MRO: THE ELEPHANT IN THE ROOM OF AIR POWER

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We often take for granted the very things that most deserve our gratitude.

— Cynthia Ozick

Aerospace power is a derivative as also an indicator of national power. The ability of a nation to use all aerospace power resources at its disposal determines its aerospace power capabilities. Aerospace power, hence, is the sum of a nation's aerospace capabilities, as is expounded in the Doctrine of the Indian Air Force (IAF) 2020-22.[1] For the application of air power, its platforms have to be available in the desired numbers, at the right time, with force levels availability sustained over a period.

While discussing the combat restorative measures in the chapter on air strategy, in the domain of the Indian Air Force the issue of techno-logistics

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1. Doctrine of The Indian Air Force, Chapter 2, "Nature of Aerospace Power and Principles of War", p. 11, https://indianairforce.nic.in/wp-content/uploads/2023/01/2MB.pdf.. Accessed on April 2024.

The air commanders must look beyond their responsibilities in existing organic capabilities, and collaborate and cooperate to be enablers in establishing the facilities in the sister Services and, more importantly, in the civil aviation sector.

has been elucidated as Aerospace power must be underpinned by sound and round-the-clock techno-logistics to ensure the highest serviceability and availability of aircraft and equipment during operations. Efficient and resilient techno-logistics ensures high sortie generation rates, shortest mission turnaround time, accelerated repairs and servicing, weapon readiness and distribution and recovery of damaged aircraft/equipment.[2]

The organic or inorganic ability of the IAF to sustain this capability is dependent on the entire eco-system supporting the air power assets.

"The strength of India's aerospace power primarily lies with the IAF. The capabilities of the air arms of the other Services, civil aviation and nations space agencies contribute to this strength."[3] Therefore, for the military air assets' sustenance, it is also important that the civil platforms' sustenance capabilities must be developed as national air power. Synergy of military-civil capabilities will enhance and provide a degree of self-sufficiency. The techno-logistics aspects of future air warfare will be crucial to success. The air commanders must look beyond their responsibilities in existing organic capabilities, and collaborate and cooperate to be enablers in establishing the facilities in the sister Services and, more importantly, in the civil aviation sector.

"Some measures that must be taken and applied to transform the IAF from a 'contemporary' to a 'future ready' force are technology enabled tools for operations, techno-logistics and administration with enough bandwidth for future accretions, including plug and play capabilities for the Indian Navy and Indian Army."[4] The Ministry of Defence (MoD) and Ministry of Civil Aviation

2. Ibid., Chapter 5, "Air Strategy", p. 68.
3. Ibid., Chapter 6, "Aerospace Power in the Indian Context", p. 75.
4. Ibid., Chapter 7, "Preparing for the Future: A Road Map", p. 84.

(MoCA) must have an organisational interface at the highest level in developing the policies for integrated sustainability of aviation platforms operating in the Indian airspace. These will then become the integrated national Maintenance Repair Overhaul (MRO) fundamental concepts in the air power sustenance to pursue national security objectives as enunciated in the air power doctrine.

It can, thus, be seen that policy-wise there is a huge traction to create an enabling environment by the MoCA for the MRO industry in India, with the goal of making India a global leader in the MRO sector.

The Indian civil aviation sector is poised to grow, with the aircraft collective orders adding up to 1,590 aircraft. These will increase in the coming years, emphasising the industry's obligation to meet the increasing air travel demand.[5] In 2019, the MoCA released a report titled Vision 2040 for the civil aviation industry in India. This policy frameworks the expansion of the sector, including an increase in the number of airports by five times, as required to manage over a billion passenger trips a year.[6] Also, Vision 2040 for the civil aviation industry was presented in the Global Aviation Summit 2019 of the Federation of Indian Chambers of Commerce and Industry (FICCI) which has envisioned the 2040 MRO industry as: "India shall be a global MRO hub, handling nearly 90% of the MRO requirements of Indian carriers. At least 20% of the Indian MRO industry's revenue shall come from foreign-registered aircraft, and nearly 90% of redelivery maintenance shall be done within India."[7] It can, thus, be seen that policy-wise there is a huge traction to create an enabling environment by the MoCA for the MRO industry in India, with the goal of making India a global leader in the MRO sector.

5. Sonu Vivek, "Indian Airlines are on a Shopping Spree. Here's Proof", *India Today*. April 26, 2024. https://www.indiatoday.in/business/story/indian-airlines-orders-indigo-air-india-akasa-airbus-boeing-2531946-2024-04-26
6. Ministry of Civil Aviation Annual Report 2018-19, https://www.civilaviation.gov.in/sites/default/files/migration/MoCA_Annual_Report_2018_19.pdf
7. Vision 2040 for the Civil Aviation Industry in India, FICCI, Global Aviation Summit 2019, January 15-16, 2019, https://ficci.in/api/study_details/23493

INDIAN CIVIL MRO

As of now, the civil aviation MRO capabilities and capacities are in the early stages of development. As a consequence, 90 percent of India's MRO is undertaken abroad, mostly in Sri Lanka, Singapore, and Malaysia. But, with the growing fleet inductions, the necessity of MRO is bound to present a very significant growth potential. The concerted effort by the Government of India to make India a regional hub for MRO services is palpable, by exploiting its geographic location between Europe and Southeast Asia and its contiguity to the Middle East which straddles the major air routes in Asia.[8]

Foreign Original Equipment Manufacturers (OEMs) are buoyant about the Indian market for their exports as well as establishing manufacturing entities because of the increasing orders for aircraft, aircraft spare parts and equipment. The unique geographic location on the air routes, combined with adequate engineering expertise and competitive labour costs, makes business sense for the OEMs to establish their facilities in India.[9] Foreign OEMs are affiliating with the Indian aerospace supply-chain and Small and Medium Enterprises (SMEs) to meet the Tier-1 requirements and also to set up an aerospace industry eco-system within the country. As the Indian civil fleet, both narrow and wide body, increases, aero-engine maintenance within India will gain importance and become a profitable segment. Economically aero-engines and airframes contribute approximatly 60-70 percent in the MRO sector by value and, hence, the markets interest in these areas.[10] The government has taken steps for the reduction of goods and services tax from 18 to 5 percent for the MRO sector and is now engaged in developing high-precision manufacturing capabilities to give an impetus to this sector.[11]

8. India - Country Commercial Guide, Aerospace and Defense, International Trade Administration (ITA) USA, Published date: 2024-01-12. https://www.trade.gov/country-commercial-guides/india-aerospace-and-defense
9. Ibid.
10. Ibid.
11. Ibid.

INDIAN MILITARY MRO

Indian military MRO is organic in the various Base Repair Depots (BRDs) for all the foreign sourced aircraft. However, for Hindustan Aeronautics Limited (HAL) licensed manufactured aircraft, HAL is the MRO service provider. In special aerial platforms sourced through the Foreign Military Sales (FMS) route from the USA, the OEMs are the MRO service agency. The Indian Army and Indian Navy are similarly dependent on HAL/OEMs for their MRO requirements. On the other hand, MRO of the civil aviation fleet is undertaken by the OEM-authorised third party vendors that are approved by the Directorate General of Civil Aviation (DGCA) . Air India is the only airline which has a resident capability of undertaking MRO approved by the DGCA and OEMs.[12]

A few private firms in India have developed the military MRO requirements' capability and expertise developed through the ancillaries of aviation manufacture or civil aviation MRO providers. The regulatory challenges and complexities in military MRO activities have to be understood by the private industry venturing into the military MRO domain. To utilise these capabilities, specific MRO activities have been partly tasked, or completely outsourced, to a few firms by the BRDs.[13] These have been encouraging moves in the military-civil MRO cooperation and collaboration.

The IAF's resident MRO capacities and capabilities have been generally OEM driven with their supply chain as the backbone. However, indigenisation and innovations have been undertaken through local industry to address obsolescence and supply chain disruptions.[14] On May 15, 2020, while announcing actions to encourage India's domestic aviation sector, Finance Minister Nirmala Sitharaman had said that steps will be taken to make the country a hub for MRO of aircraft. "Not just civil aircraft but defence aircraft

12. Air Vice Marshal Samir Borade VSM (Retd), "Intricacies of Military Aircraft Maintenance Repair and Overhaul: Challenges and Opportunities for Industry", Chanakya Forum Security, October 7, 2022, https://chanakyaforum.com/intricacies-of-military-aircraft-maintenance-repair-and-overhaul-challenges-and-opportunities-for-industry/
13. Ibid.
14. AVM Sharad Kumar Jain VSM (Retd), "Indigenisation: Vibrant Maintenance Structure In IAF", *Indian Aerospace & Defence Bulletin*, Defence, October 16, 2022, https://www.iadb.in/2022/10/16/indigenisation-vibrant-maintenance-structure-in-iaf/.

can also benefit from the MRO if we make India a huge hub ... Maintenance cost for all airlines will come down and that again will have a ripple effect on passengers. Travellers can probably pay less after that," she said.[15] With the tax policy changes, India's MRO industry has, for the first time, seen light at the end of the tunnel. However, even after four years, the progress is not what was expected. Significant Capital Expenditure (CAPEX), coupled with additional policy alignment, is still required.

MRO GROWTH TRAJECTORY

At present, the MRO industry in India is assessed to be worth around $700-800 million, which is projected to grow over the next decade at 7.7 percent annually. This is three times in excess of the global rate. This is due to the fleet growing at 9.9 percent annually, to an estimated fleet of over 2,300 in Financial Year (FY) 2040. Despite an increasing need for the MRO industry, it continues to struggle for relevance. There are about 40 overseas entities approved by the DGCA to conduct MRO on India-registered aircraft which accounts for over 90 percent of the MRO of the Indian carriers.[16] India, therefore, needs to build a robust domestic MRO eco-system.

It is not easy to expect the Indian carriers to move away from their well-established MRO service providers outside India. This needs perseverance, involving a continuous dialogue among the central and interested state governments, DGCA, airlines, OEMs and the MRO industry. Airlines in India typically spend about 12-15 per cent of their revenues towards maintenance, which is the second highest cost item after fuel. Nearly 60 percent of the MRO expense is on engine and component repairs, which India needs to focus on.[17]

Due to the predominance of the sale-and-lease-back model among the Indian airlines, the redelivery maintenance is a major part of an airline's and lessor's MRO requirements. This offers an excellent opportunity to establish component repair and heavy maintenance in India itself. Currently, this is

15. "Aviation Sector: Centre to Take Steps to Make India MRO Hub", *PTI,* New Delhi, *The Hindu Business Line*, May 16, 2020, https://www.thehindubusinessline.com/news/aviation-sector-centre-to-take-steps-to-make-india-mro-hub/article31602062.ece
16. n.7.
17. Ibid.

mostly done abroad, due to various legal and technical reasons.[18] With the leasing infrastructure being established in India, these MRO domains can now be leveraged with the aircraft OEMs to set up such facilities within India.

With the *mantra* of 'Vocal for Local' in the year 2020, the government pushed for the components manufacturing by the Small and Medium Enterprises (SMEs) and Micro, Small and Medium Enterprises (MSMEs) for almost all sectors to boost the country's manufacturing capabilities.[19] It was a welcome step to give confidence to the industry to participate in Indigenously Design, Develop and Manufacture (IDDM) in the aviation industry as well. Now, with more clarity on the embargo of restricted defence items from import, the industry can focus on specific products' development.[20] This will also allow suppliers to participate with OEMs in development and growth.

MILITARY MRO SALIENCE

MRO in defence aviation has been traditionally resident within the organisation. All the earlier IAF bases had some deep level workshops to repair the aircraft operating from that base. The Indian military aviation MRO is now primarily based in BRDs and the associated eco-system of local vendors. Aviation MRO in general is associated with line maintenance, airframe heavy maintenance and modification, engine overhaul, and components and accessories overhaul. The line maintenance is undertaken by the operator or a third party, however, the other segments which are specialised and capital intensive, and based on higher skilled domains, are undertaken by separate specialised vendors. The rigorous airworthiness and flight safety aspects are ensured by regulatory agencies like the Centre for Military Airworthiness and Certification (CEMILAC), and DGCA in India.

18. Ibid.
19. Sreeshti Singh, "Vocal for Local: How Indian Companies can Leverage This", Linkedin, https://www.linkedin.com/pulse/vocal-local-how-indian-companies-can-leverage-sreeshti-singh.
20. "Ten Industrial Sectors Empowered by PM Modi's 'Vocal for Local'", Kartavyapath Blogs. Published March 28, 2024, https://www.kartavyablogs.in/ten-industrial-sectors-empowered-by-pm-modis-vocal-for-local-call/.

The battle damage repairs capability must be integral in MRO to recover the modern high-tech expensive aircraft in the least time for re-employment in operations.

The foreign OEMs are mandated by the European Union Aviation Safety Agency (EASA) or Federal Aviation Administration (FAA) regulations which have also to be followed by the aircraft operators. Military MRO furthermore caters for the internal fleet life extensions studies and reliability improvement programmes. Also, keeping abreast of technology to counter the adversary capabilities and operational modifications is an inescapable constituent of military MRO.[21]

As discussed earlier, the combined civil and military MRO is a national air power asset needed to sustain the combat potential of air power. The military MRO has to ensure that daily aircraft availability requirements, along with surge requirements during operations are catered for to maintain and support the frontline squadrons. The battle damage repairs capability must be integral in MRO to recover the modern high-tech expensive aircraft in the least time for re-employment in operations. The MRO facility must be able to undertake rapid operational upgrades in avionics and weapon systems to be a potent threat to the adversary. The civil MRO business models must be harmonised with the military aviation linkages and the military MRO needs to be ready to utilise them, and also open their facilities for utilisation by civil MRO segments as well.[22] Mutual trust and understanding need to be developed and nurtured by the military commanders at all levels of the maintenance chain.

Civil MRO is non-existent for the Russian transport and helicopters which are purely in the military MRO domain comprising resident facilities at the platform-centric BRDs. The aging AN-32 fleet will be replaced in the near future. The lower initial cost of the Russian platforms, combined with the large numbers required will make economic sense for a Russian

21. Air Marshal Sukhchain Singh (Retd), "Synergy in Military and Civil MRO", SP's *Aviation*, issue 11-2017, https://www.sps-aviation.com/story/?id=2157&h=Synergy-in-Military-and-Civil-MRO.
22. Ibid.

transport aircraft being considered. This will open an opportunity for the Russian MRO and, hence, a good opportunity for investment in India as an independent private facility or a public-private partnership with the concerned BRD.

The sustained availability of war-fighters for operations has been a concern for the IAF and has now become of crucial importance due to the intense pressures on the defence budget. In real value terms, the decreasing revenue procurement budget requires the utmost in efficiency from the IAF MRO structures to offset the dwindling numbers of operational squadrons, and the delays in the new induction of aircraft. From the MoD's perspective, while the demand for higher allocations is genuine, the IAF must utilise the available resources efficiently to address the fleet serviceability.[23] The IAF and MoD must, therefore, look inward and find lasting solutions to procurement impediments so crucial in providing MRO.

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OUTCOME-CENTRIC LOGISTICS

Procurement of spares in the IAF is based on the consumption pattern model, corrected by the forecast factor, which depends on the projected utilisation of the war platform. The Maximum Potential of Establishment (MPE) is defined by the stocks in hand, plus those in contract, and those indented. This potential cannot exceed 5/3 years' holding, depending on the foreign/Indian vendors. This review of procurement is done annually and processed for contracts through the delegated financial powers of the Air Headquarters (HQ) Air Officer Maintenance (AOM) or the MoD. If these reviews are not converted to contracts every year, it is not difficult

23. Air Marshal Sukhchain Singh (Retd), "Linking Revenue with Desired Serviceability of IAF Fighters", *SP's Aviation*, issue 03-2018, https://www.sps-aviation.com/story/?id=2197&h=Linking-revenue-with-desired-serviceability-of-IAF-fighters

to see that it will adversely affect the sustainability of the fleet which is the basic aim of MRO.[24]

There is always a serious contention on the spares so projected vis-a vis the revenue budgetary allocations and, therefore, some sort of prioritisation has to take place at Air HQ, which results in sub-optimal acceptance of the spares package, affecting the sustainability figures. Fleet-wise revenue spending versus serviceability achieved on a year-on-year basis should have been the yardstick to measure the efficacy of the procurement process.[25] This has not been considered, which results in critical the Aircraft On Ground (AOG) and adversely affects the serviceability numbers for nearly all the IAF fleets.

PROVISIONING CHALLENGES

The IAF and the defence forces at large need to look at spares procurement models which are availability outcome-centric, and also optimally catering for operational surge requirement buffers. Firstly, by revamping the enshrined IAF provisioning and procurement system and linking it with the achievable or desired serviceability of the war platform. Secondly, looking at the Performance-Based Logistics (PBL) with the Indian or OEM vendors more aggressively to meet the desired operational availability at the optimum cost. These require a deeper analysis by the Services and MoD to suit the different fleets.

Supply chain managers have to balance between buying fewer spare parts and avoiding an idle inventory or procuring too many spares and wasting valuable resources. The METRIC (Multi-Echelon Technique for Recoverable Item Control) inventory optimisation comprises algorithms that evaluate supply requirements to support a desired availability target across the repair echelons. These targets are either detailed in the maintenance contracts or internally determined. METRIC can apply Service level targets specified as aircraft availability, fill rates, allowable back orders, back order rates, etc.

24. Ibid.
25. Ibid.

Fleet availability, the probability that an aircraft is airworthy at any point in time, is a common optimisation criterion. METRIC calculates the spares stocking levels and fill rates to achieve the desired fleet availability, also ensuring that the overall supply and repair costs are minimised.[26]

The ASM (Aircraft Sustainability Model) model by the Logistics Management Institute (LMI) of the USA is an example of this approach. This systems methodology for determining the spares inventories at various repair echelons has been implemented, in varying degrees, by the US military Services and has been the official Department of Defence (DoD) policy since 1985.[27] A student project to evaluate this model was undertaken by the College of Defence Management (CDM) during 2014-15 on the PC-7 trainer. This model needs to be seriously evaluated as a policy by the IAF.

PERFORMANCE-BASED LOGISTICS (PBL)

Civil airlines and military aviation globally are improving their management of the spare inventory by practices that reduce the size and cost of the spare parts inventory and shift more of the risk to outside parties. With '*Atmanirbhar'* and 'Make in India', the MoD/IAF prefers the fleet sustainment to be within the Service or by local indigenous industry. The push has been for the OEMs to work with local industry in establishing maintenance capabilities to quickly support the fleets in the country rather than relying on international sources that could delay availability for an aircraft. This policy needs to be leveraged by the Government of India not only for the defence MRO but aggressively pursued by the civil MRO as well.

The acquisition of aircraft and their sustainment are not separate but simultaneous and integrative, requiring analysis and synthesis throughout the products' life-cycle. The principle of PBL is buying performance, instead of the conventional approach of buying individual parts or repair actions.

26. CC Sherbrooke, "Metric: A Multi-Echelon Technique for Recoverable Item Control", RAND Corporation, https://www.rand.org/content/dam/rand/pubs/research_memoranda/2006/RM5078.pdf.
27. Aircraft Sustainability Model (ASM®) Sparing Model, Logistics Management Institute (LMI) Website. https://www.lmi.org/capabilities/solutions/asm#:~:text=The%20Aircraft%20Sustainability%20Model%20(ASM,leader%20in%20computing%20spares%20requirements.

A meticulous process to support the supply chain of the war platform is imperative and it is crucial to have an integrated Information Technology (IT) infrastructure to support it. The SAP *(System Analyse und Programmentwicklung*—literally System Analysis and Software Development) have developed cutting-edge solutions to successfully support the implementation of PBL in the aerospace and defence market. The level of accountability for on-time delivery, Mean Time Between Failure (MTBF), Mean Time Between Removal (MTBR), Production Lead Time (PLT) and Inventory Turnover Rate (ITR) have to the monitored for the performance of the contract. The ASM model based on METRIC and similar models needs to be tailored for the Indian environment which will be required for the PBL contractor.

The PBL strategy has to be customised to suit the operational and support requirements of the platform. The PBL for a tactical fighter aircraft may be very different from the PBL strategy for an army ground combat system. The institutionalisation of Public-Private Partnership (PPP) should be encouraged in order to facilitate the understanding between the military and the manufacturers when it comes to service support to achieve performance. In order to be successful in implementing PBL, such bench-marking and improvement processes need to become habits for an organisation rather than ad-hoc actions. This has relevance specially for the HAL-based MRO for the *Atmanirbhar* war-fighters.

ATMANIRBHAR DIGITAL TWINS

In the aerospace industry, MRO costs continue to rise despite aircraft being more reliable and with better maintainability. A paradigm shift in maintenance is the use of the digital twins' eco-system. This is a revolutionary high-fidelity simulation software which comprises the sensor and measurement technologies, simulation and physical modelling, industrial Internet of Things (IoT), Artificial Intelligence (AI), and Machine Learning (ML). Determining which type of maintenance is required during a limited timeframe for task execution has always been a major challenge for the

airline industry. Now aviation maintenance software solutions make aircraft maintenance management easy with the digital twins software integration, reducing the downtime of putting the aircraft back into operational use. The digital twins in the future will be developed for every manufactured platform, which will generate its specific data to be captured and analysed individually. This concept is known as a 'digital triplet' and represents the evolution of the digital twins. These individual twins' real-time data using AI analysis will make real-time predictions about the platforms' life-cycle, predictive maintenance, etc.[28]

With the *Atmanirbhar Bharat* programme in aerospace vehicles and war-fighters, the development of digital twins needs to be seriously contemplated. The war-fighters are complex multi-role systems and very expensive to develop, build and maintain. They will, therefore, be built in fewer numbers to meet the strategic and operational requirements of the Service.[29] Thus, it becomes imperative that the commander has the optimum utilisation and assured availability in their deployment. The digital twins need to be embedded in the concept and design phase itself to derive the best results. The technology and skills are available in India and need to be integrated for the development of the twins.

QUALITY ISSUES

The MRO industry is dependent on the skills of the human resource to maintain the complex aerospace systems. The existing training institutions in India need to be improved and regulated to global standards. The domestic MRO companies must be persuaded to seek global accreditations and certifications. This is because most of the aircraft are leased from European or American companies and it becomes imperative for the Indian MRO to comply with the FAA or EASA certifications.[30]

28. Sukhchain Singh, "Digital Twins in Aerospace – A Paradigm Shift", *SP's Airbuz,* issue 1-2021, https://www.spsairbuz.com/story/?id=1119&h=Digital-Twins-in-Aerospace-A-Paradigm-Shift
29. Ibid.
30. Sukhchain Singh, "Ensuring Quality in Aviation MRO", *SP's Airbuz,* issue 3-2019. https://www.spsairbuz.com/story/?id=919&h=Ensuring-Quality-in-Aviation-MRO#:~:text=The%20

The digitisation of MRO processes on and off aircraft, called the digital MRO market, is now enhancing efficiency and reducing aircraft downtime.

Engine and landing gear MROs are really complex, sophisticated and very expensive. They have their own large facilities and often have production lines very similar to those of factories. Engine and landing gear MROs also need very skilled and highly trained workers to perform the required work, and also often have their own Non-Destructive Testing (NDT) personnel. Component MROs have to be certified like all the other types, but, in many cases, the type of maintenance they provide does not require as sophisticated an approach as that of the engine or landing gear MROs.[31] The MRO market is shifting from the West to East but is being dominated by OEM monopolies. This could be partly addressed by regulators granting more widespread Parts Manufacturer Approval (PMA), opening up the spares market beyond the OEMs and getting rid of unnecessary regulatory burdens in the MRO sphere.[32] India can leverage the large scale purchase of civil aircraft towards this aspect with Boeing and Airbus.

MRO INNOVATIONS IN CIVIL AVIATION

Artificial intelligence, digital twins, augmented reality, blockchain, additive manufacturing, cloud computing, real-time monitoring of aircraft condition and predictive maintenance are the technologies which are being used to accomplish MRO with the reduced budgets of airlines. The digitisation of MRO processes on and off aircraft, called the digital MRO market, is now enhancing efficiency and reducing aircraft downtime. According to a global newswire report, the digital MRO market is projected to grow to US$ 4.7 billion by 2030. However, such inventions will necessitate changes in the industry culture and among the safety regulators.[33]

process%20includes%20overhaul%2C%20inspection,regulated%20to%20ensure%20safe%20operations.

31. Ibid.
32. Ibid.
33. "Innovation in MRO", NLR, Royal Netherlands Aerospace Centre, https://www.nlr.org/wp-content/uploads/2019/10/Innovation-in-MRO.pdf.

Blockchain: MRO players produce data which must be kept secure and tamper-proof. Blockchain technology aids this process by allowing the data to be accessed only by those with a unique key. The groups can keep track of mechanical parts, leases, inventory, digital twinning, supply chain, repairs, etc., through the blockchain. Airline companies are yet to fully implement this technology in the aviation industry.[34] This will gain acceptance for MRO as more use cases and regulatory trust is conceded by the environment.

Additive manufacturing enables the industry to print substantial, durable and lightweight replacement parts that are quick and affordable, and reduce the cost for maintenance providers.

Augmented and Virtual Reality (AR/VR): In today's world, AR is experienced through glasses or eyewear, which can provide additional data to the viewer about what they are seeing. MRO professionals are being trained with AR in aircraft maintenance, to visualise virtual 3D models of aeroplanes that MRO teams will be repairing, thus, eliminating the need for expensive physical props. Additionally, the entire repair team can view the same model which will facilitate teamwork.[35] This technology is gaining prominence in all global training institutions and may soon be widely used in India as well for MRO.

Additive Manufacturing: This is already gaining popularity in the MRO sector. It uses Computer-Aided-Design (CAD) software or 3D object scanners to direct hardware to deposit material, layer upon layer, in precise geometric shapes. Additive manufacturing enables the industry to print substantial, durable and lightweight replacement parts that are quick and affordable, and reduce the cost for maintenance providers.[36] This technology has the potential to change the way we look at MRO.

34. Ibid.
35. Ibid.
36. Ibid.

RECOMMENDATIONS

Some excellent recommendations were made in the FICCI Global Aviation Summit, held on January 15-16, 2019, including in the MRO sector[37] and in the NITI Aayog Brief on MRO in India[38] in October 2022. They are very pertinent in today's aviation environment as well to achieve Vision 2040 for the civil aviation MRO.

In the context of national air power, the setting up of an inter-ministerial high-power task force for synergetic civil military MRO needs to be considered.[39] The military and civil both plan in silos and attempt to establish linkages for utilisation of the facilities. It is high time that the MoD and MoCA have policies for the integrated development of the *Atmanirbhar* MRO sector in India. The task force may have members from any other relevant ministry and both the CEMILAC and DGCA as regulators. It should also have representatives from the airlines, Indian OEMs, MRO providers, HAL, Indian Air Force, Navy and Army. The task force may analyse the various options and steps required to make India a global MRO hub, with a vibrant military MRO set-up, formulate joint policies that are relevant towards achieving this aim, develop a clear roadmap, and report actions and outcomes to both the defence and aviation ministers.

Like the positive indigenisation lists approved by the MoD for the armed forces to source spares from local Indian sources, it is high time that the MoCA consider controlling airlines from taking Indian aircraft abroad for repairs, except in cases where the infrastructure and technical knowhow are not established in India, after giving sufficient time to develop the MRO eco-system in India.[40] Coherence of policies in military-civil MRO will send the right signals to the industry for investment. Disturbing the present affiliations between Indian carriers and foreign MROs will not be easy. Therefore, the MRO task force may consider additional incentives like capital subsidies and interest subsidies to attract investments.

37. n.7.
38. "MRO in India, Trends, Challenges and Way Forward", NITI Aayog Brief, October 2022, https://www.niti.gov.in/sites/default/files/2022-10/MRO_Report-FINAl.pdf.
39. n.7.
40. n.38.

The MRO skill sets of both the civil and military need to be inter-deployable and also in their resident infrastructures. The skill sets need enhancement and, hence, there is a requirement for super-specialised training facilities to be established. These have to be mapped in close coordination with the Aerospace and Aviation Sector Skill Council (AASSC). [41] The consideration to relax the certification process of military aviation personnel for civil MRO needs deliberation. They have significant experience in handling complex military aircraft. A sub-study in the task force is suggested to address this issue.

The civil MRO eco-system needs to be established near large airports for it to be viable for the airlines. But many airports like Mumbai, Delhi, etc are already congested. Similarly, the military MRO bases have been established near industrial cities or close to HAL. The necessity to have the MRO facilities close to the operational areas has dictated their establishment in a few cases. The Uttar Pradesh government has been actively pursuing the setting up of an MRO hub with the Centre as a competitive domestic MRO industry, which will cater to both civil and defence aircraft. MRO in Jewar will cater to bigger aircraft, and the facility in Meerut will cater to smaller ones.[42] Kanpur houses an important BRD for Russian aircraft overhaul and Western fighter engine MRO as well as the HAL transport division. Why not consider C-295 MRO at Kanpur in Public-Private Partnership (PPP) with the IAF resident BRD? If the C-295 is civil certified for operations in India, it would be a fit project for the demonstration of military-civil MRO synergy.

The MRO facility for the A-320 aircraft family will be established by HAL, Nasik, and ready for aircraft induction by November 2024, with the required DGCA approval. In future, this Nasik facility will also be available for the entire Asian region after obtaining EASA approval, in partnership with Airbus.[43]

41. n.7.
42. Deepa Jainani, "Infra Boost, UP in Advanced Talks with Centre for Aircraft MRO Hubs in Jewar and Meerut", *Financial Express*, June 9, 2020. https://www.financialexpress.com/business/airlines-aviation-infra-boost-up-in-advanced-talks-with-centre-for-aircraft-mro-hubs-in-jewar-and-meerut-1985232/.
43. "HAL and Airbus Sign Contract for Establishing Civil MRO Facility for A-320 Family at Nashik", HAL Media Releases, November 9, 2023. https://service.hal-india.co.in/HAL%20and%20Airbus%20Sign%20Contract%20for%20Establishing%20Civil%20MRO%20Facility%20for%20

The helicopter operations are such that two to three MRO hubs are considered essential for the Indian military and civil operators catering to the northern, southern and eastern areas.

"HAL wants to establish an integrated MRO hub in the country and provide airlines with an effective MRO solution. This step by HAL is also aligned to civil-military convergence and the Make-in-India mission of the Government of India," said Saket Chaturvedi, Chief Executive Officer (CEO) (MiG Complex), HAL.[44] Why could this not be at Jewar? This needs serious introspection as a proposal to establish civil MRO is already with the Uttar Pradesh government. HAL already has its Transport Division at Kanpur, so why not consider a fighter manufacture and overhaul facility for this project?

It has been reported in the media that Dassault Aviation is looking at Jewar International Airport to establish an MRO facility for India's Mirage 2000 and Rafale fighter jets.[45] This is a welcome integrated step in the right direction and needs to be closely followed by the IAF. This is also significant since Safran SA is also building an MRO facility at Hyderabad [adjacent to its Leading Edge Aviation Propulsion (LEAP) engine plant] to undertake MRO of M88 engines of Rafale fighters with a rider of sufficient engines being in service in India.[46] Leveraging the civil MRO of engines for military engines needs to be coordinated as a policy for this project—a win-win situation for all stakeholders.

Military helicopters are being indigenously manufactured in India by HAL and have civil potential after due certifications. A huge potential for

A-320%20Family%20at%20Nashik/ND__429#:~:text=The%20MRO%20facility%20for%20the,approval%20in%20partnership%20with%20Airbus.

44. "HAL Lnks Pact with Airbus for Civil Aircraft Maintenance Facility at Nashik", *The Hindu Business Line*, November 9, 2023, https://www.thehindubusinessline.com/economy/logistics/hal-inks-pact-with-airbus-for-civil-aircraft-maintenance-facility-at-nashik/article67517280.ece.
45. Sakshi Tiwari, "France Makes Big Move To Win IAF's $20B Deal; Experts Say MRO Facility For Rafale Fighters, A Hint To India", *The EuraAsian Times*, July 4, 2024, https://www.eurasiantimes.com/france-makes-audacious-move-to-win-iafs-20/.
46. Ibid.

MRO exists and suitable partnerships need to be forged with HAL as the OEM in public-private models catering to the individual armed forces' special requirements, as well as to civil operators, which will grow over time. The helicopter operations are such that two to three MRO hubs are considered essential for the Indian military and civil operators catering to the northern, southern and eastern areas. It is necessary to synergise the civil-military helicopter MRO efforts for optimum utilisation of resources and ensuring higher availability for their deployment in operational roles. The BRD at Chandigarh, which undertakes MRO for the Russian helicopters can become a nodal hub in this. The existing eco-system of vendors needs nurturing by HAL for establishing MRO facilities of their range of helicopters at Chandigarh. Indocopters,[47] a company, based in Greater Noida, is providing MRO support for Airbus, Leonardo and Bell Textron helicopters. It is the largest MRO operator for helicopters in India, operating at Nagpur, Mumbai, Pune and New Delhi. Pawan Hans[48] is India's largest helicopter carrier and also has the `biggest' MRO set-up in Rohini, Delhi, and Juhu, Mumbai. These companies need to be taken on board for civil-military helicopter MRO synergy in India in the task force.

The existing eco-system of vendors needs nurturing by HAL for establishing MRO facilities of their range of helicopters at Chandigarh.

CONCLUSION

To ensure a coherent, comprehensive and synergist civil-military MRO as a national air power asset for *Atmanirbhar Bharat*, policies have to be formulated which give confidence to the investors and stakeholders to establish the infrastructure which is commercially viable, as well as sustainable. Pocket-wise individualistic growth and plans will not be beneficial for the MRO sector. Therefore, while the suggested task force can look into all these issues of policy formulation and implementation, it is suggested that, thereafter,

47. Indocopters Website, https://www.indocopters.com/mro.asp.
48. Pawan Hans Website, https://www.pawanhans.co.in/english/inner.aspx?status=4&menu_id=170.

a suitable inter-ministerial nodal agency[49] comprising the MoD/MoCA be established to monitor and coordinate the effort to implement the vision of synergistic civil-military MRO in the national air power potential.

49. n.38.