Atmanirbhar Indian Naval Aviation Technology Roadmap - 2047

A Formidable Force of Viksit Bharat...

FOREWORD

1. As a maritime nation with growing global influence and interests, the oceans are central to India's continued progress and prosperity. Our national vision of becoming a developed country by 2047, requires the Indian Navy to assume a larger role in safeguarding our maritime interests, facilitate economic growth and shape India's strategic influence across our areas of interest as elucidated in 'Indian Navy – Vision 2047' released in Dec 24.

2. The Naval Air Arm plays a crucial role in maritime operations in all three domains, be it surface, sub-surface or air. Aligned with the vision of Indian Navy, the Naval Air Arm is on an evolutionary path keeping abreast with technological developments around the globe so as to remain contemporary. This '*Atmanirbhar* Indian Naval Aviation Technology Roadmap - 2047' highlights the priorities and objectives of Naval Aviation that will guide its growth over the next two decades by unshackling innovation, creating a conducive ecosystem and associating with academia and industry to enable capability development by becoming a catalyst towards enabling an indigenous military technology revolution.

3. We intend to embark on this journey together with not only our partners like DRDO and DPSUs, but also with all citizens of the country and Indian industry who wish to mutually benefit from the growth of the Naval Air Arm and in the bargain, increase Indigenous Content of our asset profile. Indian Navy has always considered the industry, as 'partners' and not 'vendors'. We intend to support our new partners with full zeal and enthusiasm in their endeavours to succeed and deliver new and unique technologies to the Naval Air Arm.

4. I also intend to walk the extra-mile and say that any Indian citizen or entity who can bring 'critical technology' to the table, our doors are always open and we would jointly find a path to develop and operationalise these.

5. As we observe 2025 as the ‘Year of Reforms’, Indian Navy is set to steer the course to become ‘*Atmanirbhar Nau Sena*’ of *Viksit Bharat* embracing the reforms to transform the Naval Air Arm into a technologically advanced and combat ready force capable of multi-domain integrated operations. I am sanguine that the ‘*Atmanirbhar* Indian Naval Aviation Technology Roadmap - 2047’ will serve as the guiding document for the Indian Naval Air Arm and also for the military technology innovators of the country.

Jai Hind. Sam No Varunah.

(Dinesh K Tripathi)
Admiral
Chief of the Naval Staff

12 Feb 25
New Delhi

PREAMBLE

1. The Naval Air Arm is a technology intensive force. Therefore, there is a need to stay abreast with the latest global technological developments, maintain an evolutionary approach to new ideas, and encourage modernisation through indigenisation. Aligned with Indian Navy's Vision 2047 to transform into an *Atmanirbhar* force through leadership-driven focus on invention, innovation, indigenisation and integration of niche, disruptive and emerging technologies, the Naval Air Arm aims to protect the nation's strategic maritime interests, by being a formidable and reliable arm of the Indian Navy.

2. Technological superiority is increasingly going to be the decisive factor in future battles. Therefore, there is a critical requirement to develop and transform advancements in technology into credible and potent military capability. This roadmap is aimed to enable the country's R&D establishments, both government organisations and industry partners, to focus on specific capability requirements and concentrate efforts on indigenous development of critical and niche technologies.

3. India is on a planned track to be the third largest economy by end of this decade or early next decade[1] and has already embarked on a journey of self-reliance in all sectors. Aligned with the National vision of *Viksit Bharat* 2047, Ministry of Defence has announced the Year 2025 as the "Year of Reforms", to bring transformation in the defence sector, marking a significant milestone in the modernisation journey of the Indian Armed Forces. These reforms aim towards streamlining procurement processes, to facilitate swifter capability development and public-industry partnerships to drive innovation and growth in the defence sector[2]. Apropos the technology roadmap for Indian Naval Air Arm has been prepared with an aim to inform industry and provide a

[1]https://www.thehindubusinessline.com/economy/india-will-become-third-largest-economy-in-my-third-term-says-pm-modi/article67830259.ece/amp/ by KR Srivats posted on 19 September 2024.

[2]https://pib.gov.in/PressReleasePage.aspx?PRID=2089184#:~:text=In%20order%20to%20give%20impetus,of%20multi%2Ddomain%20integrated%20operations. Posted by MoD on 01 January 2025.

catalyst to the transformation, leapfrogging in military capability through technological advancements.

4. The "*Atmanirbhar* Indian Naval Aviation Technology Roadmap - 2047" outlines the plan of Naval Air Arm to leverage the technological revolution and changing character of warfare and ensuring that Indian Navy remains a credible force, capable of addressing future maritime security challenges effectively and efficiently. It also aims to expeditiously bridge critical capability gaps through innovation and asymmetric solutions. The roadmap is an unclassified document which addresses various aspects required to maintain and enhance the effectiveness, capability, strategic depth of naval aviation operations and serve as a reference document for innovators to work upon indigenous solutions. The document is expected to serve as a catalyst for the indigenous industry / MSMEs/ Startups to innovate, indigenise and lay the foundation for a credible *Atmanirbhar* Naval Aviation industry in the country.

5. As technology is a rapidly evolving field, there would be a need to revisit and revise this document, as and when necessitated, to keep it contemporary, so as to ensure that the Naval Air Arm maintains its Cutting Edge.

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CHAPTER - I

NAVAL AIR ARM OPERATIONAL PHILOSOPHY: READY TO DELIVER ANYTIME, ANYWHERE, ANYHOW

Introduction

1. The Naval Air Arm is the branch of the Indian Navy (IN) which is tasked to provide long range anti-ship and land strike capability operating from afloat and ashore, and undertake Maritime Reconnaissance (MR), Anti-Submarine Warfare (ASW), Casualty Evacuation (CASEVAC), and special helo-borne operations. The Naval Air Arm also undertakes benign tasks such as Search and Rescue (SAR) and Humanitarian Assistance and Disaster Relief (HADR). The operational philosophy of the Naval Air Arm is derived from the Indian Navy's concept of operations to safeguard and promote India's maritime interests which flows from the national interest.

National Interests

2. India's national interests are expressed in the Preamble to the Constitution, and are centred on the preservation of the Nation's core

values, from external aggression and internal subversion, providing a conducive environment for economic and social wellbeing of the citizens.

Maritime Interests

3. With growing global influence and interests, the seas are central to India's growth being a maritime nation. Aligning with the National Vision to be a developed country by 2047, Indian Navy assumes a larger role to safeguard and promote our maritime interests, facilitate economic growth and shape India's strategic influence across our areas of interest[1]. The importance of the seas and dynamics of the maritime environment in Indian Ocean Region (IOR) and beyond highlight the need for maintaining stability, security and safety at sea, particularly in the areas of interest. This would enable use of the seas to progress economic development, and provide the appropriate maritime environment for unfettered pursuit of our national interests.

Indian Navy: Protecting India's Maritime Interests

4. Navies traditionally operate in high seas well beyond the territorial waters and maritime zones of the nation to address various traditional and non-traditional threats and challenges that emanate in the maritime domain. The additional mandate for coastal and offshore defence necessitates IN to operate in waters closer to the coast too.

5. The Indian Ocean is traversed by numerous Sea Lanes of Communication (SLOCs) and also hosts some of the most important choke points, through which most of the world's, and India's, trade and energy transit. The related economic interests have led to increase in the presence of extra regional forces, which complicates the geo-strategic and maritime security matrix of the region. Therefore, possession of critical capabilities to protect national interests and ensure security of shipping in SLOCs and ability to control

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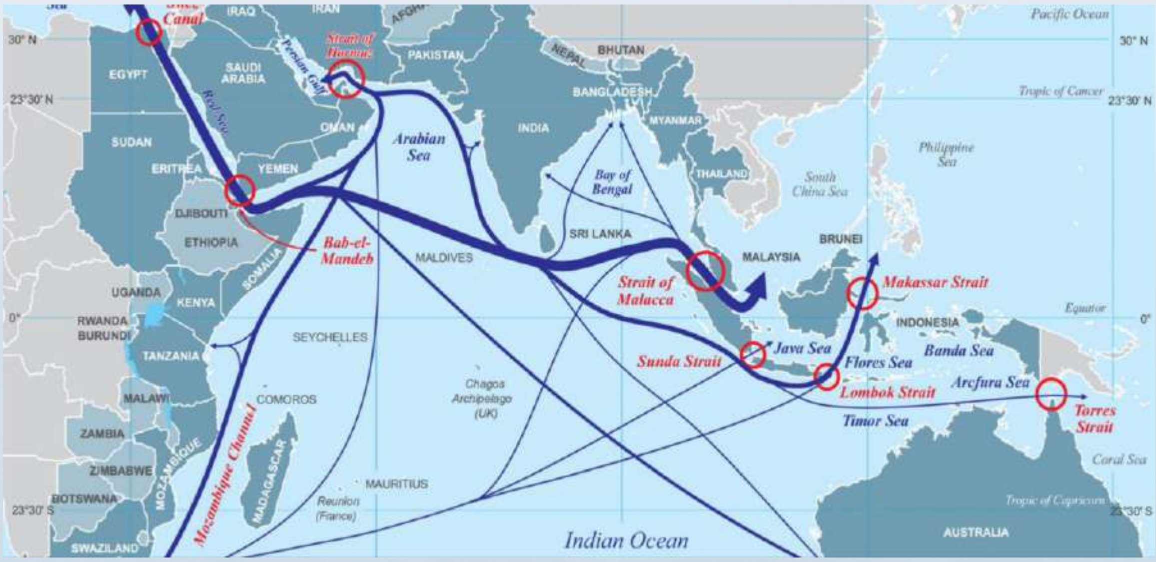
[1]Indian Navy Vision 2047 published on 02 December 2024

the choke points in our maritime zones, and on the high seas in times of conflict, is an essential maritime necessity.



<u>Naval Air Arm: A Formidable Force of the Indian Navy</u>

6. Maritime air power, in conjunction with other elements of the *IN*, plays an important role in securing India's maritime interests in the IOR and beyond. Accordingly, the Naval Air Arm needs to possess adequate reach and combat power, so as to meet the requirements of the Navy's roles, objectives, missions and tasks.

7. Maritime air power, both integral to the Fleet and in support of it, possesses the signature characteristics of speed, flexibility, reach and force projection. Operating from afloat and ashore, it exponentially complements various facets of maritime operations such as sea control, battle space dominance and sea denial while significantly aiding Maritime Domain Awareness (MDA). At sea, an aircraft carrier bolsters the potency of the Fleet by deploying aircraft that can apply combat power at great ranges. More often than not, naval aircraft operating from ship or ashore would make the first contact with the adversary.

Naval Aviation: Roles, Objectives, Missions and Tasks[2]

8. The roles, objectives, missions and tasks assigned to Naval Air Arm, encompass its core activities and describe the utilisation of naval aviation assets in times of peace and conflict. The broad distinct roles, objectives, missions and tasks for Indian Naval Aviation are assigned as per the *IN*'s Military, Diplomatic, Constabulary and Benign roles laid down in Indian Maritime Doctrine (NSP 1.1).

9. **The Military Role**. The raison d'être of Naval Air Arm is to serve the Navy's role in safeguarding the nation's use of the seas for its legitimate purposes, whilst concurrently guarding against inimical use of the sea by others.

10. **The Diplomatic Role**. Naval diplomacy entails the use of maritime air power in support of foreign policy objectives to strengthen international cooperation on the one hand, and to signal capability and intent to deter potential adversaries on the other.

11. **The Constabulary Role**. The main objectives under this role are coastal and offshore defence, EEZ security and maintenance of good order at sea.

12. **The Benign Role**. The primary objectives in this role involve promoting civil safety and security whilst projecting national soft power, that are complemented by missions consisting of HADR, aid to civil authority, hydrography and SAR.

Adapting to Changing Character of Warfare

13. **Doctrines, Strategy and Tactics**. Successful militaries of the world are identified by their ability to constantly evolve and adapt to the challenges associated with the ever-changing character of warfare with adaptation or modification of doctrines, strategies and tactics.

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[2] Indian Maritime Doctrine (NSP 1.1)

Today, Artificial intelligence (AI), space and cyber realms are fusing with sensors, Unmanned Aerial Vehicles (UAVs) and beyond-visual-range (BVR) weapons on the modern battlefield, dramatically reducing Sensor to Shooter (STS) kill chains. The Naval Air Arm's strategies and tactics need to be agile to encompass these changing technologies.

14. **Lessons Learnt from Recent/ Ongoing Conflicts**. The primary lesson derived from the war between Armenia and Azerbaijan, is the overwhelming difference that drones can make on the battlefield. Drones have firmly established their place in an era of network-centric warfare and the same has been re-emphasised during the Russia-Ukraine war. Deployment of drones initially proved effective but also spurred the development of counter - drone systems. Simultaneous attacks using low-cost rockets and commercially available drones to overwhelm the state-of-the-art ISR capabilities of the opponent is testimony to the changing character of warfare as also seen during Israel-Hamas conflict[3]. Also, use of drones for counter threat operations against Unmanned Surface Vessel (USV) and Unmanned Aerial System (UAS) has become a reality in recent conflicts. Network centric and autonomous operations have proven to be one of most important factors or the key to success of swarm drones operations.

15. **Indigenisation with Advanced Technology**. The need of the hour is to bring in asymmetry in warfare in quick time and in great numbers to supplement the conventional naval force structure which would align with the changing operational philosophy in the maritime domain. Aiming to be ahead of the curve, the Naval Air Arm is already adapting to the changing character of warfare with planned induction of platforms capable of AI enabled autonomous, collaborative and disruptive operations. Catering to all aspects such as the weapon grid, sensor grid, Network Centric Operations (NCO) grid, aircraft systems and platform inductions, the roadmap charts a plan for modernising the Naval Air Arm through indigenisation and promoting innovation, supporting research & development, and harnessing the resident technology know-how through effective utilisation of government initiatives such as iDEX challenge and Make II schemes.

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[3]Tech Wars or Old Battlefields: Lessons from the Recent Conflicts by Sujan R. Chinoy in Expert Speak Raisina Debates, Published on 21 February 2024

CHAPTER – II

BROAD CONTOURS OF THE ROADMAP

Introduction

1. The "Indian Naval Aviation Technology Roadmap" is an unclassified document that outlines the future technological advancements and inductions envisaged for the Air Arm of the Indian Navy. This roadmap addresses various aspects required to maintain and enhance the capability and effectiveness of air operations and serve as a reference document for the 'Diamond of Development' i.e, user, industry, academia and government. It will guide the innovators to work upon indigenous solutions, and for planners to steer the course towards achieving an *Atmanirbhar* Naval Air Arm by 2047.

Purpose and Importance

2. **Strategic Vision**. Establish a clear vision for future Naval Air Arm, whilst aligning, sequencing and leveraging technological advancements to ensure readiness for future operational challenges and opportunities.

3. **Catalyst for Pioneering Research**. The roadmap lays down future requirements of the Naval Air Arm and leaves the methods to reach there, open to academia, researchers and innovators. The aim is to find innovative methods of achieving the end-state more efficiently and effectively. Thus, the roadmap is aimed to act as a catalyst for pioneering work by Indian academia, start-ups, private industry, DRDO/ DPSUs, with the aim to close the technological gap and leapfrog into the future.

4. **Capability Enhancement**. Focus on enhancing the operational capabilities of Indian Naval Air Arm through in-country Maintenance Repair Overhauls (MROs), modernisation and acquisition of advanced platforms, and incorporation of cutting-edge technology in weapons

and sensors including intelligent, unmanned systems and network-centric warfare capabilities. It is also intended to use asymmetric technology to counter advanced capabilities of adversaries.

5. **Force Multiplication**. Strengthen the naval fleet with versatile and multi-role aviation assets that can perform the entire spectrum of naval air operations.

6. **Operational Flexibility and Readiness**. Ensure quick adaptability to dynamic maritime challenges by having responsive, flexible, and efficient aviation units capable of rapid deployment.

7. **Standardisation and Efficient Life Cycle Costing**. It is of paramount importance that future systems are designed as standard equipment with cross platform utility and efficient life cycle costing.

8. **Maintenance Repair & Overhaul (MRO) Facility and Mid-Life Upgrade (MLU)**. The roadmap acknowledges the urgent need for in-country MRO and MLU capabilities of existing platforms so as to maintain high degree of operational readiness. Setting up of MRO facility in-country will promote indigenisation through technology transfer, as well as, provide a boost to indigenous manufacturing capability.

9. **International Collaboration and R&D**. The roadmap acknowledges the importance of global partnerships for technology transfers, joint research, and collaborative development projects that can enable access to the latest advancements in naval aviation technology.

10. **Indigenisation Efforts**. The roadmap prioritises self-reliance by encouraging the development of indigenous technologies and partnering with domestic industries for the production and integration of new systems with an aim to bring in the micro shift in the ecosystem which will lead to a breakthrough in technology. This supports the national agenda of "Make in India" for defence procurement.

11. **Training Aids and Simulators**. Training aids and simulators are vital cogs in the aviation ecosystem and play a key role in off-setting

aircrew training requirements thereby, ensuring availability of platforms for operations. Moreover, in naval aviation domain simulators play a vital role in training of aircrew to keep them current due to dynamic training requirements. Simulators are being included as part of initial induction of platforms. This roadmap acknowledges development of indigenous training aids, simulators, emulation, VR and AR devices for platforms in service and future inductions.

12. **Critical and Unique Qualitative Requirements of Naval Aircraft**. It is important to understand that the flight-testing requirements of any aviation platform and/ or system designed for only land-based operations is a subset of the naval flight-testing requirements. Hence, a platform or system designed and developed for naval conditions could be modified to suit land-based operations, however, the contrary may not be true. Considering the harsh operational environment which includes extreme temperatures, sea motion, salt laden air, high humidity, with winds from 0 to 50 kts, an aviation platform, system, sub-system or support equipment developed for the maritime environment can be adapted for use on land.

13. **Naval Flight-Testing Ecosystem**. The naval flight-testing has been institutionalised with establishment of Naval Flight Test Squadron (NFTS) at Goa. The critical and unique requirements of naval flight testing and stringent integration standards of naval aircraft necessitates hand holding of Indian industries engaged in development and production of weapon, sensors, equipment and systems for naval aircraft. The Naval Air Arm will provide complete support to the industry partners in this regard for promoting indigenisation.

14. **Promoting MSMEs and Start-Ups**. Whilst emphasising on indigenisation efforts, the roadmap also acknowledges the procedural and financial aspects involved in progressing projects through novel schemes of the government such as iDEX challenge.

(a) **Procedural Aspects**. Though the procedures for defence procurement are stringent to draw a balance between technology development and financial requirements, Indian

Navy would provide necessary guidance to MSMEs and Start-Ups, to overcome these.

(b) **Financial Planning**. It is important to sequence capability development to match the necessities and the availability of funds. The Indian Navy is aware of the necessity of supporting Start-Ups and MSMEs to tide over the financial requirements, while the ecosystem aims to provide credible technology.

Key Elements

15. **Arming with Advanced Weapon System**. Combat power is primarily derived from the lethality quotient of a platform. With advancement in weapon systems worldwide, the focus is to integrate indigenously developed modern and advanced weapon systems along with cheap and smart solutions onto Naval Aviation platforms to reduce the OODA loop.

16. **Reach and Sustainability**. Enhancing the reach and sustainability of our surveillance cover is a major driving criterion for the future inductions. Likewise, sustainability in terms of reliability and maintainability is a key element which will drive future inductions and thereby research, design and development. Sustainability would also drive the repair and turn around capability in India.

17. **Enhancing ISR Capabilities**. ISR (Intelligence, Surveillance, and Reconnaissance) is a crucial component, with plans focused on acquiring and developing sensors, radars, and electronic intelligence systems that can provide real-time data analysis and support maritime domain awareness. This includes the use of space-based assets also.

18. **Network-Centric Warfare**. Significant advancements are aimed at enhancing network-centric warfare capabilities, ensuring higher interoperability and coordinated operations through advanced communication and data-link systems.

19. **Data and Network Security**. Data and network security, and ability to disrupt networks of adversaries is an important driver for future wars which will not be fought on physical vectors only, rather will be jointly fought on armament and data availability.

20. **Modernisation of Fleet**. The document provides plans for updating the existing fleet of aircraft by introducing advanced fighters, helicopters, and other essential platforms capable of multi-role operations, including anti-submarine, anti-surface warfare, reconnaissance, sub-conventional and asymmetric operations.

21. **Uncrewed Systems**. Emphasis is placed on integrating uncrewed aerial vehicles (UAVs) for various operations, including surveillance, reconnaissance, search and combat roles, to expand the reach and effectiveness of naval operations.

22. **Counter UAV Systems**. Uncrewed systems have changed the conventional warfare paradigm. Low-cost UAVs/ Drones have proven to be a potent war fighting machines during conflicts/ wars in the First quarter of the 21st century. Therefore, the need of the hour is to have a credible air launched cost effective counter UAV system.

23. **Asymmetric Warfare Capability Development**. There is a need to understand and apply asymmetric means to produce asymmetric results. The core fundamental of this approach is not to meet strength with strength but to meet the enemy's weakness with our strength and avoid exposure of our weakness to enemy's strengths. In the realm of asymmetric warfare, the real advantage lies in having cost effective, high reliability, high effect, precision massed, certified/ non-certified systems or re-purposed systems.

24. **Development of Non-kinetic Weapons with Same Lethality**. Non-kinetic weapons like lasers and microwave systems have the capability to deliver precise damage to the intended targets. A well-tuned system may not get saturated and could ensure a high kill rate and may not require replenishment like conventional weapons. Developing and optimising size of these weapons for airborne use is an area presenting a technology challenge.

25. **Aggregating Civil Aviation Resources**. Leveraging private industry investments in foreign companies to gain strategic and technological autonomy is the need of the hour. Our private airlines orders for a large number of aircraft from foreign OEMs which can be leveraged gainfully to enable military requirements. Also, advancement in commercial aviation technology needs to be harnessed for military use.

26. **Adopting Quantum Computing, AI and Synthetic Biology Solutions**. The next wave after internet is that of quantum computing, AI and synthetic biology. This has applications ranging from mission planning to execution. These capabilities need to be expeditiously introduced into the Military. This requires a concentrated effort and needs the involvement of private industry, DRDO and the military to utilise this niche technology. A nation having an edge in these areas has a distinct advantage. Plugging in of the armed forces to the National Quantum and National AI missions to join the national effort and harness its potential in military applications is a critical imperative.

Conclusion

27. The technologies planned and envisaged for induction into Naval Air Arm over next two decades are illustrated in subsequent chapters which include the niche domain of naval flight testing, future tech, indigenous platforms, the sensor grid, the weapon grid and the NCO grid. The roadmap has been prepared keeping in mind the existing and envisaged capability enhancement. However, considering the ever-changing character of warfare in the dynamic geopolitical environment, the requirements of the Naval Air Arm will need to continuously evolve to remain ahead of the curve. Accordingly, the *Atmanirbhar* Indian Naval Aviation Technology Roadmap is also planned to be revised, as and when necessitated so as to remain abreast with technology.

CHAPTER - III

FUTURE TECHNOLOGY: ADAPTING TO CHANGING CHARACTER OF WARFARE

Introduction

1. The character of warfare is undergoing transformation driven by rapid advances in technology, shifting geopolitical dynamics, and the increasing importance of the maritime domain. Naval Air Arm, a critical component of naval power, must adapt to these changes to remain effective. The proliferation of unmanned systems and the growing importance of information warfare are redefining the character of warfare at sea. The Naval Air Arm must evolve to address these new challenges, leveraging advances in technologies to maintain its operational edge.

2. As we look to the future, it is clear that the Naval Air Arm must become more agile, more networked, and more resilient to succeed in this new era of warfare. This requires a fundamental shift in how we think about the naval air battle, from a focus on individual platforms and systems to a more integrated, distributed approach that leverages the power of the network to achieve operational advantage. Adapting to the changing character of warfare in naval aviation is not simply a matter of acquiring new technologies or platforms, it requires a profound cultural and operational transformation, that emphasises innovation, indigenisation, experimentation, and continuous learning.

Embracing Next Gen Technology

3. **Manned Unmanned Teaming (MUM- T)**. Joining capabilities of manned and unmanned systems to exploit benefits of both ie, human dimensions of warfare and modern robotics, is termed as Manned - Unmanned Teaming. It is domain agnostic and applicable to unmanned

platforms operating in air, surface and subsurface domain. However, presently, air domain has taken the lead.

(a) **Levels of Interoperability**. The Levels of Interoperability (LOI) of MUM-T are as follows:-

Ser	LOI	Capability
(i)	LOI 1	Receipt and Transmission of payload data indirectly from the unmanned system.
(ii)	LOI 2	Receipt of imagery or data directly from the unmanned system.
(iii)	LOI 3	Control of the payloads of the unmanned system.
(iv)	LOI 4	Control of the unmanned system during flight but not take-off and landing.
(v)	LOI 5	Full function and control of the unmanned system to include take-off and landing.

(b) **Induction of MUM - T**. The use of MUM-T capability by *IN*, would provide better situational awareness, survivability and enduring superiority in the backdrop of complex adversaries. The Naval Air Arm is looking forward to induction of this capability.

(c) **Envisaged Projects for MUM-T**. A number projects are already in the pipeline or envisaged for induction in near future which would be capable of MUM-T LOI 5.

4. **Swarming Capability**. Swarm technology will be a giant step in futuristic deployment of RPAs. Swarming brings in cheap and affordable solutions, utilising asymmetry to gain an edge in warfighting. Adaptive swarms are the next gen of this technology and once developed will provide multi-role tasking, autonomous

capability, limited only by the war fighter's ability. Once developed, the swarm can be used for deployment of any payload. Optimised Swarm Cognitive Adaptive Response is the latest technology in swarming which is being experimented by some countries. Some of the projects envisaged, for induction or being developed, are mentioned in subsequent chapters.

5. **Manning**.

(a) **Optional Manning**. This is a concept in which manning of the aerial platform is optional. If the aerial platform is going for a routine mission or a high-risk mission, it can be sent as an unmanned vehicle. However, if human intervention is a must in the mission, the platform could be manned by the pilot or requisite crew. Optional manning will be one of the primary qualitative requirements for all future platforms being developed for the Naval Air Arm.

(b) **Surrogate Manning**. Surrogate Manning can be implemented with LOI 5 of MUM-T. The UAV control during launch could be the launching platform and thereafter, it would be handed over to one or more controlling platforms, depending upon the mission, range and endurance. The concept of UAV control by subsequent platforms is the Surrogate Manning concept by which, one UAV could be used to accomplish several tasks. Robust communication network/ data link is the backbone for such operations.

6. **Dynamic Reconfiguration Architecture**. The UAVs are modular and hence can be configured into the desired role prior take-off. However, Dynamic Reconfiguration Architecture would entail transition of UAV configuration from one role to another whilst in air. This can be achieved by a Swarm of Drones and their capability to form different patterns depending upon tasking. A Swarm may be utilised for ISR collection at a designated area and upon requirement, it could be configured as a weapon for strike, or provide AMD to Surface Units. The change of Swarm Configuration could also entail launching of more

drones from the base or converting the drones in air into a pattern to achieve the new task.

7. **Automation of RPAs**. Complete automation of unmanned system is the way ahead. It will include launching, operations, mission completion, mission adaptability and recovery. Launching and recovery by far, have been automated to a great degree. However, human intervention is required for operation and mission completion. By use of Artificial Intelligence and Machine Learning, it is envisaged to achieve complete autonomy of uncrewed operations.

8. **Persistent Surveillance UAV**. Persistent surveillance or infinite endurance UAV are uncrewed aerial systems designed to operate for extended periods, potentially indefinitely, without the need for refuelling or maintenance. These are equipped with solar panels to generate electricity, reducing reliance on traditional fuels and utilise fuel cells or other alternative power sources to extend endurance.

9. **Collaborative Combat Aerial Vehicles**. Collaborative Combat Aerial Vehicles (CCAVs) are uncrewed aerial systems (UAS) designed to operate collaboratively with crewed aircraft, enhancing combat effectiveness in complex, dynamic environments. They can accompany the fighter aircraft as the Loyal Wingman.

10. **Re-purposed Phoenix Aircraft System**. Utilisation of existing crewed aircraft to operate autonomously or remotely on completion of their operational life, leveraging the benefits of uncrewed systems is termed as Re-purposed Phoenix Aircraft system.

Weapons

11. **Explosives and Fuzes**. For platforms/ technology to be effective in war, these must have explosives and fuzes. There is need to develop an ecosystem to produce low cost, safe and highly reliable explosives and fuzes in a variety of configurations, equip our platforms, whether small size drones or large missiles. Multiple sources and high production are key attributes to meet the future requirement of the naval air arm.

12. **Air to Air Missiles**. Long range Air to Air missiles provide an operational edge to the aircraft in an air battle. Considering the stringent qualitative requirements of naval weapon systems, development of indigenous Air-to Air missiles for naval aircraft needs a focussed approach.

13. **Loitering Munitions (LM)**. Smart and cheap loitering munitions have proven to be an effective solution complementing expensive conventional weapon systems to enhance the combat effectiveness. Induction of smart and autonomous AI enabled air launched LM is planned for aviation platforms of the Indian Navy.

14. **Hypersonic Missiles**. Hypersonic missiles travel at speeds above Mach 5, making it extremely difficult to detect by adversary sensors. With planned indigenous development of hypersonic missiles, Indian Navy also intends to integrate hypersonic missiles onto aviation platforms.

15. **Pulsed Laser - Next Gen Directed Energy Weapons**. The pulsed laser DEW is a weapon system, offering unprecedented precision and speed for countering asymmetric threats. This high-energy laser weapon uses advanced pulse technology to deliver precise, high-power bursts of energy to disable or destroy targets, including small boats, drones, and anti-ship missiles.

16. **Microwave Weapons**. Microwave weapons offer a revolutionary capability for naval aircraft, enabling them to disrupt and disable enemy electronic systems without causing collateral damage. These high-powered microwave (HPM) systems can be integrated onto naval aircraft to provide a non-kinetic effect against enemy air defences, communication systems, and other electronic targets. By emitting high-powered microwave energy, these systems can cripple enemy systems, creating a clear advantage for naval aircraft in contested environments. Moreover, microwave weapons provide a low-cost, high-reliability alternative to traditional kinetic weapons, reducing the risk of friendly fire and minimising logistical burdens. It is envisaged to integrate Naval air platforms with these weapons sourced from indigenous resources.

Sensors

17. **Quantum Sensors**. Quantum sensors are set to revolutionize navigation and sensor capabilities of naval aircraft, offering unparalleled precision and resilience in the most challenging environment. By leveraging the unique properties of quantum mechanics, these sensors can provide ultra-accurate measurements of magnetic fields, acceleration, and rotation, enabling naval aircraft to maintain precise navigation and orientation even in GPS-denied or contested environments. Moreover, quantum sensors' inherent resistance to interference and jamming makes them ideal for naval operations, where electromagnetic warfare is increasingly prevalent. Integration of quantum sensors onto naval aircraft will significantly enhance their ability to conduct autonomous operations, execute precise targeting, and maintain situational awareness in the face of emerging threats.

18. **LiDAR Imaging Systems**. The LiDAR (Light Detection and Ranging) Imaging system is a cutting-edge technology that enhances the situational awareness and tactical capabilities of naval aircraft. By emitting laser pulses and measuring the reflected signals, LiDAR creates high-resolution 3D images of the environment, allowing naval aircraft to detect and track targets, navigate through complex terrain, and conduct surveillance in various weather conditions. The LiDAR Imaging system's advanced capabilities include obstacle avoidance, automatic target recognition, and change detection, making it an invaluable asset for naval aircraft conducting anti-submarine warfare, anti-surface warfare, and reconnaissance missions. Moreover, LiDAR's compact size and low power consumption make it an ideal sensor for integration onto unmanned aerial vehicles (UAVs) and manned aircraft alike.

19. **Radar Systems**. Indigenous development of airborne radar systems with advanced radar technology for the naval aviation platforms is an area of importance. Development and manufacturing airborne radars being promoted through DRDO and private partners. Details of radar required for Naval Air Arm are enumerated in succeeding chapters.

20. **<u>EW Systems</u>**. EW system is the most critical sensor of an aircraft to detect presence of adversary without being detected. With advancement in radar technology with features such as Low Probability of Interception and usage of lower band radars onboard ships, development of EW systems with high range advantage factor is an imperative to maintain the operational edge. Also, utilisation of advanced signal processing features and utilisation of AI based solutions for effective analysis will make the EW system robust and effective.

21. **<u>Sonic Systems</u>**. With increased focus on Underwater Domain Awareness (UDA), development of indigenous underwater sensors for aviation platforms such as sonobuoys and dunking sonars is an important area requiring special attention.

<u>Systems</u>

22. **<u>Aero Engines</u>**. Development and manufacturing of Aero Engines is a niche domain limited to a handful of countries only. With steady progress on development of aero engines in country, the future platforms of Naval Air Arm are planned to be fitted with indigenously developed engines. For the same, industry partners and DPSUs are required to work in tandem with R&D organisations to build the ecosystem for indigenous development and manufacturing of aero engines in country.

23. **<u>Aqueous Based Zinc Batteries</u>**. Aqueous-based Zinc batteries are emerging as a promising alternative to traditional lithium-ion batteries, offering enhanced safety, sustainability, and cost-effectiveness. By leveraging Zinc's abundance, low toxicity, and high energy density, these batteries can replace flammable organic electrolytes with a water-based solution, significantly reducing the risk of fires and explosions. Aqueous-based Zinc batteries also demonstrate improved charging rates, longer cycle life, and reduced environmental impact, making them an attractive option for naval applications, including unmanned underwater target vehicles, sensors such as sonobuoys, and communication devices. Additionally, the

potential for scalable and cost-effective manufacturing processes further positions aqueous-based Zinc batteries as a viable solution for future naval aircraft energy storage requirements.

24. **<u>Modular Construction</u>**. Modular construction of naval aircraft is transforming the way these complex machines are designed, built, and maintained. By breaking down the aircraft into interchangeable modules, manufacturers can streamline production, reduce costs, and enhance customization. This approach enables rapid integration of new technologies, such as advanced sensors, communication systems, and artificial intelligence, allowing naval aircraft to stay ahead of emerging threats. Moreover, modular construction facilitates easier maintenance, reducing downtime and increasing aircraft availability for critical naval missions. As the naval aviation landscape continues to evolve, modular construction will play a vital role in ensuring that naval aircraft remain adaptable, effective, and operationally relevant.

25. **<u>Automatic Homing and Approach System</u>**. The Automatic Homing and Approach System (AHAS) is a cutting-edge technology designed to enhance the safety and efficiency of naval aircraft operations. AHAS enables autonomous approach and landing capabilities, allowing naval aircraft to automatically navigate to and land on an aircraft carrier or ships, even in adverse weather conditions or degraded visibility. By leveraging advanced sensors, GPS, and flight control systems, AHAS reduces pilot workload, minimizes the risk of controlled flight into terrain (CFIT), and enhances overall operational effectiveness. This technology is particularly critical for naval aviation, where the challenging and dynamic maritime environment demands precise and reliable aircraft control. With AHAS, naval aircraft can operate with greater autonomy, precision, and safety, ensuring successful mission outcomes. All deck-based aircraft are planned to be integrated with AHAS system including fitment of the ship component on all naval ships capable of deck-based operations.

26. **<u>Green Technology</u>**. By embracing Green Technology, the Naval Air Arm can reduce its environmental footprint, enhance operational efficiency, and support a more sustainable future. This would need to

be weighed against the impact on the operational and fighting efficiency. Some of the green tech initiatives planned or envisaged for naval air platforms are as follows:-

(a) **Sustainable Aviation Fuels (SAF)**. Biofuels will reduce dependence on fossil fuels, and electric and hybrid-electric propulsion systems will aid in reducing emissions and noise pollution.

(b) **Energy Efficiency**. Optimising aircraft design and materials will help in reducing drag. Also, using advanced materials like carbon fibre and titanium result in reduction of aircraft weight. Further, integrating energy-harvesting technologies, such as solar panels or wind turbines, can reduce reliance on fossil fuels.

(c) **Sustainable Practices**. Transitioning to electric ground support equipment will reduce emissions and noise pollution. Also, implementing sustainable maintenance practices, such as using eco-friendly cleaning solutions, will reduce environmental impact.

CHAPTER – IV

INDUCTION OF PLATFORMS: AN ATMANIRBHAR FLEET POWERED BY NEXT GEN TECHNOLOGY

Introduction

1. Enhancing operational capabilities of naval aviation through modernisation of platforms, acquisition of advanced aircraft, and incorporation of cutting-edge technology including unmanned systems through indigenous means, is the focus area for the next two decades. This would be achieved through induction of versatile and multi-role aviation platforms that can contribute to the complete spectrum of naval air operations.

Fighter Aircraft

2. **Deck Based Fighter Aircraft**. The Naval Air Arm requires 5th Generation warfighting capability through the twin engine deck-based

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Disclaimer:- All images used in this chapter are from open source and for illustration purpose only.

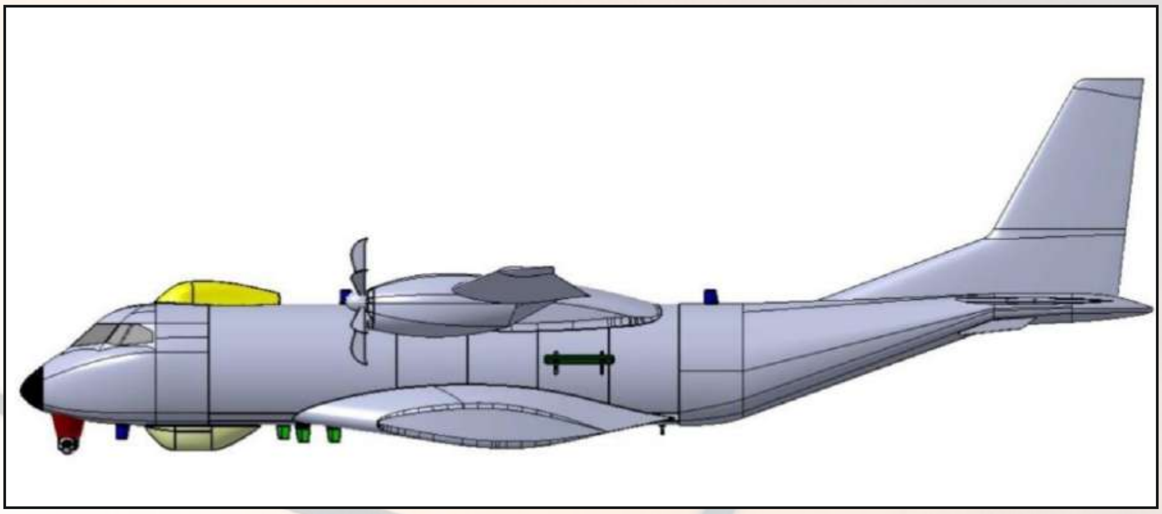
fighter aircraft to replace the present fighter fleet. To qualify for deck-based operations, the aircraft must be capable of shorter take-offs from the Short Take-Off But Arrested Recovery (STOBAR) aircraft carriers presently in the Indian Navy and also from future aircraft carriers with Catapult Assisted Take-Off But Arrested Recovery (CATOBAR) facility, with specific features such as foldable wings for more compact storage, robust landing gears to meet shock requirements of arrested landing and also, automatic Take-off and landing (ATOL) capability. The aim is to develop an indigenous deck-based fighter aircraft capable of a multitude of missions, including air supremacy, air interdiction, anti-access/area denial (A2/AD), anti-ship warfare (ASuW), land attack, MUM-T, networked and electronic warfare (EW) missions. TEDBF project is being progressed through Aeronautical Development Agency (ADA) for design and development of a twin-engine, carrier-based, multirole combat aircraft. The TEDBF will predominantly be equipped with indigenous weapons, sensors and networking systems.

Maritime Reconnaissance Aircraft

3. **Long-Range Maritime Reconnaissance Aircraft (LRMR)**. LRMR aircraft are designed to conduct maritime surveillance, Anti-Submarine Warfare (ASW), reconnaissance and patrol missions including SAR and HADR missions over long ranges, typically exceeding 600 nm with 04 hours of time on task. These aircraft are designed to operate at long ranges, allowing them to cover vast maritime areas which are predominantly the IOR region for the Indian Navy whilst operating from the Indian Sub-continent and also covering the entire areas of interest of Indian Navy by stage-through operations. The aircraft are required to be equipped with advanced sensors, including radar, electro-optical/infrared (EO/IR), acoustic sensors such as sonobuoys and magnetic anomaly detector. These aircraft also carry weapons such as long-range strike missiles, both anti-ship and land attack capable, and underwater weapons such as light-weight torpedoes and underwater bombs. With advancement of technology, Indian Navy also plans to launch loitering munitions, swarm drones and collaborative combat aerial vehicles from these aircraft to

complement its combat power. Indian Navy is presently operating the P8I LRMR ASW aircraft. There is a need for production of wide body aircraft in-country which could then be integrated with required weapons, sensors and capabilities.

4. **Medium-Range Maritime Reconnaissance Aircraft (MRMR)**. MRMR aircraft are designed to conduct maritime surveillance and reconnaissance missions over medium ranges, typically beyond 400 nm with 4 hours of time on task. The roles of these aircraft are similar to that of LRMR aircraft. The sensor suite is equivalent to that of LRMR aircraft whereas the weapon carrying capability may be reduced catering for the endurance. Indian Navy is planning to induct indigenously manufactured C-295 aircraft by M/s TASL. These aircraft will be fitted with state of the art indigenously developed weapons and sensors to undertake Maritime Reconnaissance operations. CABS is the nodal DRDO laboratory for integration of weapons and sensors on the MRMR aircraft.



5. **Short-Range Maritime Reconnaissance Aircraft (SRMR)**. SRMR aircraft are designed to conduct maritime surveillance and reconnaissance missions over short ranges, typically upto 200 nm with 4 hours of time on task. Indian Navy presently operates a fleet of Dornier aircraft indigenously built by HAL. However, indigenous development of components presently imported, would reduce the risk of disruptions in global supply chains.

6. **Aircraft Carrier-Borne Airborne Early Warning and Control Aircraft (AEW&C)**. AEW&C aircraft are designed to provide airborne early warning and command and control capabilities to naval task forces. Indian Navy aims to induct carrier borne AEW&C aircraft. This could be manned or uncrewed aircraft.

7. **Air to Air Refueller Aircraft (AAR)**. With an envisaged fleet of 400+ aircraft in next two decades, the Naval Air Arm also aims to induct integral manned or uncrewed AAR aircraft capable of both boom type, and hose and drogue type refuelling capability. The AAR aircraft should be capable of refuelling fighters, UAVs, as well as, MR aircraft. The option for long endurance unmanned AAR aircraft would also be explored to enhance operational efficiency.

8. **Amphibious Aircraft**. Amphibious aircraft are designed to take off and land on both water and land, providing versatility and flexibility for various operations. To augment the benign role of Indian Navy, manned or uncrewed amphibious aircraft are planned to be

inducted for various operations such as HADR, delivery of critical items/ equipment to ships at sea as part of operational logistics, Search and Rescue (SAR), and also CASEVAC from high seas.

Helicopters

9. **<u>Critical Features of Maritime Helicopters</u>**. Critical features required in a helicopter for maritime operations, especially deck-based operations are as follows:-

(a) Twin engine.

(b) Blade folding.

(c) Tail folding (for medium lift helicopters).

(d) Optimised engines, structure and systems for protracted operations in tropical marine conditions.

(e) Strengthening undercarriage for deck landing.

(f) Stringent EMI/ EMC.

(g) Networked.

(h) ATOL capability.

(j) High reliability and low maintenance downtime.

(k) Low footprint of maintenance aggregates.

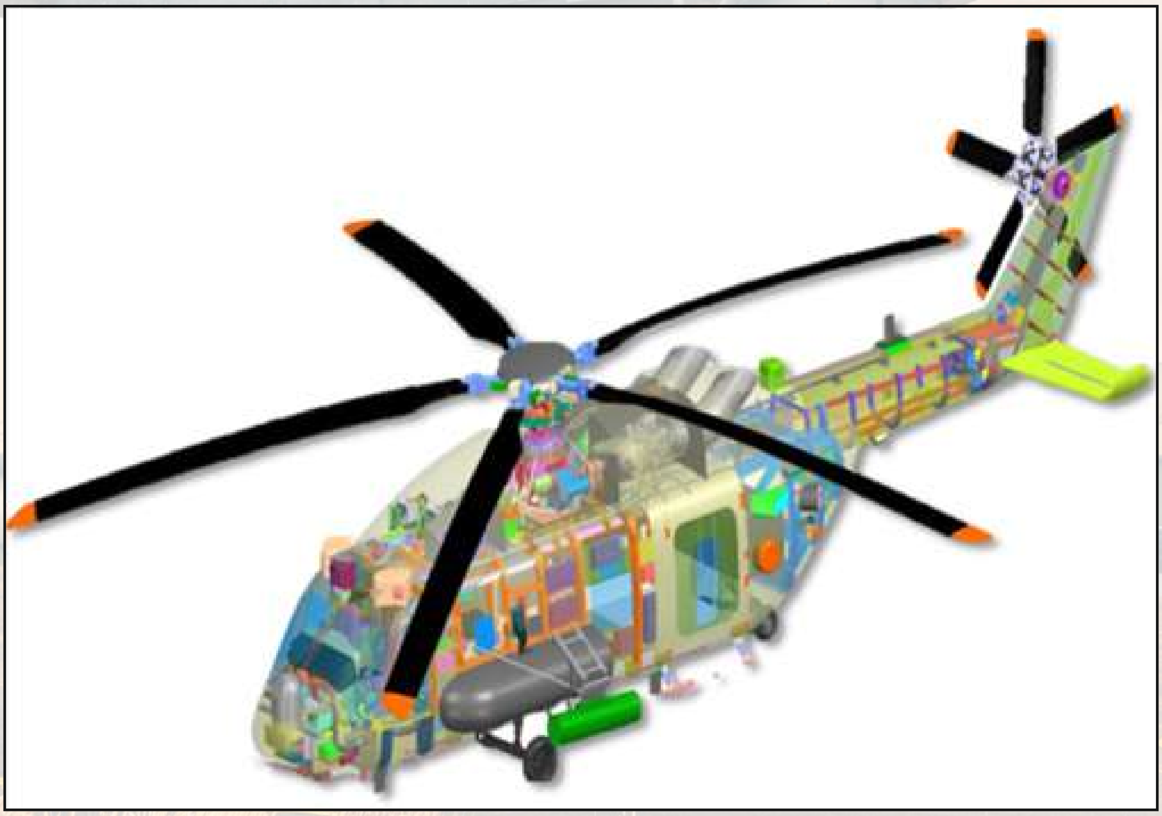
(l) Optionally manned operations (in future).

10. Indian Navy currently envisages induction of helicopters in the light, medium and heavy lift categories. The heavy lift helicopters are required in limited numbers, and are envisioned to be indigenised post stabilisation and consolidation of indigenous light and medium lift manned helicopters.

(a) **<u>Utility Helicopter</u>**. Utility helicopters are versatile aircraft designed to perform a variety of tasks, including transportation, cargo carrying, medical evacuation, search and rescue, and reconnaissance. Utility helicopters are often smaller and more manoeuvrable than other helicopters, allowing them to operate in confined areas. Utility helicopters are also to be equipped with sensors like radar and EO/IR for limited reconnaissance and surveillance mission. Utility Helicopter Maritime (UHM) is a twin engine helicopter being developed indigenously by HAL. The Indian Navy is also exploring options for other OEMs to design and develop these helicopters either independently or through joint ventures.

(b) **Multirole Helicopter**. Deck-Based Multi-Role Helicopters are designed to operate from aircraft carriers and ships, providing a range of capabilities to support naval operations. Multi-role deck-based helicopters are designed to be compact and lightweight, allowing for efficient storage and deployment from ships. Equipped with advanced avionics, including radar, electronic support measures, and communication systems, the helicopters are required to be designed to perform multiple tasks, such as anti-submarine warfare, anti-surface warfare, airborne early warning and EW missions. Design and Development of Deck Based Multi Role Helicopters is being currently pursued. Three variants of DBMRH viz., Anti-Submarine Warfare and Anti-Surface Warfare, Air Early Warning and Special Operations are planned to be developed.

11. **Heavy Lift Helicopter (HLH)**. Both the aircraft carriers and the future LPDs would cater for heavy lift operations. The HLH program would be pursued based on maturity of the indigenous helicopter manufacturing capability in the DBMRH program.



Uncrewed Aerial Systems

12. Indian Navy is steadily but surely increasing its reliance on uncrewed systems. Many aspects of air operations in future would be shared between crewed and uncrewed systems. It is envisioned that all repetitive and time intensive tasks would predominantly be taken over by the uncrewed systems, like surface and sub-surface surveillance, maintaining unbroken presence over areas of interest like the SLOCS and choke points, tactical logistics at sea, overwhelm enemy AD through swarm strikes, kamikaze strikes, loitering ammunitions etc. Hence, the envisaged roadmap for UAVs in IN is to replicate autonomous conduct of roles currently being done by manned aircraft. The UAV platforms/ systems envisaged for induction in the period covered by this vision document are enumerated in subsequent paragraphs.

13. **HALE RPAs**. High-Altitude, Long-Endurance (HALE) Remotely Piloted Aircraft (RPAs) are uncrewed aerial systems designed to operate at high altitudes (above 30,000 feet) for extended periods (often exceeding 24 hours). These are equipped with efficient engines, lightweight materials, and advanced power management systems to extend flight duration. They carry a range of sensors and payloads, including electro-optics/infrared (EO/IR), radar, ASW and communication systems in order to provide a continuous surveillance and monitoring of areas of interest. These UAVs can additionally carry an array of weapons in anti-ship role. Indian Navy is presently inducting MQ9B HALE RPAs. In the future, the plan is to augment these RPAs with indigenously built HALE RPAs which could undertake maritime strike and surveillance missions including ASW operations.

14. **MALE RPAs**. Medium-Altitude, Long-Endurance (MALE) Remotely Piloted Aircraft (RPA) are uncrewed aerial systems designed to operate at medium altitudes (up to 30,000 feet) for extended periods (often exceeding 24 hours). Roles of these UAVs are similar to that of HALE RPAs, wherein the payload carrying capacity changes catering to endurance. Indigenous MALE RPAs by M/s ADSTL with its full suite of integral sensors and SATCOM enabled control has been inducted.

Indigenous armed version of MALE RPAs is envisaged to be inducted in the future.

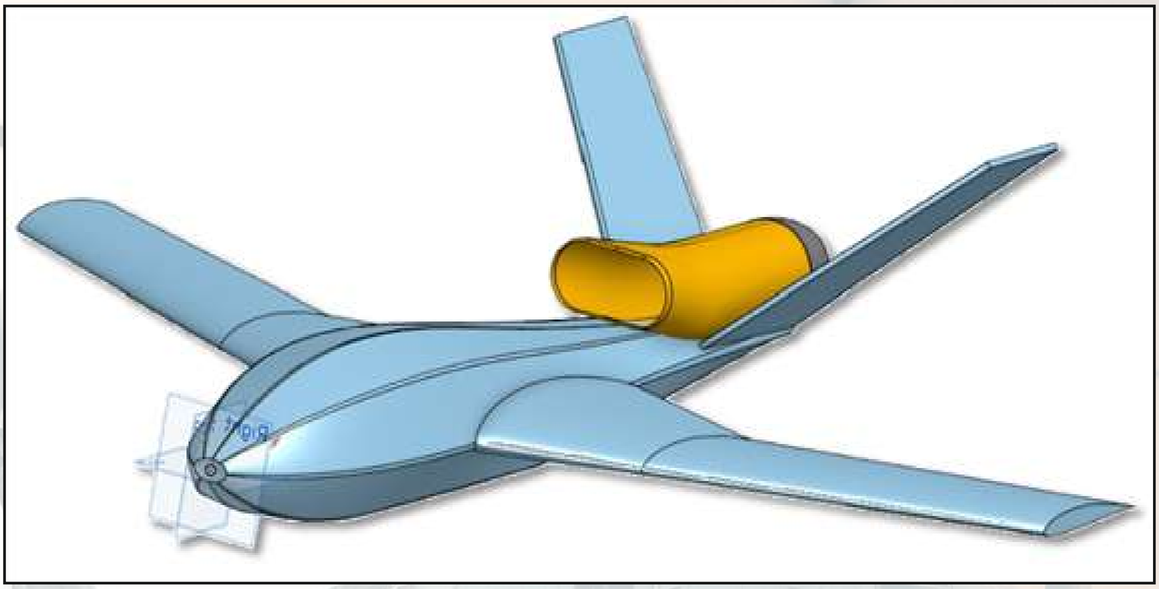
15. **Deck Based UAS**. Deck-Based Uncrewed Aerial Systems (UAS) are uncrewed aerial systems designed to operate from the deck of a ship, providing maritime surveillance, reconnaissance, and communication relay capabilities. These UAS are to be equipped with various sensors, including electro-optical/ infra-red (EO/IR), radar, and electronic warfare (EW) systems. With heavy lift capability these UAS could be utilised for transhipment of stores from Fleet Support Vessels to other ships at sea in Op Logistics role. Expeditious deployment and enhanced Time on Task with drastic reduction in the transit time to the area of operation, are the main operational advantages of deck based UAS over shore based UAS. These are further divided into two categories based on their platform of operation as mentioned below:-

(a) **Rotary Wing UAS**. Rotary Wing deck based UAS is designed to be compact and lightweight, allowing it to operate from the limited deck space of a ship including aircraft carrier. These UAS should be capable of VTOL technology, enabling them to take of and land vertically from the deck and operate autonomously, with pre-programmed mission plans and real-time data transmission.

(b) **Fixed Wing UAS**. This deck based UAS is designed to operate only from aircraft carriers. They are required to withstand the rigorous demands of carrier operations, including being launched and recovered on deck. These need to be optimised for minimal footprint on the carrier, allowing for efficient storage and deployment.

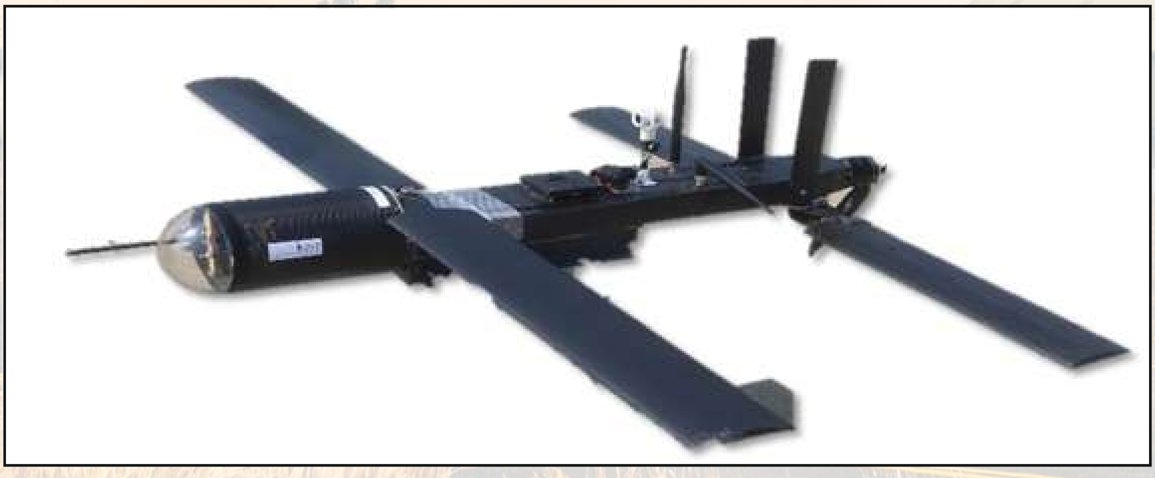
16. **Persistent Surveillance RPAs**. Indian Navy plans to induct HAPS with surveillance & intelligence gathering capability and flexible on-station time of at least 90 days, to provide continuous surveillance and standby networking cloud/ monitoring of areas of interest.

17. **<u>Loyal Wingman</u>**. A "Loyal Wingman" is an UAV designed to accompany and support a manned fighter aircraft during missions. These UAS should be capable of operating from ashore and also from aircraft carriers. Naval Combat Air Teaming project is being progressed as a step towards induction of this capability.



18. **<u>Collaborative Combat Aerial Vehicle</u>**. Advanced version of Loyal Wingman is Collaborative Combat Aerial Vehicle (CCAV). Indian Navy plans to induct this capability.

19. **<u>Aircraft Launched UAS</u>**. These are disruptive drones planned to be launched from both helicopters and fixed wing aircraft either using existing tube launchers such as sonobuoy launcher or by gravity launch method. The drone laden with warhead after launch would unfold the wings and target the adversary to achieve the desired Air Launch Effect.



20. **<u>Containerised UAS</u>**. Containerised Uncrewed Aerial Systems (UAS) are designed to be compact, portable, and easily deployable. The main purpose of these is to enable rapid deployment and setup, minimising downtime and increasing operational efficiency. These are containerised fire-and-forget, kamikaze swarm drones capable of being launched from ships/ shore and undertake strike at ranges more than 1000km.

21. **<u>Re-purposed Phoenix Aircraft System</u>**. Indian Navy is planning to utilise manned aircraft in uncrewed role either as a target or multi-mission capable UAS, on completion of their operational life.

CHAPTER - V

THE SENSOR GRID: ENHANCING COMBAT EFFICIENCY THROUGH ADVANCED SENSORS

Introduction

1. The sensor grid is one of the most important components which provides the capability to detect, classify and destroy the target in a dynamic maritime environment. Indigenisation of sensors for naval aviation platforms marks a significant strategic shift in enhancing maritime security and operational efficacy. As global maritime challenges evolve, the ability to develop and induct advanced sensor technologies locally becomes crucial for ensuring self-reliance and technological superiority. These sensors include radar, sonar, sonobuoys, electro-optical/infrared (EO/IR) systems, and electronic warfare capabilities, each playing a critical role in surveillance, reconnaissance, target acquisition, and electronic intelligence.

Roadmap for Indigenous Sensor Integration

2. The Naval Air Arm has already embarked on the journey of integrating indigenous sensors onto its platforms. This roadmap lays out the plan for induction of sensors planned, as well as, envisaged for naval aircraft. By 2047, the Naval Air Arm is confident of being a self-reliant force with indigenous sensors on all its platforms.

Radar Systems

3. **Airborne High Performance Multi-Mode AESA Radar**. With advancement of radar technology, Naval Aviation is investing in upgradation of the radar systems of all its aircraft. A two-pronged approach, through DRDO and also through industry partners, has been adopted to develop radar systems for the aviation platforms.

4. **Multi-Role Maritime Patrol Radar**. Maritime Patrol radar for Maritime Reconnaissance aircraft and multi-role helicopters are being developed by DRDO and the private industry, and is planned for induction in near future.

5. **Active Electronically Scanned Array Fire Control Radar**. AESA FCR for fighter aircraft is also being developed indigenously, both by DRDO and by industry partners.

6. **Cognitive Radar**. Indian Navy is also looking forward to development of cognitive radars for its Air Arm.

ELINT/ COMINT Systems

7. **Low Frequency Band Coverage Airborne ESM System**. With proliferation of radar technology, the need for an ESM system capable of intercepting emissions of radars operating in low frequency (A/ B Band) has become a necessity. Development of ESM systems with this capability is in progress by DRDO/ DPSU and industry partners.

8. **Airborne COMINT System**. Induction of advanced COMINT systems with DF capability for aircraft is also being pursued with DRDO and industry partners.

9. **Light Weight ELINT/ COMINT System**. Indian Navy is also progressing projects through iDEX challenges for development of light weight ELINT and COMINT systems for Unmanned Aerial Systems.

10. **Radar Finger Printing System**. Modern ESM systems with integrated radar finger printing aid to classification of emissions are also being progressed.

11. **RWR and Jammer Pods**. Modern RWR and jammer pods for fighter aircraft are being planned to be developed through private firms.

12. **High-Powered Electronic Warfare Systems**. Development of advanced jamming and cyber-attack capabilities for suppressing

enemy radar and communication systems is also being looked at for integration on to all types of aircraft of the Naval Air Arm.

13. **Cognitive EW System**. Development of Cognitive EW System is also planned through indigenous sources for naval aviation platforms.

Underwater Sensors

14. **Directional Sonobuoys**. Indigenous development of active and passive directional sonobuoys is being explored through DRDO and industry partners.

15. **Bathy Sonobuoys**. Development of Bathy sonobuoy is also being progressed by both DRDO and industry partners.

16. **Multi Access Coherent System (MAC)**. MAC system is a niche domain available with a select few countries at present. *IN* is keen on developing and integrating MAC system onto all Air ASW platforms and requires this capability by 2030.

17. **Low Frequency Dunking Sonar (LFDS)**. Indian Navy is also looking forward to indigenous solutions for a LFDS system to be integrated onto the multi-role helicopters.

18. **SUS Buoys**. Signal Underwater Sound (SUS) buoys are low-cost expendable air/ ship launched underwater signalling devices capable of transmitting a pre-programmed sound signal once deployed. These are utilised for communicating with submarines during coordinated exercises. There is intended to develop of these buoys for all ASW aircraft.

19. **Indigenous Sonic System**. Indigenous sonic systems compatible with indigenous sonobuoys are also being developed through private firms to overcome the dependency on foreign OEMs for sonobuoys.

20. **Digital Magnetic Anomaly Detector (MAD)**. MAD is an important confirmatory sensor for ASW operations. Only a select few countries have this capability of manufacturing the MAD sensor. Indigenous

development of the digital MAD sensor is being pursued through DRDO and the Indian Navy also looks forward to participation of industry partners for the same.

21. **Airborne Mine Detection and Mine Sweeping**. Airborne mine detection and sweeping capability is presently non-existent in the country. There is scope to develop these sensors in the country as the multirole helicopters could be integrated with this sensor.

Electro Optics/ Infra-Red Systems

22. **EO/ IR Systems**. Indigenous EO/ IR system for all types of aircraft is being progressed through DRDO/ IRDE and also through industry partners.

23. **Light weight EO/ IR Pod for RPAs**. Development of Light weight EO/ IR pod is being pursued for RPAs.

24. **EO/ IR Pod for Fighter Aircraft**. EO/ IR Pods akin to Laser Designator Pods for fighter aircraft are also planned for induction.

25. **LiDAR Based Imaging System**. Indian Navy also plans to induct LiDAR based imaging system for its platforms and welcomes industry partners for development of this capability in-country.

26. **Imaging Pods**. Development and integration of imaging pods onto all types of aircraft in naval air arm is also planned.

Conclusion

27. By leveraging indigenous resources and talent, nations can develop tailored solutions that accommodate unique geographical and operational challenges faced by their navies. This strategic initiative not only contributes to national security but also aligns with broader policy objectives of self-reliance and sustainability in defence capabilities. The naval air arm has taken the lead in harnessing the in-house potential in sensor technology to achieve maritime dominance through self-reliance.

CHAPTER – VI

THE WEAPON GRID: ARMING WITH INDIGENOUS WEAPONS TO DELIVER THE LETHAL PUNCH

Introduction

1. With advancement in weapon systems worldwide, the main focus is to integrate indigenously developed modern and advanced weapon systems onto Naval Aviation platforms. Advanced weapon technology for naval aircraft focuses on enhancing range, precision, lethality, survivability, and adaptability in modern combat scenarios. Some of the indigenous weapon programs are being pursued through DRDO. Production of the weapons and associated systems by private defence industries apart from DPSUs, however, needs greater impetus.

2. **Specific Qualitative Requirements of Air Launched Weapons**.

(a) **Weight**. Light weight to cater for stringent take-off and landing weight requirements of aircraft whilst operating from deck and ashore.

(b) **Ruggedisation**. Adequate ruggedisation or strengthening to withstand deck landing shocks.

(c) **Stealth Design**. Stealth-optimised design to minimise radar signatures to facilitate covert penetration of enemy defences without early detection. Radar absorbent material to reduce RCS.

(d) **Extended Range**. Weapons capable of engaging targets at stand-off ranges while remaining outside enemy air defence zones and anti- air weapon ranges.

(e) **Reconfigurable Warhead**. Considering dynamic maritime operational environment, reconfigurable warhead is best suited for naval aviation platforms for effective utilisation of the weapons. Also, the lethality quotient has to be higher to counter adversary air defences.

(f) **Advanced Seeker**. RF and IIR Seeker or a combination of both is required for anti-ship version and multi-constellation GNSS and INS based navigation for land attack version. More importantly the Seeker has to be compact and light weight so that the overall weight and length of the missile is not affected due to the Seeker. The Seeker must have ECCM features against countermeasures employed by the target platform.

(g) **Data linking of Weapons**. Another important requirement of naval weapon systems is robust data linking for collaborative and cooperative engagement with mid-course guidance to achieve the element of surprise.

(h) **Insensitive Munition Compliance**. Explosives used in naval weapon systems are required to be insensitive munition complaint *iaw* STANAG 4439.

(j) **Fuze**. Fuze is a critical component of any weapon system. The mechanical/ electrical Fuze used in naval weapon systems should be capable of withstanding high deceleration/ stresses produced on landing / take-off and dense EMI/ EMC environment of the ships.

Missiles

3. **Roadmap for Missile Induction**. The Naval Air Arm is in pursuit of self-reliance by harnessing the technological advancement in the field of indigenous airborne missile design and development capability. Development of a variety of airborne missiles is being pursued to be inducted in next five years such as anti-ship and land attack missiles with smart Seekers, enabled with advance ECCM features and autonomous guidance capability. Induction of indigenous air launched supersonic, hypersonic and ballistic missiles are also envisaged in the next decade. Indian Navy requires missiles capable of dual role,

selectable trajectory, reconfigurable warheads and swappable guidance and homing system. The types of missiles required for naval aviation platforms are divided based on role, speed, trajectory and homing as mentioned below:-

(a) **Role**.

(i) Anti-ship missile

(ii) Land attack missile

(iii) Air to air missile

(b) **Speed**.

(i) Subsonic (< 1 Mach)

(ii) Supersonic (> 1 Mach)

(iii) Hypersonic (> 5 Mach)

(c) **Trajectory**.

(i) Sea Skimming

(ii) Quasi-ballistic

(iii) Ballistic

(iv) Manoeuvring

(d) **Homing**.

(i) Active.

(aa) Radio Frequency (RF)

(ab) Laser

(ii) **<u>Passive</u>**.

(aa) Infra-Red (IR)

(ab) Imaging Infra-Red (IIR)

(ac) Anti-radiation

4. **<u>Short Range Anti-ship Missile</u>**. The short-range anti-ship missile with capability to interdict targets at ranges upto 50 km is planned for integration onto helicopters and RPAs.

5. **<u>Medium Range Anti-Ship Missile</u>**. This anti-ship missile with ranges above 250 km is planned for integration onto fighter aircraft, maritime reconnaissance aircraft and HALE. A project is being pursued through DRDO. Integration of this missile onto naval fighter aircraft and MR aircraft is envisaged by end of this decade.

6. **<u>Anti-Ship and Land Attack Supersonic Cruise Missile</u>**. To complement the present inventory of airborne missiles and to bridge the capability gap of supersonic cruise missile, the Indian Navy also plans to induct airborne supersonic cruise missiles. The aim is to induct a highly manoeuvrable and sea-skimming missile capable of travelling at supersonic speeds with advanced guidance system to destroy enemy ships and also land targets. The missile is required to be integrated onto MR and fighter aircraft of Indian Navy.

7. **<u>Anti-Radiation Supersonic Missile</u>**. Anti-radiation missile is designed to detect, acquire, and destroy radar and communication systems on adversary's ships and ashore. The missile homes on to the electromagnetic emissions from radar installations. Indian Navy plans to induct anti-radiation missiles for its aviation platforms.

8. **<u>Hypersonic Missile</u>**. With planned indigenous development of hypersonic missiles, Indian Navy is also looking forward to integration of hypersonic missiles onto aviation platforms. The plan is to progress parallel development of air launched hypersonic missiles in tandem with the land version. The hypersonic missile would provide naval aviation platforms long-range strike capability against high-value targets of the adversary.

9. **Air Launched Ballistic Missile**. An air launched ballistic missile combines the speed and range of ballistic missiles with the flexibility and deployment advantages of the air-launch capability from an aircraft. To achieve a strategic edge in terms of long-range stand-off strike capability, it is envisaged to induct air launched ballistic missiles onto MR and fighter aircraft of the Indian Navy in the future.

10. **Beyond Visual Range Air to Air Missile (BVR AAR)**. BVR AAR missiles are also a quintessential requirement for aerial combat by naval fighters and Indian Navy also plans to induct indigenous BVR AAR missiles.

Torpedo

11. **Lightweight Torpedo**. Anti-Submarine Warfare aircraft have proven to be the most deterrent platforms for ASW operations. A torpedo is the main weapon for an aircraft employed for ASW operation. Considering weight carrying capacity, light weight torpedo is best suited and the most suitable weapon for an ASW aircraft.

12. **Air Launched Rocket Assisted Torpedo (A-RAST)**. Torpedo with rocket propulsion enhances range and speed of the torpedo. The A-RAST adds to the tactical advantage by providing an element of surprise to the employing aircraft as it can be launched from far off distance vis-à-vis a normal torpedo which is dropped on top of the adversary submarine by an aircraft. Also, due to the high speed of the torpedo, it complicates the countermeasures employed by the target. Indian Navy plans to induct A-RAST for MR aircraft and multi-role helicopters.

Miscellaneous

13. **Air Launched Loitering Munition**. Recent wars have changed the character of warfare with uncrewed platform and loitering munitions. Loitering munitions have proven to be more effective in saturating enemy air defences owing to their long endurance and low

RCS. Air launched loitering munitions are more potent and effective because of the flexibility of deployment at stand-off ranges by an aircraft. Few projects are already being progressed by the Indian Navy through the iDEX challenge for development of the air launched loitering munitions which could be deployed from MR aircraft and helicopters.

14. **<u>AI enabled Smart Loitering Munition</u>**. Induction of smart loitering munitions which can undertake autonomous operations through AI enabled solutions are also planned for all types of aircraft.

15. **<u>Directed Energy Weapons (DEWs)</u>**. DEW weapons or use of high-energy lasers or microwaves to disable enemy systems and as a countermeasure against air-to-air missiles has proven to be an effective solution. DEW weapons are also being planned to be integrated onto MR aircraft and helicopters due to their low cost, rapid engagement, and precision targeting capability.

16. **<u>Smart Anti Airfield Weapon (SAAW)</u>**. SAAW provides the capability to target the adversary airfield and to knock it out of the fighting grid for a specific duration. Development of SAAW is being pursued by Indian Navy.

<u>Conclusion</u>

17. Indigenising airborne weapons, especially for naval platforms, provides several strategic advantages. Firstly, it fosters technological independence, reducing reliance on foreign suppliers and mitigating risks associated with external supply chain disruptions. Secondly, it allows for customisation and integration specific to stringent requirements of a naval aircraft, thereby enhancing its operational effectiveness. Additionally, development of local expertise boosts domestic defence industry, creating opportunities for research and innovation, and potential for economic growth. The Naval Air Arm aims to be at the fore front in indigenising the weapon grid.

CHAPTER - VII

NETWORK CENTRIC OPERATION GRID: A ROBUST NETWORK TO SHORTEN OODA LOOP

1. **Introduction**. Modern naval battlefield is characterised by rapidly evolving threats, increasing complexity, and a growing reliance on information dominance. In this environment, Network-Centric Operation (NCO) has emerged as a critical enabler of effective naval air operations. By facilitating the real-time sharing of tactical information across platforms, NCO enables naval forces to achieve a shared awareness of the battlespace, accelerate decision-making, and synchronise actions to achieve decisive effects, thereby shortening the OODA (Observe-Orient-Decide-Act) loop.

NCO Grid Enablers

2. **Software Defined Radio (SDR)**. Software Defined Radio (SDR) transforms the way naval aircraft communicate, by providing a highly flexible, adaptable, and secure communication networking capability. SDRs utilise software to modulate and demodulate radio signals, rather than traditional hardware-based approaches, enabling rapid reconfiguration and reprogramming to support diverse communication protocols and waveforms. This allows naval aircraft to seamlessly communicate with different platforms and units, across various frequency bands and networks, ensuring interoperability and enhancing tactical operations. SDR for naval aircraft catering to deck based operations and critical requirements of carrier borne fighter aircraft is a niche domain yet to be realised through the indigenous route. Efforts are in place through DRDO to develop a SDR for naval aircraft. Development of SDR by private firms is also encouraged. However, considering operational security issues related to waveforms, the Firms developing the SDR would be required to coordinate with DRDO for SAG grading of the waveforms with support from Indian Navy. The Naval Air Arm plans induction of SDR on the

existing platforms at the earliest and the same is being planned as a standard fit for all future platforms.

3. **Cognitive Radio (CR)**. Cognitive Radio is a wireless communication technology that enables radios to intelligently adapt to their operating environment. By leveraging advanced signal processing, machine learning, and real-time spectrum sensing, CR systems can dynamically detect and exploit unused spectrum bands, thereby optimising spectrum utilisation and minimising interference. This allows for more efficient use of the electromagnetic spectrum, enabling seamless communication and networking in congested and contested environment. The Indian Navy is looking forward to indigenous design and development of CR systems for aviation platforms through industry partners.

4. **High Speed Data Link**. Integration of high-speed data links on naval aircraft is a critical enabler of net-centric operations, providing a secure, reliable, and high-bandwidth communication capability that facilitates the real-time exchange of tactical information. These advanced data links, such as the Multifunctional Information Distribution System (MIDS) and the Tactical Targeting Network Technology (TTNT), enable naval aircraft to share situational awareness, sensor data, and command and control information with other platforms and units, enhancing speed and accuracy of decision-making. With data rates exceeding 100 Mbps, these links support the transmission of large amounts of data, including video, imagery, and targeting information, allowing naval aircraft to operate as nodes in a dynamic, networked environment, and to deliver more effective and coordinated combat effects. With planned induction of air launched swarm drones, CCAs, Loyal Wingman and enabling MUM-T LOI 5, the requirement of a robust and secure high speed data link is critical. A project like the Standard Control Link for deck based unmanned platform is in the pipeline.

5. **Quantum Encryption System**. Quantum encryption systems offer security of sensitive communications, providing unparalleled protection against interception and eavesdropping. By harnessing the principles of quantum mechanics, these systems generate

unbreakable encryption keys, ensuring that critical information, such as mission plans, tactical data, and sensor feeds, remain confidential and authentic. Quantum encryption systems, such as Quantum Key Distribution (QKD), enable naval aircraft to securely communicate with other platforms, ships, and shore-based stations, safeguarding against cyber threats and maintaining operational security, thereby ensuring a robust and secure NCO grid. This cutting-edge technology is particularly crucial for naval aircraft, which often operate in contested environment and rely on secure communications to execute their missions effectively.

6. **LEO / MEO based Satellite System**. The integration of Low Earth Orbit (LEO) and Medium Earth Orbit (MEO) satellite-based communication systems is revolutionizing naval communications, providing a high-speed, low-latency, and global connectivity. LEO constellations offer high-bandwidth and low-latency communications, ideal for real-time video, voice, and data transmission. MEO satellites provide a complementary capability, offering higher-power and wider-beam coverage, suitable for larger naval vessels and shore-based stations. By leveraging both LEO and MEO satellites, naval aircraft can establish a resilient, adaptable, and global communication network, enabling seamless connectivity and information sharing between ships, shore-based stations, and other platforms, regardless of their location or operational environment.

7. **High BW SATCOM with Global Coverage**. With advanced sensor capability, high-bandwidth satellite communications (SATCOM) for naval air operations is the need of the hour which will enable rapid and secure transmission of large volumes of sensor data. This high-bandwidth capability is essential for naval air operations, supporting the transmission of high-resolution sensor data, real-time video feeds, and critical command and control information. With high-bandwidth SATCOM, naval aircraft can operate more effectively, making faster and more informed decisions, and staying ahead of the curve in the maritime domain. SATCOM requirements are being factored by the Indian Navy. The associated systems for aircraft SATCOM component are being planned to be sourced from indigenous resources.

8. **Airborne SATCOM Antennae**. Presently, only S and Ku band antennae are available for aircraft. With advancement in technology, Ka band SATCOM antennae have been developed. There is a requirement for indigenous development of airborne SATCOM antennae especially for Ku and Ka band. Also, the Indian Navy looking forward to development of a beam steering SATCOM antennae in Ku and Ka band as a replacement for the gimballed antennae to reduce the antennae failure rate.

Conclusion

9. Need of a robust NCO Grid for naval air operations as a subset of Naval/ Joint operations cannot be overemphasised. It enables the seamless integration of sensors, shooters, and decision-makers, allowing naval aircraft to detect, track, and engage threats quickly and accurately. Moreover, NCO facilitates the dynamic re-tasking of assets, enabling naval forces to adapt rapidly to changing circumstances and exploit emerging opportunities. As the naval operating environment continues to evolve, the importance of robust NCO in enabling effective naval air operations will only continue to grow. With planned induction of state-of-the-art platforms, the NCO grid is also planned to be enabled with self-reliant advance technology making the Navy a future ready force.

CHAPTER - VIII

AIRCRAFT SYSTEMS: HARNESSING IN-HOUSE TECHNOLOGICAL REVOLUTION

Introduction

1. Indian Navy's pursuit of self-reliance in naval aviation has led to a concerted effort to indigenise aircraft systems, with an aim of reducing dependence on foreign suppliers and fostering domestic expertise. As the Indian Navy continues to modernise its aircraft fleet, the need to develop indigenous capabilities in aircraft design, development, and production has become increasingly important. Indigenisation of aircraft systems not only enhances national security by ensuring the availability of critical components and systems but also promotes growth of a domestic aerospace industry, driving innovation, and creating opportunities for Indian companies to become part of the global supply chain.

Indigenisation Efforts in the field of Aircraft Systems

2. **Multi-Constellation GNSS Receiver**. Position, Navigation and Timing or PNT is a critical requirement for aircraft operations. With operationalisation of indigenous PNT service NaVIC, the Naval Air Arm is progressing fitment of multi-constellation GNSS receiver with NaVIC (RS code) capability. The system is required to be capable of anti-spoofing and anti-jamming operations.

3. **Directional Infra-Red Counter Measure System (DIRCM)**. Directed Infrared Counter Measures (DIRCM) systems on naval aircraft provides protection against infrared-guided missiles, enhancing their survivability in hostile environment. DIRCM systems utilize a high-powered laser to detect, track, and jam the infrared seekers of incoming missiles, disrupting their guidance and preventing them from striking the aircraft. This advanced countermeasure capability is

particularly vital for naval aircraft, which often operate in littoral zones and are vulnerable to attacks from shoulder-fired missiles and other infrared-guided threats. DIRCM systems sourced from indigenous sources are envisaged to be integrated onto helicopters and MR aircraft fleet.

4. **IR Flares**. Indigenous development of IR flares is being pursued for naval fighter and MR aircraft. The future plan is to utilise indigenous flares on all types of aircraft capable of counter measure dispensation system.

5. **Indigenous Chaff**. Indigenisation of Chaff for both fighter and MR aircraft is in progress.

6. **Air Droppable Container (ADC)**. *IN* is pursuing a project of ADC for delivering critical stores to ships at sea by MR aircraft to augment Op Logistics.

7. **Expendable Self-Propelled Target System (ESPTS)**. ASW being a training intensive domain, indigenisation of ASW targets is being progressed through DRDO and private firms. Many advanced features like evasive manoeuvres and magnetic generator capability is also being integrated on to the target to make it a more effective training solution. Expendable Self-Propelled Target System (ESPTS) project is being pursued through DRDO and industry partners.

8. **Multipurpose Pylon for Indigenous Missile**. Presently, the airborne missile systems use pylons being sourced from foreign OEM. The Indian Navy is looking forward to development of a multipurpose pylon with adjustable lugs through industry partners/ MSME which could be utilised for all type missiles, bombs, torpedoes, Depth Charge, etc, and also compatible for indigenous weapons under development.

9. **Optical Landing System**. The Optical Landing System (OLS) is a critical component of air operations from aircraft carriers, providing pilots with precise glide slope and lineup guidance during carrier landings. The OLS uses a combination of lights and optics to project a

stabilized, three-dimensional glide slope indicator onto the flight deck, enabling pilots to accurately judge their rate of descent and alignment with the carrier's centerline. This advanced visual landing aid is particularly essential for night, low-visibility, or instrument meteorological conditions (IMC) landings, where pilots rely heavily on the OLS to ensure safe and successful recoveries onboard the carrier. Indigenisation of OLS for naval aircraft carriers is also being pursued. Indigenous development Improved Fresnel Lens Optical Landing System (IFLOLS) is also being looked forward to in near future.

10. **GNSS Based Helicopter Approach and Landing Aid**. Landing on the deck of a ship is a critical evolution. GNSS (NAVSTAR, GLONASS, GALILEO, GAGAN SBAS & IRNSS compatible) based approach & landing aid for naval helicopters would assist pilots in approach and landing onboard ships, in bad weather/ reduced visibility/ night/ GPS denied environment. Though development of only approach system is being pursued as of now, IN is also looking forward to induct the landing aid in the near future.

11. **Identification Friend or Foe (IFF)**. Modern IFF systems are a critical component of naval aircraft operations, providing enhanced situational awareness and combat identification capabilities. These advanced systems utilize Mode 5, Mode S, and other secure protocols to enable secure and reliable identification of friendly forces, while also providing resistance to electronic countermeasures and cyber threats. Modern IFF systems also integrate with other onboard systems, such as radar and electronic warfare systems, to provide a comprehensive picture of the battlefield. Additionally, these systems enable the use of advanced tactics, such as network-centric warfare and cooperative engagement, allowing naval aircraft to operate more effectively and safely in complex and dynamic operational environments. Though Indian DPSUs have developed credible IFF systems being used onboard IN aircraft, fitment of advanced systems is also planned for induction.

12. **Inertial Navigation System**. Inertial Navigation Systems (INS) provide highly accurate and reliable navigation and orientation data to naval aircraft, even in a GPS-denied environment. Development of

indigenous INS systems with improved performance, reduced dependence on foreign suppliers, and enhanced operational security is the way forward. The Naval Air Arm encourages R&D agencies and industry partners to develop an indigenous INS system by leveraging cutting-edge technologies, such as RLGs and micro-electro-mechanical systems.

13. **Glass Cockpit**. Advanced glass cockpit on naval aircraft have revolutionised the way pilots interact with their aircraft, enhancing safety, efficiency, and mission effectiveness. Glass cockpits replace the traditional analog instruments with digital displays, providing a highly intuitive and customisable interface that streamlines critical flight information. High-resolution liquid crystal displays, head-up displays, and helmet-mounted displays enable pilots to access vital data, such as navigation, engine performance, and tactical information, at a glance. These advanced avionics suite reduces pilot workload, enhances situational awareness, and enables more effective decision-making, ultimately improving the overall combat readiness and effectiveness of the naval aircraft. All existing naval aircraft fleet are being upgraded with glass cockpit and this is a mandatory QR for future inductions.

14. **Reconfigurable Cockpit**. To meet training requirement and effective utilisation of platform, Indian Navy also plans to have reconfigurable cockpit for all future inductions. The same aircraft will be utilised in both operational and training role with reconfigurable cockpit.

15. **Advanced Undercarriage Systems**. Naval aircraft undercarriage systems are designed to withstand the rigorous demands of carrier-based operations, featuring robust and reliable designs that ensure safe and successful take-offs and arrested landings. Advanced undercarriage systems incorporate cutting-edge materials and technologies, such as titanium alloys, composite materials, and advanced hydraulic systems, to minimize weight while maximizing strength and durability. Additionally, modern undercarriage systems often feature advanced monitoring and health management systems, enabling real-time tracking of system performance and predictive

maintenance to reduce downtime and increase overall fleet readiness. The naval aircraft fleet is planned to be equipped with indigenous advanced undercarriage systems.

16. **AI based Data Analysis System**. Artificial Intelligence (AI)-based data analysis systems has transformed the way critical data is collected, analysed, and utilised to enhance operational efficiency and effectiveness. These advanced systems leverage machine learning algorithms and big data analytics to process vast amounts of data from various sensors onboard the aircraft, such as ISAR data from radar and RFPS data from EW system. Integration of such solutions for existing platforms is being pursued. Future sensors are planned to have this feature integrated.

17. **AI Based Maintenance**. Introduction of AI in aircraft maintenance would bring in predictive capability. By applying AI-driven insights, naval aircraft maintainers can identify trends, detect anomalies, and predict potential maintenance requirements, enabling proactive decision-making and reducing downtime.

18. **AI Based Supply Chain Management**. This aids in better management of air logistics functions. Various projects in this field are being pursued through the iDEX scheme.

19. **Additive Manufacturing of Aviation Components**. Additive manufacturing utilising 3D printing is being explored to bring solutions in aircraft component manufacturing and wean away dependency on foreign suppliers, especially for aircraft of foreign origin. The Indian Navy in collaboration with IIT Madras has progressed repair and manufacturing of some components for MiG 29K as a step towards in-country capability in addtive manufacturing.

20. **Materials**. Low observability or stealth is one of the critical features of an aircraft to achieve operational advantage over an adversary in terms of radar detection range. Stealth can be achieved by design features, as well as, by using advanced radar absorbent materials for the aircraft skin. Also, advanced laser absorbent material can be used as aircraft skin as an effective counter measure

against the DEW systems. Stealth being a mandatory QR for all future naval aviation platforms, as well as, requirement to enhance stealth quotient of in-service platforms, indigenous development of these materials is the need of the hour, both by R&D agencies and industry partners.

<u>Conclusion</u>

21. Indigenisation of aircraft systems for naval aircraft is a strategic imperative for the Indian Navy, enabling the force to enhance its operational independence, reduce foreign dependence, and foster domestic aerospace capabilities. Through concerted efforts by Indian defence research organisations, industries, and academia, significant progress has been made in developing indigenous aircraft systems. The Naval Air Arm is steadfast to modernise through harnessing indigenous technological revolution.

CHAPTER - IX

FLIGHT TESTING IN INDIAN NAVY: CHALLENGING THE LIMIT

Introduction

1. Rapid technological advancement and absolute criticality of upgrading combat capabilities of aviation assets necessitates a dedicated and robust infrastructure for flight testing. Flight testing serves as the foundation of safe and reliable operational deployment of new platforms, systems, and technologies in naval aviation. From the primary role of undertaking Ship Helicopter Operating Limits (SHOL) trials and the occasional Field Evaluation Trials (FET) of new induction naval aircraft, Flight Testing in IN has grown in leaps and bounds, to cover a vast expanse of prototype aircraft testing, integration, and testing of sophisticated weapons, systems, as well as, complete integration of the air wing on an aircraft carrier. The expanse, therefore, makes it imperative that the Naval Air Arm maintains a potent, versatile and integrated flight-testing ecosystem capable of ensuring the successful integration of new systems throughout their lifecycle, right from conception to operational induction. This chapter explores the evolution, current scope, and future vision of Indian Naval Flight Testing.

Evolution of Flight Testing in the Indian Navy

2. Initially, flight testing was limited to SHOL trials, but gradually the necessity and hence the sphere of influence grew by leaps and bounds which led to the commissioning of the Naval Flight Test Squadron (NFTS) on 01 Jul 2017. Formation of NFTS marked a critical step in formalizing and institutionalizing flight testing in the Indian Navy.

Current Scope of Flight Testing

3. Over the years, NFTS has evolved to cover the flight-testing requirements of the complete IN inventory of aircraft. As the Indian Navy seeks to expand and modernize its fleet with new-generation aircraft and cutting-edge technologies, NFTS and the co-existing Flight Test eco-system continues to play a vital role in testing and integration of these systems. The broad scope of flight testing being undertaken by NFTS includes: -

(a) **CONOPS and Conceptualisation of Requirements**. While not a direct scope of flight testing, IN has instutionalised the procedure of CONOPS development and feasibility study for a future system. NFTS is a crucial stakeholder in this critical step which enables IN program definitions to be role-related, future ready and yet grounded in reality so as to meet the induction timelines.

(b) **Hand-Holding the D&D Process**. IN gives utmost importance to handholding the D&D process. Undertaken by NFTS as an integral part of the development-integration-testing-induction process, this handholding has afforded rich benefits to IN and the development agencies, especially the start-ups.

(c) **Prototype Aircraft**. IN is at the cusp of rapid expansion and modernization of aviation assets. Multiple prototype aircraft are planned to be inducted within the next decade in all streams which are under design and development currently. The Utility Helicopter -Maritime, Deck Based Multi-Role Helicopter, Twin Engine Deck Based Fighter, Medium Range Maritime Reconnaissance aircraft, Medium Altitude Long Endurance UAV, High Altitude Pseudo Satellite are the major prototype programs under progress.

(d) **Carrier Compatibility Testing (CCT)**. IN presently operates two aircraft carriers and ensuring integration of both helicopter & fighter wing with the carriers is one of the key responsibilities of NFTS. It includes, assessment of Ski Jump launch performance, Wind on Deck (WoD) Optimisation, Launch & Recovery Envelope Expansion and Arresting gear recovery performance in all newly integrated store configurations of each individual aircraft. CCT also encompasses proving of new weapons and sensors for deck-borne operations. In the near future, IN would commence CCT of deck based fixed wing UAVs as well.

(e) **Ship Helicopter Operating Limitations (SHOL)**. Naval aviation is primarily ship-centric. Hence, Dynamic Interphase and integration of helicopters with all ships forms a major share in the flight test role of IN. SHOL trials include day, night, NVG assisted, emergency envelope, armament role, hangarage/ traversing, VERTREP and Helo In-Flight Refuelling (HIFR). This also could be undertaken on simulators with induction of advanced simulators.

(f) **Performance Testing**. Undertaking performance testing to ascertain range and endurance speeds, payload capacity, range and endurance in deck configurations in addition to configurations cleared for ashore operations also forms an essential part of testing undertaken by NFTS. It also includes evaluation of system performance in extreme marine conditions of high humidity and salinity. Performance testing forms a critical part of any integration trials to assess the effect of fitment of a new system on an existing aircraft.

(g) **Handling Qualities Testing**. Handling qualities testing includes but is not limited to assessment of Handling Qualities during launch and recovery from deck, owing to limited runway, dynamic ship motion (roll, pitch, yaw and heave) and limited visual references especially during dark night operations. Handling qualities assessment, also forms a critical part of integration trials of any new weapon or system towards assessing the effect of carriage of new external store/ system which includes asymmetric carriage of stores.

(h) **Integration of Avionics Systems and Sensors**. Testing of radars, sonobuoys, Electro-Optical sensors, Laser, communication radio, Data Link Systems and Electronic Warfare (EW) suite including Radar Warning Receiver (RWR), Jammer & Missile Approach Warning System (MAWS).

(j) **Weapon Integration**. Integration of Air-to-Air missiles including Beyond Visual Range (BVR) missiles and Passive homing missiles, Air-to-Surface missiles, Anti-Ship missiles, conventional & smart bombs, Torpedoes, Rockets, Gun and Drone swarms. This should be done by dedicated training.

(k) **UAV Testing**. Uncrewed Aerial Vehicles (UAV) have become an integral part of modern naval warfare, offering enhanced surveillance, reconnaissance and strike capabilities. Testing UAVs by NFTS is critical to ensure their compatibility for deck borne operations, reliability, performance and interoperability in the challenging maritime environment.

(l) **Testing of Deck Borne Systems**. In addition to airborne systems, the scope of flight testing includes ground systems fitted on airfields and on deck like helicopter traversing systems, aircraft approach aids, two-way data links, aviation facilities on deck such as starting supply, arrestor gear and deck lighting systems.

Future of Flight Testing in the Indian Navy

4. The future of Naval Flight Testing lies in creating a robust self-reliant cutting-edge ecosystem to support the entire lifecycle from Research & Development to integration of system or store on the airborne platform. Towards meeting the full spectrum of flight-testing demands, the existing eco system is required to be bolstered with state of the art flight testing infrastructure as elaborated below:-

(a) **Enhanced Testing Facilities**. Few necessary facilities that will be critical to meet the need of future systems are as follows:-

(i) State of the art testing facilities including advanced 3D motion simulators, instrumentation & telemetry along with mobile installation for ship deck integration trials, computational fluid dynamics lab and real time data analysis.

(ii) Development of a dedicated radar range with corner reflectors for testing of Air to Ground radar.

(iii) Development of ground targets with different contrast ratios for testing of electro-optical (EO) devices and targets with the ability to achieve temperature differential for testing of infrared (IR) devices.

(iv) Development of weapon ranges with integrated radars for concrete prediction of circular error probable (CEP) during weapons testing.

(v) Development of an instrumentation lab for testing of night vision goggles (NVG).

(vi) Development of an instrumentation lab with modern flight controls model designed on Simulink, which is a MATLAB based graphical programming for modelling, simulation and analysing multidomain dynamic systems. The design model will provide understanding of various nuances of feedback based modern flight control systems.

(vii) Development of ADS-33 site for handling qualities testing of helicopters.

(viii) Development of an anechoic chamber and associated systems for EMI/ EMC checks of naval aircraft.

(b) **Focus on Emerging UAV Technologies**. Indian Navy is gradually moving towards relying on uncrewed aerial vehicles (UAV) for a variety of roles. The future of naval flight testing will increasingly focus on autonomous platforms including autonomous swarm drones, unmanned combat aerial vehicles (UCAVs), drone swarm technologies, HAPS and autonomous refuelling systems. Additionally, all future aircraft would gradually tilt towards optionally manned and hence, would require flight testing for both, manned and unmanned operations parallelly.

(c) **Advanced Data Analytics and AI Based Systems**. There is a need for integration of AI and ML systems to analyse test data, predict performance, and optimise flight test strategies will be critical in the years to come. Real-time data analytics will help detect performance anomalies earlier, providing valuable insights for improvements in both hardware and software for further testing.

(d) **Indigenous Capability Development**. Collaboration with start-ups and academia for development of indigenous systems is another task of NFTS. It is aimed at fostering self-reliant research, development, testing and integration of systems and technologies.

(e) **Womb-to-Tomb Lifecycle Testing**. To maximise the efficiency and readiness of new systems, a womb-to-tomb approach for end-to-end flight testing is essential. This comprehensive lifecycle model will span from concept validation, initial design, prototype developmental testing, operational testing, midlife upgrades, maintenance, and eventual decommissioning. By integrating all stages of a system's life into a single, coordinated flight testing ecosystem, the Navy will ensure consistent performance, reduced downtimes, and quicker adaptation to new operational needs.

(f) **Collaborative Ecosystem within India**. Increased collaboration with defence OEMs, the Defence Research and

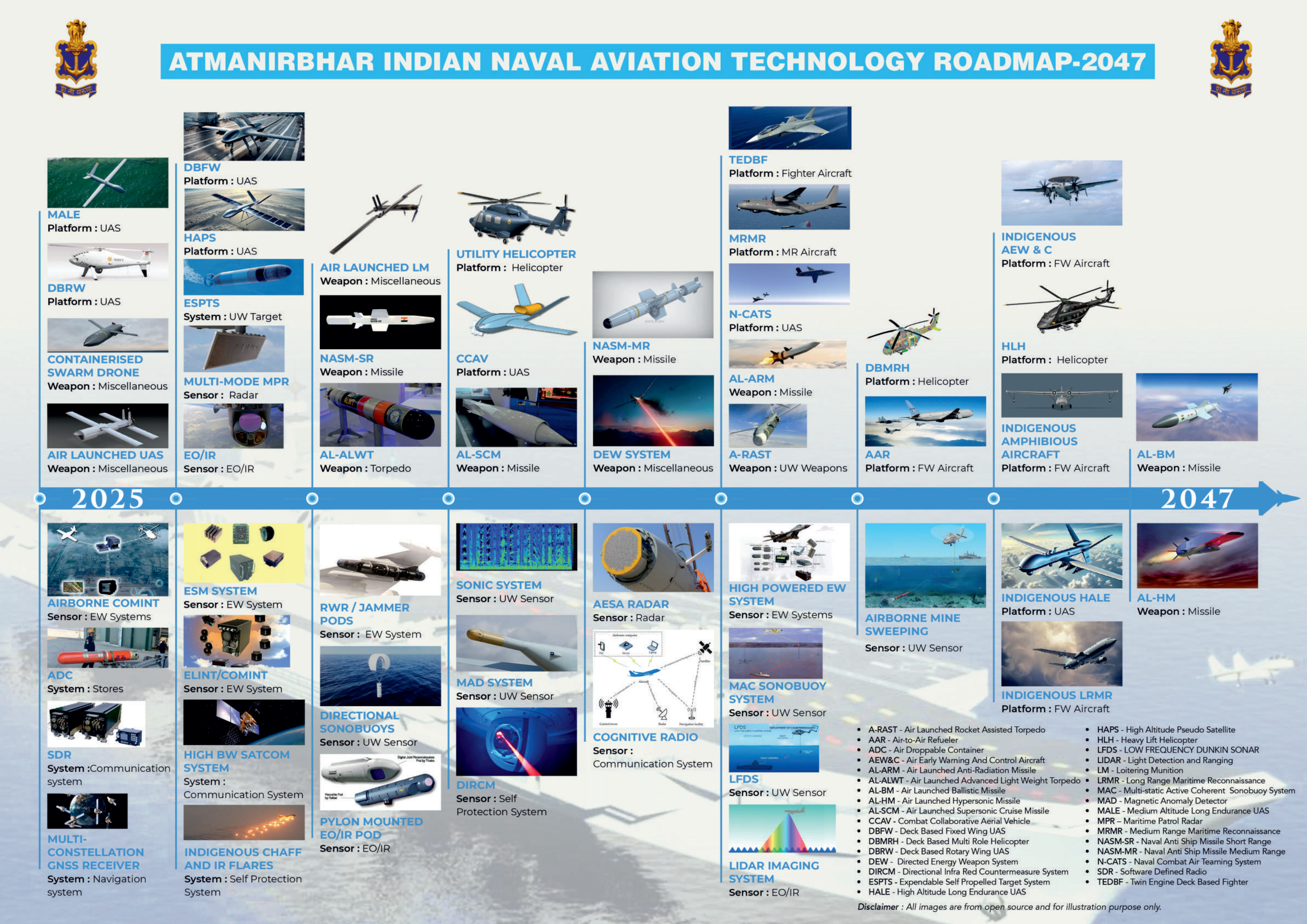
Development Organisation (DRDO), and academia would be critical for advancement in flight testing. The pooling of knowledge, resources, and test data will ensure faster and more effective development cycles.

(g) **Global Collaboration**. Hosting flight test seminars, Qualitative Evaluation (QE) sorties and joint testing exercises with Testing Organisations, in-country, as well as, across the world would result in enhancing capability by knowledge sharing. It would aim at establishing NFTS as a part of the national and global hub for naval aviation testing.

(h) **Centralised Repository**. Creating a centralised digital flight-testing repository of all flight testing would be critical for streamlining, storing and analysing flight test data for future integrations. This system would serve as a single, secure platform, for managing all flight test data for ensuring data availability for operational, developmental and training purposes.

Conclusion

5. Naval flight testing is an indispensable pillar of the Indian Navy's efforts towards achieving supremacy in modern warfare and towards achieving *Atma Nirbharta*. With emerging technologies and increasingly complex airborne systems, there is a need to continue evolving flight-testing infrastructure to meet the new challenges. By consolidating resources, embracing cutting-edge technologies, and ensuring a coordinated lifecycle approach to testing, the Indian Navy will maintain its edge in the domain of maritime air power.



ATMANIRBHAR INDIAN NAVAL AVIATION TECHNOLOGY ROADMAP-2047
2025
2047
MALE
Platform : UAS
DBRW
Platform : UAS
CONTAINERISED SWARM DRONE
Weapon : Miscellaneous
AIR LAUNCHED UAS
Weapon : Miscellaneous
DBFW
Platform : UAS
HAPS
Platform : UAS
ESPTS
System : UW Target
MULTI-MODE MPR
Sensor : Radar
EO/IR
Sensor : EO/IR
AIR LAUNCHED LM
Weapon : Miscellaneous
NASM-SR
Weapon : Missile
AL-ALWT
Weapon : Torpedo
UTILITY HELICOPTER
Platform : Helicopter
CCAV
Platform : UAS
AL-SCM
Weapon : Missile
NASM-MR
Weapon : Missile
DEW SYSTEM
Weapon : Miscellaneous
TEDBF
Platform : Fighter Aircraft
MRMR
Platform : MR Aircraft
N-CATS
Platform : UAS
AL-ARM
Weapon : Missile
A-RAST
Weapon : UW Weapons
DBMRH
Platform : Helicopter
AAR
Platform : FW Aircraft
INDIGENOUS AEW & C
Platform : FW Aircraft
HLH
Platform : Helicopter
INDIGENOUS AMPHIBIOUS AIRCRAFT
Platform : FW Aircraft
AL-BM
Weapon : Missile
AIRBORNE COMINT
Sensor : EW Systems
ADC
System : Stores
SDR
System :Communication system
MULTI-CONSTELLATION GNSS RECEIVER
System : Navigation system
ESM SYSTEM
Sensor : EW System
ELINT/COMINT
Sensor : EW System
HIGH BW SATCOM SYSTEM
System : Communication System
INDIGENOUS CHAFF AND IR FLARES
System : Self Protection System
RWR / JAMMER PODS
Sensor : EW System
DIRECTIONAL SONOBUOYS
Sensor : UW Sensor
PYLON MOUNTED EO/IR POD
Sensor : EO/IR
SONIC SYSTEM
Sensor : UW Sensor
MAD SYSTEM
Sensor : UW Sensor
DIRCM
Sensor : Self Protection System
AESA RADAR
Sensor : Radar
COGNITIVE RADIO
Sensor : Communication System
HIGH POWERED EW SYSTEM
Sensor : EW Systems
MAC SONOBUOY SYSTEM
Sensor : UW Sensor
LFDS
Sensor : UW Sensor
LIDAR IMAGING SYSTEM
Sensor : EO/IR
AIRBORNE MINE SWEEPING
Sensor : UW Sensor
INDIGENOUS HALE
Platform : UAS
INDIGENOUS LRMR
Platform : FW Aircraft
AL-HM
Weapon : Missile
A-RAST - Air Launched Rocket Assisted Torpedo
AAR - Air-to-Air Refueler
ADC - Air Droppable Container
AEW&C - Air Early Warning And Control Aircraft
AL-ARM - Air Launched Anti-Radiation Missile
AL-ALWT - Air Launched Advanced Light Weight Torpedo
AL-BM - Air Launched Ballistic Missile
AL-HM - Air Launched Hypersonic Missile
AL-SCM - Air Launched Supersonic Cruise Missile
CCAV - Combat Collaborative Aerial Vehicle
DBFW - Deck Based Fixed Wing UAS
DBMRH - Deck Based Multi Role Helicopter
DBRW - Deck Based Rotary Wing UAS
DEW - Directed Energy Weapon System
DIRCM - Directional Infra Red Countermeasure System
ESPTS - Expendable Self Propelled Target System
HALE - High Altitude Long Endurance UAS
HAPS - High Altitude Pseudo Satellite
HLH - Heavy Lift Helicopter
LFDS - LOW FREQUENCY DUNKIN SONAR
LIDAR - Light Detection and Ranging
LM - Loitering Munition
LRMR - Long Range Maritime Reconnaissance
MAC - Multi-static Active Coherent Sonobuoy System
MAD - Magnetic Anomaly Detector
MALE - Medium Altitude Long Endurance UAS
MPR – Maritime Patrol Radar
MRMR - Medium Range Maritime Reconnaissance
NASM-SR - Naval Anti Ship Missile Short Range
NASM-MR - Naval Anti Ship Missile Medium Range
N-CATS - Naval Combat Air Teaming System
SDR - Software Defined Radio
TEDBF - Twin Engine Deck Based Fighter
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सत्यमेव जयते

शं नो वरुणः