *Janes*, a DRDO official confirmed the system had "recently qualified" and is now in the process of being supplied to the Indian Air Force (IAF). The DRDO official said the CFF "provides a total

solution to paratroopers jumping from as high as 30,000 ft and gliding 30 km to land at a desired target”. The parachute features a nine-cell ram air design measuring 8.84 m in length and providing a lift/ drag ratio of 3.3:1. It offers a maximum forward speed of 40 km/h, supporting descents from 2,000 to 30,000 ft above ground level. Rate of descent is 1,000 ft in two minutes, the DRDO official said. The CFF system has an assembly weight of 22 kg and a maximum payload of 150 kg. It also features a wrist-mounted altimeter and a GPS-based navigation system as well as a breathing and post bail-out breathing system and an oxygen console.

8. **QUAD Summit : September 2024.** The leaders of the Quad group of countries met a their sixth summit level meeting at Archmere Academy, Mr Biden’s former school in Claymont, Delaware, to announce a broad range of outcomes. Important among these include the Quad-at-Sea Ship Observer Mission in 2025, to improve interoperability and maritime safety. Future coast guard missions are planned for after 2025. A logistics network pilot project was also launched, which will involve Quad countries sharing airlift capacity to support disaster response across the region, A Maritime Initiative for Training in the Indo-Pacific (MAITRI), to train Quad partners “to monitor and secure their waters, enforce their laws, and deter unlawful behaviour” was also announced. India will host the first MAITRI workshop in 2025. Significantly, a maritime legal dialogue has been launched to support actions to uphold the rules-based order, the joint statement said.

9. **AUKUS & Japan’s Drone Tech.** Maritime autonomous systems have been identified as an initial field japan could collaborate in with the United States, Britain and Australia under their AUKUS security pact as the U.S.-led grouping also launchers talks with Canada, New Zealand and South Korea to join its advanced capabilities program, known as Pillar II. After singling out Tokyo in April as a potential candidate for Pillar II projects, AUKUS leader said in a joint statement Wednesday that the two sides are “exploring opportunities to improve interoperability of their maritime autonomous systems as an initial area of cooperation.” Those projects include areas such as hypersonics, anti-submarine warfare and cyberweapons, as well as quantum computing, electronic warfare and artificial intelligence.

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