A Research Report on Indian Aircraft Manufacturing Industry, 2019

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1.0 Executive Summary

The Aerospace Industry in India is a strategically important sector for the country. Aerospace industry is symbol of a nation's economic prosperity and supports the country's security by augmenting defence capabilities. Deloitte (2018) in its outlook for global aerospace and defence industry stated that, India is likely to be the third largest aviation market by 2025. It is forecast to have a demand for 2300 new aircrafts in the next 20 years. Thus, there is enormous potential for collaboration and creation of joint ventures in this sector for establishing maintenance, repair, overhaul (MRO) facilities for civil and military aircraft, overhaul and maintenance of aero engines and production of avionics, components and accessories, both in civil and military aviation sectors. India is also fast emerging as a centre for engineering and design services in this sector. Over the past few years, the Indian government has taken multiple policy initiatives to enhance the self-reliance in aerospace manufacturing and procurement. Several foreign OEMs (original equipment manufacturers) are setting up bases here in strategic partnership with Indian aerospace companies for different activities involved in aerospace manufacturing value chain ranging from procuring materials, making components or LRUs (line replaceable units), MRO to whole aircraft or equipment assembly/manufacturing. However, the Indian aerospace supply base is fairly new and their level of capability is yet to be assessed on a global scale. There have been some clusters of aerospace manufacturing in the country but still country's best talent is yet to be tapped into this path-breaking and economy-building industry sector.

A comprehensive assessment of the industry's integrated capability is provided in this report. A detailed profiling of the industry is done to chart its development path towards making it world-class. The report starts with some fundamental questions - While Indian aerospace companies are good at engineering and design but do they have the capabilities to handle high-end design and development? Do these companies possess end-to-end value chain capability needed to manufacture and service equipment (aircraft/UAV)? With more business flowing in due to government initiatives, can the industry develop inimitable tier-1 or tier-2 component/LRU manufacturing or materials capabilities to play a bigger role in global aerospace industry value chain? The market trends and pressures of new entrants to the aerospace manufacturing industry, are leading the supply network to adapt and go through a reconfiguration worldwide (Jose Luna et al., 2018). India's low cost labour makes it attractive to transform the aerospace manufacturing more labour intensive than automated while ensuring global quality standards. The question is, to sustain this advantage of favourable cost structures what is the status of building/training of a consistent stream of skilled R&D personnel, skilled manufacturing/service personnel? Are all the government policy measures sufficient or they need modification? Then there is a need to understand the status of private players in the aerospace domain - are they responsible enough to build country's competitiveness or just attracted to grab the timely opportunity and expand their business? What is the level of capability in terms of technology transfer and manufacturing available in Indian aerospace-defence industry? What are the barriers in transitioning capabilities from different manufacturing sectors or defence to aerospace and vice versa? The MRO capabilities are studied: whether Indian companies are self-sufficient or need strategic partnerships to gain advantage of low cost skilled labour for commercial and defence aerospace industries. Access to modern technology needs to be evaluated for Indian aerospace manufacturing companies. The industry is badly in need to keep pace with global aerospace technology across the value chain. Thus a profiling study of the Indian aerospace industry is expected to encompass the structure of the industry (players, collaboration, value chain position, and competitiveness), the supply base, performance requirements (quality, efficiency) for global competitiveness, resources, skills/expertise availability and development, infrastructure, and technology readiness.

The study uses a combination of primary and secondary research to arrive at policy level interventions for the government. First market study databases, past research by MoD, MoCA, data

from various government, UN, OECD databases are collated and analyses to study the global status of the industry (Aerospace and Defence including MRO and UAV). Then several news databases, company databases, annual reports are explored to develop a global and national capability assessment. We carried out workshops and interviews with multiple industry experts, government experts, MRO providers, aerospace OEMs, customers (defence and civil), UAV manufacturers, policy makers, aerospace industry supply base in India to arrive at our recommendations.

The global aerospace industry is analysed to identify the opportunities for India to join the global value chain. In a market dominated by few leading OEMs as Boeing, Airbus, Lockheed, Leonardo etc., India is a latecomer or new entrant to the value chain. It is found that India is present in the $368.5 (2018 figures) billion civil and military aircraft manufacturing market not as an OEM but in the subsector (worth approximately $360b in 2018) as Tier 2/3 player. There is no value in catching up with the OEMs as in 5-10 years' time, they will be much ahead in the learning curve and technology development. Still India's only aerospace OEM, HAL can pursue opportunity in global military/commercial (light, single engine) helicopter market with its highly capable ALH, ACH, LUH, LCH models. There are few opportunities/low hanging fruits in the subsector of this industry where the entry barriers are little low and particularly industry is fragmented. For example, global aerostructure industry is worth $65 billion and going to grow to $111 billion in 5 years. Already many Indian players are present in this sector. There are also opportunities in the engine manufacturing value chain to develop capabilities. Advanced Electronics segment can be seen as an opportunity for Indian IT industry. India can think of growing their indigenous civil aerospace capabilities to serve the regional market to be thrown open by Indian government's UDAN scheme. UAV (worth $26b in 2018) and MRO industry (worth $77.5 in 2018) of India is on the verge of expansion and opportunity creation with many pro-industry government steps and action plan. This also holds opportunity to expand the industry manifold. We are noting down our recommendation for policy interventions. However from our findings, currently, the aerospace industry vendor base has no capability to design or develop their own products and only have capability to copy. We should ensure proper utilization of "Make in India" opportunity and build our own LRUs, components and materials. UAV sector is evolving very fast and the vendor base is spending lot of effort (in the form of private or startup route apart from DPSUs) in R&D and futuristic capability development. MRO industry, lack of volume is discouraging Indian supply base to invest in facilities. We adopted a SWOT analysis for the Indian aerospace manufacturing capability and come up with the following recommendations.

Indian Aerospace Manufacturing Recommendations:

1. Government to identify **crucial national projects** of national safety, security and prosperity (as AMCA, UAV Swarm) and deploy a task force to implement it in a time bound manner and use **enhanced Capital Budget** in defence to fund such projects. This will ensure "Design and Make in India" for the first time. The team should have clear objectives for national benefit and involve top industry representatives, top research establishment and armed forces with government as facilitator.
2. Building **self-reliant Tier-1** Indian supplier and a strong ecosystem should be a **priority for India's national champion of aerospace industry – HAL**. Government need to give HAL **autonomy** to develop this second line of industry. **Long term contracts and co-development** projects to be awarded to capable vendors.
    a. Find a commonality between civil and military so that vendor will get volume.
    b. Single certification for both civil and military.
    c. Consultation on common and similar components.
    d. Training of manpower in aerospace and defence aircraft production and assembly, LRU level technologies etc at HAL facilities to be absorbed by vendor base.
    e. R&D support to vendor base through state or central government incentive schemes

   f. Making the testing facilities available to vendor base or facilitate/train in certification
   g. Train in process innovation, quality systems
   h. Modifying the concept of L1 based tendering
   i. More informal relationship with supply base by giving up adversarial mindset
   j. Internal process streamlining for faster decision making
   k. More lenient approach towards private industries considering their lack of access to facilities and infrastructure
   l. Organise vendor meets where smaller tier to facilitate cross learning on manufacturing practices and capabilities
3. India can make some changes to the **current offset policy** to develop access to advanced technology. (details are in section 5)
4. Establish '**Defence Fundamental Research Fund'**. Separate sufficient funds, other than the DRDO budget, should be earmarked to encourage fundamental research in the futuristic defence and aerospace technology.
5. **Expedite** establishment of **Defence Corridors**.
6. **Formulate New Defence Procurement Procedure** to ensure easy execution. **A single window clearance is required for getting approvals**. **Common standards for civil and military procurement**. While transparency and probity need due consideration, yet the speed and flexibility of execution must be realised. Level playing field should be ensured in **terms of payments** to foreign and Indian partners. Specific guidelines or standards to be laid down in the DPP with regard to the IP being transferred in TOT arrangements. Most of the TOT arrangements are in the form of restrictive licenses with regard to the IP being transferred. In fact, management of IP rights, whether in procurement-cum-manufacturing contracts such as "Buy & Make", or public-funded R&D-cum-production contracts such as "Make" cases, or licensing of DRDO developed technologies for that matter, is still one of the relatively unaddressed areas in the DPP. Expert help should be sought for drafting such contracts.
7. **Promulgate New Production Policy for Critical parts:** A revised, improved production policy is likely to catalyse indigenous defence manufacturing and facilitate creation of a military industrial complex. This policy should identify critical technologies as **aero engine** and facilitate development of aero engine complex in a time bound manner. In order to ensure steady long-term production and meet stringent quality requirements, the aero engine industry players and academia, each responsible for a different process, may come together to form an industrial cluster. Furthermore, this will attain subsidies to lessen the burden of capital investment and establish a streamlined production process to enhance both productivity and price competitiveness. In this manner, depending on the performance of the cluster/complex India can think of building **sensor complex, avionics complex, actuator complex** as part of national aerospace manufacturing capability.
8. **Devise a new Defence Innovation Authority** to channelize fund for special loans to start-ups in the field of science and technology. This can be linked to startup India with special focus on defence and aerospace. If the project succeeds, the government will take back the loan or ask for equity in business; if it fails, the loan will not need to be repaid, thus encouraging people to venture. **Government might not choose to invest as the money invested in successful startup will add to the economy**. In the Defence Innovation Authority, there will be experts (from IIMs, IITs, banks, VCs, industry) who assess each innovation project in four aspects, namely, technology description, global market potential, market and technology team, and the impact of Indian economy.
9. **Advanced Materials Policy**: Promote R&D programmes for the development of high-tech and advanced materials that can address the need of both defence and civil communities. Indian materials industry has to work closely with different educational institutions and

research organisations, preferably on a Public Private Partnership (PPP) mode. A synergistic network of universities, laboratories and industries in this front will be a powerful enabler to achieve excellence in this sector. Regular interaction between all stakeholders like prime producers, downstream product manufacturers, regulators, traders, information providers & end-users is essential. More applied R&D – with industry involvement in areas like new alloy development: Industry, R&D Centres and Academic Institutes to join hands. Organising regular training programmes using films showcasing international best practices for individual industries or industry clusters, highlighting material's intrinsic properties for the end users & for personnel involved in material selection. Unless Indian R&D improves its record of timely delivery of projects and develops aggressive plans to launch new products in line with the demands of preferred customers, the metal sector may further lag in development. The Industry must develop at least 3 to 4 World Class Laboratories, employ a number of Doctorates (foreign or Indian) to carry out research in the areas of Scientific and Industrial importance, in close collaboration or contact with industry, generate IPRs. For India to achieve a leading position in best utilising the resources, the concerned authorities in private and public sectors must keep an eye and track the research being carried out in other countries in the forefront of research. **However the success of such collaborative ventures would largely depend on preparing a framework covering financial, legal and administrative aspects**.

10. **Grant of "special" status to the aeronautics industry under the Harmonised Master List of Infrastructure Sub-Sectors**.
11. Although the government announced tax incentives for investment in sunrise or advanced technology sectors. It is hoped that **section 35AD of Income-tax Act, 1961 is suitably amended.** Under the Buy (Global) procurement category, an Indian company can compete with the foreign company. In the event the Indian company wins the competitive bid, it would be deemed to be import substitution (since the item would have otherwise been imported from the foreign company). In such cases, the items manufactured and provided by the Indian company should be accorded 'deemed export' status. Other tax incentives and price preferences should be provided to private firms in order to offset the large costs incurred by the companies
12. The establishment of **skill development institutes** and **dedicated educational and technical institutions** that will create skilled workforce to address a predicted shortfall of around 1.5 million workers with specialized skills who will be needed in the near future by the domestic defence and aerospace manufacturing industry.
13. **Following on the successful model of LCA development, Indian government should think of building the civil helicopter industry using a public private partnership model (PPP)**
14. Setting up of a National Aerospace Council as steering body to guide industry-government collaboration in implementing the National Aerospace recommendations. Aerospace manufacturing does not feature in national accounts survey under separate head. The vendor base capabilities are not available anywhere. Government can have a dashboard or a mobile app which can show the status of capabilities and opportunities in aerospace industry value chain. The national council can have its own website and report all such features of Indian aerospace industry.

MRO Recommendations:

1. MoCA should issue a formal notification to all the **airport operators** (private as well as AAI) directing **not to impose any royalty** (or any other equivalent charges) on MROs
2. **Repair and Return**: Clause 4 (e) of the FEMA notification needs to be amended and Industry should be permitted to import : if the serial number of a part to be repaired gets changed due to reconditioning/ overhauling / repairing or procuring new unit with all duties on

differential between the value of part imported and the old part sent for repair. Exports under warranty programs should be allowed to be executed as NFEI transaction

3. **Import for repair of parts**: At present there is no such regulation for situation where an Indian MRO does repair for jobs originating from foreign customers. Parts being imported for repair in India and then re exported, being temporary in nature, should be made completely customs duty and GST free.
4. **Warehousing**: MROs, who act as authorized services facilities for OEMs, should be permitted to import parts on Customs duty / GST free basis as these are temporary imports and the stock belongs to OEMs. MROs should enjoy custom duty exemption if parts are used on maintenance of aircraft by anybody in the industry. A provision to re export (under NFEI) the goods after the 3 years' time provided for utilization of aircraft parts cleared under notification no. 50/2017 Customs dated 30th June 2017 Sl.no.536, read with condition 75, without any penalties, interest and applicable customs duty. Export of unserviceable parts back to OEM for replenishing the pool should be permitted.
5. **Customs Clearances**: All customs process should be operational round the clock (365 days) including Bill of Entry (BOE) filling, BOE assessment (RMS and Non RMS both), Bond debit, Duty payment, Gate pass, OOC etc.
6. **Skill Development**: Fast Track Certification to CAR 147 organizations. Dedicated desk / cell in DGCA should look after matters related to 147 organizations and time bound clearances for applications. DGCA examination frequency should be increased and candidate should be able to appear for an exam whenever ready. Online examination process can be outsourced to professional agencies. DGCA should make some exemptions in the examination for foreign certified candidates. Some different form of examinations (oral/interview/practical) can be conducted through an expert panel (using retired staff of DGCA or on the job).
7. **Security Clearance from by BCAS**: There should be separate security clearance application procedure for MROs de linking it from Ground Handling Services.
8. **GST**: Common rules, regulations and procedures to be followed across India greatly simplifies the tax procedures. Before GST MROs used to export duty free. NFEI transaction should be kept outside ambit of Bond/Undertaking or payment of GST requirement as these are not transaction involving any foreign exchange. GST on NFEI transactions should be permitted under a cashless mechanism for GST payout and input credit.
9. **IGST**: As per Notification no. 2/2017 Integrated Tax (Rate), Exemption is given for levy of IGST against Chapter 8803 and it shows "Parts of goods of heading 8801". However, 8801 is not relevant for MRO industry and it should be 8802.
10. **Customs**: Non RMS clearances and shipments on which a query has been raised should be put under a timebound resolution mechanism. Engine, APU, Starter Generator etc. should be declared as aircraft parts throughout India.
11. **Course**: Focus should be on providing quality practical training in the institutes itself so that the students are equipped with all the necessary engineering and technical skills when they complete the course. Alternately, there should be collaboration between industry and the training institute. The industry also can be asked to adopt the training institute to build synergy. Infrastructure available in the institutes needs to be suitably upgraded for this and the duration of the courses should also be increased.
12. **Aerodrome entry permit**: AME's AEPs are restricted due to validity of their license, since renewal of license is an ongoing process which takes 2 - 3 weeks , the affected AME is not able to perform his duties which disturbs the day to day functioning of MROs. Process of renewal of licenses should ensure delivery of new license within 2-3 working days.
13. Aviation experts noted that the government will have to create a level playing field in terms of rationalising tax levies on MRO and aircraft leasing activities to fulfill its ambitions. For instance, the **domestic MRO activities are taxed at 18% as compared to 5% in nearby**

countries Sri Lanka, Singapore and Thailand, forcing airlines to do service jobs on aircraft overseas.

14. Government can re-categorise few items for **dual use to** reduce the additional costs incurred by domestic MRO industry. These items can be taken for indigenisation based on strategic criticality and commercial viability.
15. Getting an approval for a small MRO is not easy for an SME (Small & Medium Enterprise) due to the vast regulatory requirements laid out by the regulators. **Regulators in India should work along with entrepreneurs to develop new entrants** with open & vast outlook. This will also ensure building of ecosystem for the MRO industry.
16. **Industrial planning policy of HR for Defence MRO**: it took astoundingly large nos of training and R&D institutions to build HR required for these industries. We are already defining the NOS(National Occupational Standards) under the NSDC. We may broaden these skills by setting A&D institutions in the county. These skills can be gradually be passed on to the civilian use. Industry, R&D and academia need to come under one roof to find path-breaking solutions in MRO.
17. **Common standards** should be initiated for consumables, so that they can be procured in bulk for defence and civilian requirements. Government should prepare a list of **dual use items** which can be governed by single standards. These can be easily manufactured in domestic vendor facilities thus ensuring their development. Indigenised product which are certified, common in standard and got approval**, civil airlines should be notified**.
18. Government should **bring out policy to develop advanced capabilities** as reverse engineering, additive manufacturing, artificial intelligence for MRO.
19. Policy should be made to **incentivise OEMs through royalties or other means to supply components at cheaper price** or **allowing use of parts made by other providers/local** vendors. OEMs can certify those parts at a fee or develop the vendor to gain lifecycle royalty.
20. MROs and **component/spares warehouses need to be declared as free trade zones with zero rate of GST** and a ten-year holiday on corporate tax, capital gains tax and dividend distribution tax. This will particularly help in encouraging new players to enter the market and grow the industry. State governments can build separate policies for encouraging development of MRO parks in tandem with logistics parks to ensure fast movement through connected networks.

UAV Industry Recommendations:

1. **Single Window Clearance**: Single window application for issue of UIN and UAOP involving all stakeholders

2. Setting up **common industry standards for UAV industry** will help alleviate the problems with self regulation or import quality control. Setting up standards for airworthiness of UAVs and agency nomination to certify them.

3. **Voice and data recorder** to be made mandatory in larger UAVs for effective post accident analysis

4. **Industry self-regulation/co-regulation with audit and enforcement powers involving all stakeholders would alleviate the regulation challenges**

5. Setting up a **centre of excellence for UAV operations**, manufacturing and regulation would help develop technology and build competitiveness.

6. Steps to protection **against unjustified, disproportionate and unsafe surveillance** can only be given by formal **Governmental control**.

7. **Legal inputs while designing control of UAV surveillance** and preventing the biggest risk of privacy invasion. Laws are needed to spell out the obligations of drone operators, with limitations on the type of technology and, in particular, the camera lenses that can be installed on civilian drones.

8. There should be **awareness programmes (dos/donts, offences/crimes, legal aspects) by Government to educate the public** about drones before opening the sky for civil/commercial drones.
9. Government should **focus on quality control to test the digital security mechanisms** of each UAV to prevent hacking or unethical activities
10. The **insurance industry should be encouraged to play a constructive role**, by declining to quote a price where an operator's practices are uninsurably unsafe
11. **Proper guidelines in drone policy for UAV repair and maintenance** to enhance safety
12. Level playing field to be given to all Indian manufacturer by **simplifying the process of issuing industrial licenses for civil RPA manufacturing.**
13. **Tax structure for imported spares** should be favourable and can follow the recommendations made in MRO section.
14. **Additional time after RFP** to be given to Indian companies to develop products before field trials
15. **RPA testing site** to be earmarked and industry should not wait for permission to use the airfield or the site.
16. UAV advanced capabilities as swarm, AI, ML, anti drone, detect and avoid, BVLOS, night operations, unmanned taxies, human transport, integration of manned and unmanned platforms require continuous research - **policies must have special provision and exemptions for promoting such research** and it has to be stated in the policy document. There is no clear understanding regarding which institution will take prototyping accident responsibility. There should be policy intervention for trials of UAVs.
17. We have challenges on Electric propulsion system, new radar, motors and battery packs (most important). We have opportunities on Indigenous components, BLDC Motors and Battery Packs. We need **quality assurance agency, skilled labour, proper training and colleges with curriculum on UAV** (Not only Basic but also in-depth).
18. Currently in India, micro to small UAV manufacturing is going on but multirole UAV manufacturing is not happening. Research is going on in artificial intelligence and vision based landing. For military, research is going on mainly in payload, search and rescue drone. **Tangible investment in local manufacturing is needed from cross Industry (such as, material Industry, Microprocessor Industry) should contribute in UAV Industry**. Through this we will not be dependent on imports and we can start our indigenous manufacturing. We need a centre of excellence for technology based infrastructure which will help both civil and military industry.
19. We are importing Electro optical sensors because we don't have awareness of our indigenous manufacturing sector. **So a portal is needed where all product information of our manufacturing sector that will be shared with UAV manufacturers**. We have to develop ecosystem for future capability enhancement.
20. Dedicated repair system is not available for RPAs. Currently major operators repair at their own level. **Transfer of technology to the distributor is needed and tutorial is also important. For military, most important is transfer of technology and proper MRO Setup.** Flight logs, Schedule Management, Component life time information, Awareness for not only manufacturer but also for customers- these are most important in near future.

2.0 Methodology

2.1 How to measure aerospace industry data? The method we used:

Despite a considerable public interest in the aviation industry, there is surprisingly little consistent statistical data available to compare the industry performance of aircraft producing countries around the world. The most commonly used indicator to measure the size and changing geography of the global commercial aircraft industry has been the relatively most easily available export statistics and company sales data. The main advantage of export statistics is their global coverage and the systematic collection and publication of data from both trading partners. At the same time, export data does not distinguish trade in new or used products, so it is only a second-best indicator of successful foreign sales of domestically produced aircraft, if figures are biased by the foreign sales of used wide-body aircraft in the million-dollar price range. This makes it particularly difficult to compute indicators of international specialization and comparative advantage of countries. Company sales data offer better insight into the performance of actual products, however, not all aerospace companies are publicly traded or are forced to publish their detailed results. More aggregate national statistics for the aircraft industry on gross value added (GVA/VA) output converted to dollar values are therefore better indicators of actual aircraft production activities. This indicator helped us avoid the double counting while adding the different country or company revenue/output. A simple explanation of this GVA concept is provided in Scottish Parliament's economic briefing (2018), which is given in Figure 2.1. We then used company data to get an estimate of different subsectors as components, UAVs and MRO activities. We faced the same struggle while estimating the industry size for India. There is no segregation of aerospace manufacturing in any database. The UN database does not give the recent data. Only Indian Ministry of Commerce provides data on aerospace exports. However, we had access to individual company annual reports. It is very hard to calculate GVA for Indian aerospace industry and hence we reported the size adding components, supplier revenues to the OEM revenues.

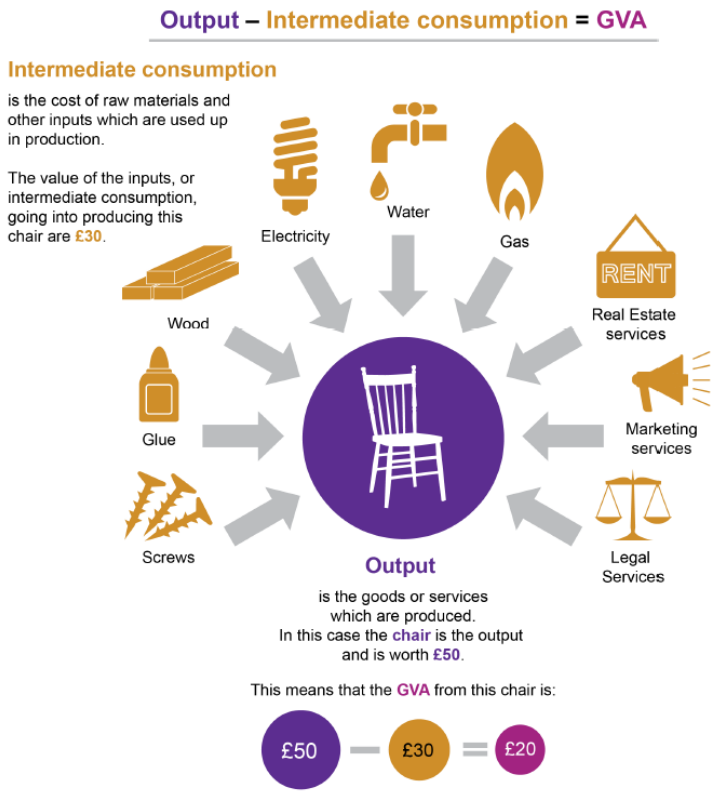

Figure 2.1: Concept of GVA/VA

2.2 Data Sources Used and Assumptions/Models used for arriving at the growth factors for the industry

First secondary data is gathered from multiple reliable sources. We used institute subscribed multiple third party forecasts to use an average CAGR to estimate the future outlook of each industry and validate the findings from reliable subscribed techno-commercial market research databases as Technavio, Frost & Sullivan, IBISWorld, Grand View Research, Allied Research, BIS, statistical databases as Oxford Economics, UN Comtrade, OECD STAN, UNIDO. We also interacted with international and national experts in the form of surveys and workshops. Secondly, we used company reports, aerospace industry magazine articles and news articles to aggregate the Indian capabilities and opportunities and estimate the global market size. For example, for commercial aerospace industry we used an average of Boeing and Airbus's future market growth rates. The market size is rounded to the nearest billion/million or one decimal place wherever possible. Multiple workshops were conducted during the course of study using multiple formats. For understanding the evolution of new technology and industry as UAV, we used a creative style to allow participants to brain storm and come up with future scenarios, challenges and opportunities for the UAV industry. They were asked to do breakout sessions and come up with recommendations. Quantitative questionnaire survey is also carried out. Similar format is adopted with little more structure for MRO workshop. Unlike the previous workshop's blue sky thinking approach, the participants are allowed to tell success or failure stories and report their industry sizes. This was more of an experience sharing workshop on MRO activities which helped us understand the key challenges and the interventions needed. We also met the Economic Advisor to the MoCA and her team to get input on our report and possible recommendations they are working on for improving Indian MRO industry performance globally. Finally, we carried out a multi method approach to conduct a supplier workshop at HAL Bangalore. Here the suppliers are asked to share their story using a presentation mode (using slides) rather than freely speaking out as in the earlier case. At the same time in parallel we conducted individual one to one interviews with the suppliers to understand their success factors, challenges and recommendations for improving aerospace manufacturing in India. At the same time, we also had sessions with armed force customers (maintenance services) and quality agencies and few DPSUs to get their views on the current As Is condition of the Indian aerospace industry. We also got a fairly good idea from a sample of 21 suppliers, the size of the industry, offsets, tier structure of the supply chain and the different capabilities. Few interviews were carried out on telephone.

2.3 Disentangling the definitions and concepts of the aerospace value chain

The focus of this study is the aerospace manufacturing industry. By definition, this excludes air transport services, but includes aircraft maintenance, repair and overhaul (MRO). These latter activities require engineering and technical skills which are also required for parts and components manufacturing or aircraft assembly, but are much less capital intensive and research intensive. They do require specialized education and training, but far less than manufacturing. Since a limited level of MRO work is carried out at every major airport, countries with no other production facilities seem to be aerospace producers due to this MRO-bias.

Aerospace manufacturing includes the manufacturing of aircraft and spacecraft, as well as their engines or propulsion units. In the global statistical overview we have no means to distinguish aircraft and spacecraft production within the aerospace industry. Nevertheless, since the space industry is not characterized by mass production, even in countries with space programs the largest part of aerospace value added originates from the aircraft segment. In the report we focus on the more narrowly defined aircraft manufacturing industries.

3.0 Aircraft Manufacturing – Commercial/Civil and Military

The aerospace industry is considered a highly strategic sector in all advanced and developing countries of the world. A solid national aerospace industry is therefore a symbol of strength. Countries may also assert their sovereignty by being recognized players in the defence segment of aerospace. The aerospace industry is highly sensitive to the macroeconomic environment. The aerospace sectors are first to reflect that whether the overall economy is booming or in depression. Economic analysts also see aerospace sector as a bellwether for wider global economy. In addition, aerospace is an industry with high technological content; over the years, aerospace innovations have been used to develop and manufacture a wide variety of products. A number of structural changes have taken place along the global aerospace supply chain in recent years.

1. **Business Model of System Integration:** A risk-sharing approach in which the overall development and assembly of an aircraft is divided between different companies is now a well-established industry recipe (Spender 1989): various first-tier suppliers are now responsible for performing the detailed design work and manufacturing the major subassemblies of airplanes, while Original Equipment Manufacturers (OEMs), such as Boeing, Airbus and Bombardier act as "system integrators" (Cohen 2003; Ferreri 2003; Pritchard 2002). This business model has clear financial advantages because it allows aerospace OEMs to invest less capital into new programs. While the system integrator business model multiplies business opportunities for lower tier aerospace suppliers, it also raises the pressure for low cost, quality, dependability, and flexibility.

2. **LSSI:** Beelaerts et al. (2012) coined the term large scale system integrator (LSSI) for the OEM where the LSSI contributes with its own unique value such as technology development and integration, and interacts as a "value flow processor" between demand and supply to process the "inflow" of value towards suppliers and the "outflow" of value towards the customers. Creating profitable value nowadays requires a balance between what the customer wants (demand chain), the focal company unique value contribution (own chain), and the suppliers (supply chain). Core competencies of the LSSI are sharing knowledge, collaboration skills, product vision and market knowledge. Consequently, Tiers 1-3 suppliers gain influence as risk, responsibility and revenues flow upstream the supply chain or network in the aerospace industry (Figure 3.1) as researched by Petrick (2007). The changing dynamics of the industry are causing Tier 1 suppliers to gradually become LSSIs of airplane production, for example the engine manufacturers (Liberty Ridge Advisors, 2018).

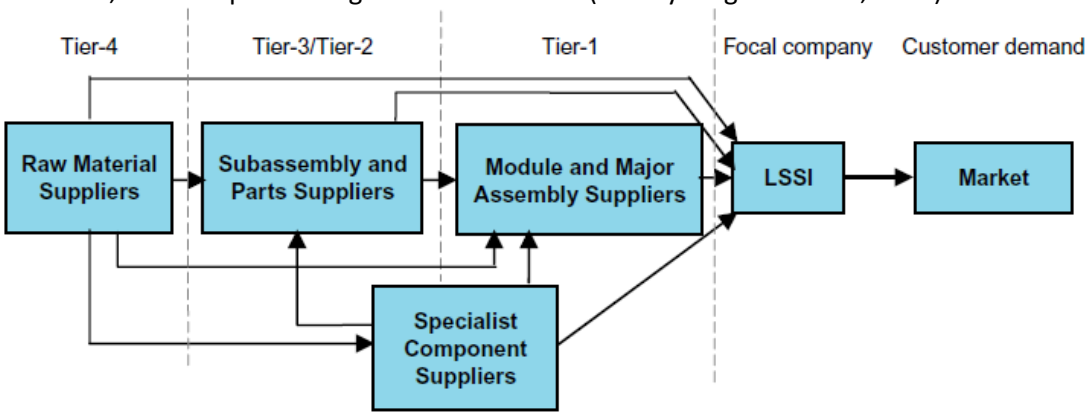

Figure 3.1: Simplified aerospace supply chain (Petrick, 2007)

3. **Top 20 global companies:** According to a report by Deloitte, the revenues of top 20 global aerospace companies accounted for nearly 73.7% of the global aerospace and defence (A&D) sector revenues in 2016 (in line with the 74.2% in 2015), reflecting continued consolidation within the industry. The revenues of the top 20 global A&D companies

accounted for nearly 73.6 percent or US$504.6 billion of the overall A&D industry revenues in 2017, in line with 2016 (Deloitte, 2018). Also all these companies are active in both defence and civil/commercial markets as is observed in the following figure.

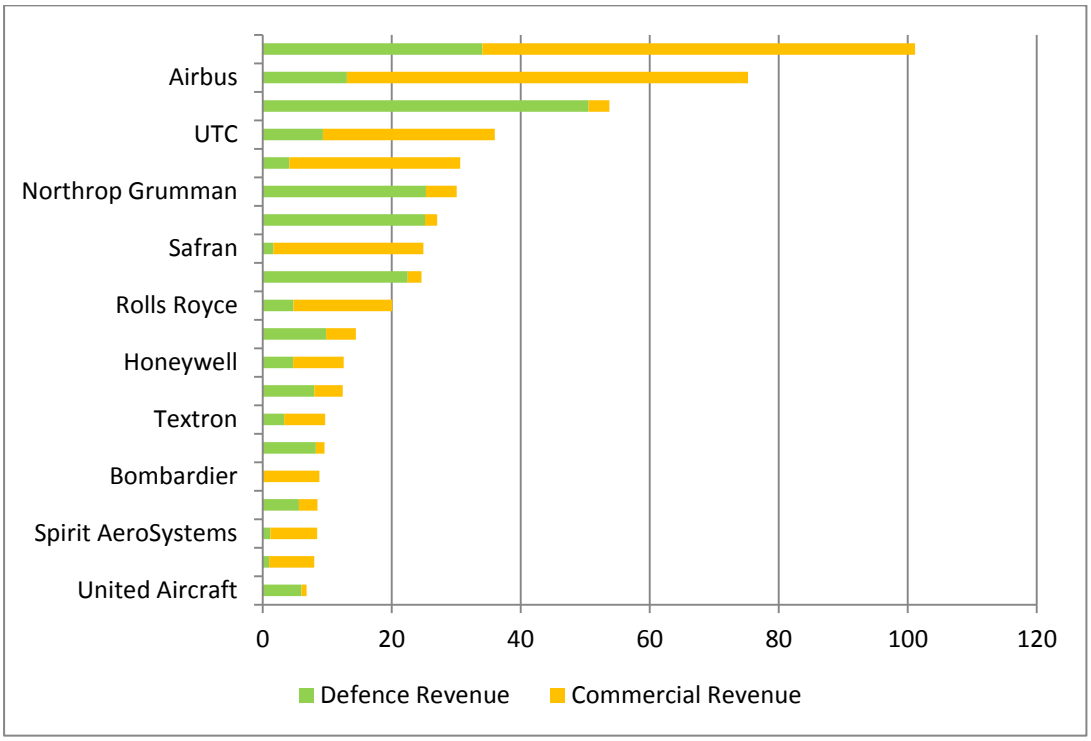

Figure 3.2: Commercial, Defence and Total revenue (billion USD) for the global Top 20 commercial aerospace producers in 2018, source: FlightInternational, 2018, individual company reports

4. **Consolidation in lower tiers to build large scale suppliers:** OEMs/LSSIs continued to put pressure on suppliers to reduce costs and increase production rates, which, in turn, pushed many suppliers to consolidate for scale, cost-effectiveness, and higher negotiating power (Even this trend is observed in Tier 3 or 4. This trend is likely to continue as OEMs focus on expanding their margins. Hence, the highly fragmented supplier base is likely to become more concentrated in the near term. For example, Arconic acquiring Alcoa to grow bigger in materials sector, Subaru acquiring Fuji aerospace, Sonaca acquiring LMI Aerospace. Aerospace's notoriously complex supply chain has created concerns about suppliers' capacity to meet growing demand, encouraging recent merger and acquisition activity as manufacturers seek to increase supply chain transparency, efficiency and capacity.

5. **PE Firms' Active participation:** Not only these, there has been increasing participation of PE firms in the global aerospace industry. For example, Berkshire Hathway acquired Precision Castparts Inc for $37b in 2015, Penta Investments acquired Aero Vodochody in 2006, AE group acquired aerostructures supplier Atlas Group.

6. **Vertical Integration:** We saw some megadeals as bigger players focus on vertical integration. Top suppliers merged to counter balance the power of OEMs and capture a greater share of the aircraft. For instance, we saw a large aerospace supplier acquire an avionics and interiors manufacturer (UTC's, owner of engine maker Pratt & Whitney, $30.0 billion acquisition of avionics leader Rockwell Collins; and in Europe propulsion business Safran's acquisition of interior business Zodiac), and more recently, we witnessed the merger of two major communications and electronics contractors (L3 and Harris)—one of the biggest-ever mergers in the defense sector. Apart from this, large, prime contractors are expected to

consider acquiring small to mid-sized companies to gain access to new technologies and markets (Figure 3.3). The industry is likely to experience increasing M&A (merger and acquisitions) activity even when valuations of aerospace and defence companies are high and near pre–financial crisis levels. Specifically, the enterprise multiple—enterprise value (EV) on earnings before interest, tax, depreciation, and amortization (EBITDA) of the A&D industry—rose from 9.9 times in 2015 to 14.2 times in 2018. Figure 3.4 shows the volume and value of M&A activities until 2017.

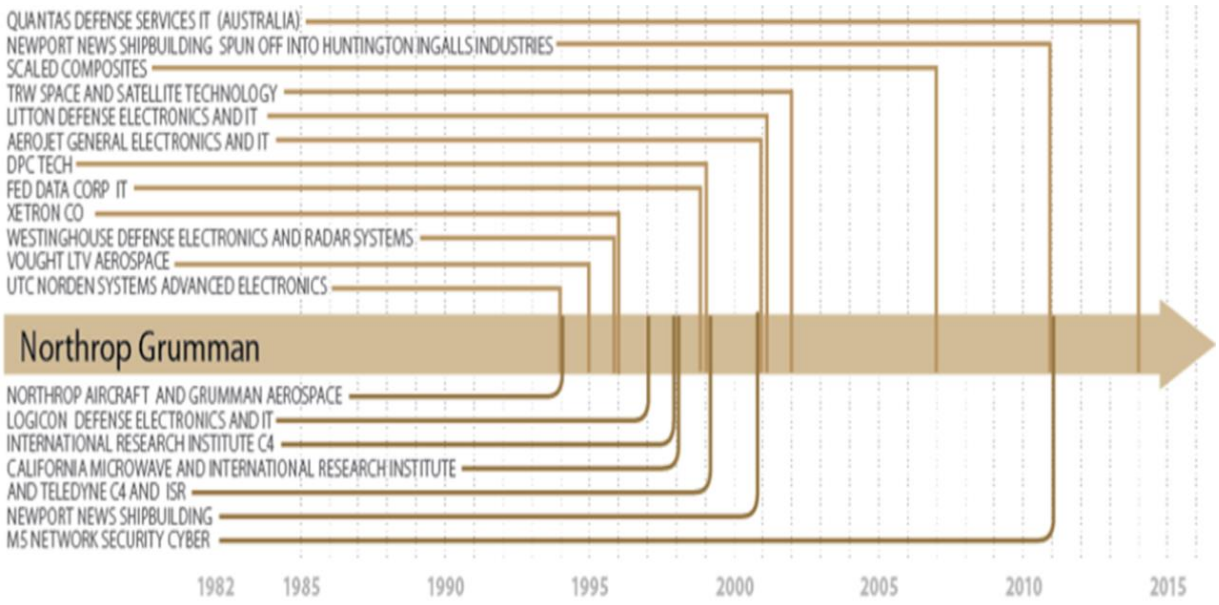

Figure 3.3: Northrop Grumman Acquisitions (source: https://www.northropgrumman.com/)

7. **Commercial Aerospace Consolidation at OEM level:** In commercial aerospace sector, Airbus and Boeing sought to secure their dominance, through combinations with makers of smaller regional aircraft: Airbus agreed to buy a 50.0% stake in the Bombardier CSeries program and Boeing seeks formal ties with Embraer. Bombardier continues – for now – to build the CRJ series airliner, which is physically much smaller than mainline single-aisle airliners, and is facing a declining global demand. Airlines are not looking for new "more of the same" airplanes. To gain entry into the global market, any new entrant will need to offer materially better operating economics and/or much-advanced customer attractiveness over the current Airbus and Boeing products - a very tall order. Chinese and Russians are working on CR929 to compete with B787 and A330 but not before 2028. In the mainline airliner space – from 100 seats up – the global market belongs to Airbus and Boeing.

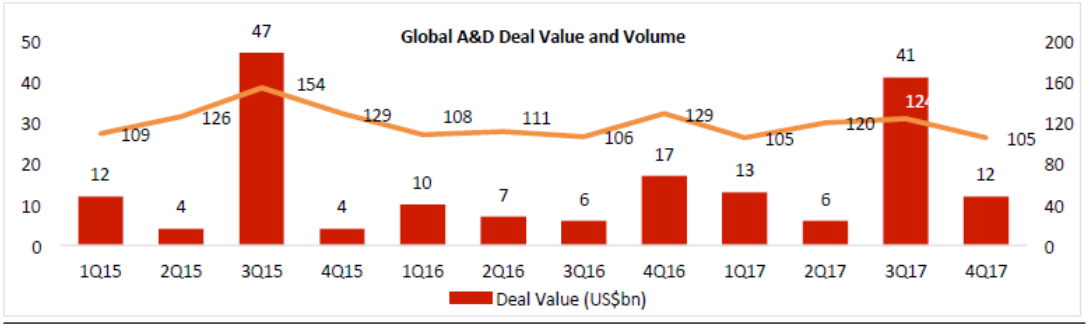

Figure 3.4: M&A in Global Aerospace Sector (Source: Thomson Reuters, PwC)

8. **Consolidation in military aerospace at OEM level:** Current participants in the market include the U.S. producers of military aircraft - Lockheed Martin, Boeing, and Northrop Grumman (Figure 3.3). European firms that compete in the market are Dassault Aviation, Eurofighter

(Airbus/Leonardo/BAE Systems) and Saab. Although the Euro-Atlantic fighter market is dominated by these Western participants, the legacy of former Eastern Bloc countries' participation in the Warsaw Pact and/or operation of Soviet equipment means that residual use of Russian airframes persists, although only Serbia has chosen to acquire further Russian-supplied equipment to refresh existing inventory (Bozinovski, 2017). Overall, however, the Euro-Atlantic fighter market is bound together well through the widespread, long-term use of fourth-generation platforms produced by U.S., French, Swedish, and joint efforts undertaken by Britain, Germany, and Italy, sometimes together with Spain. These platforms will soon be joined by significant numbers of the F-35, the first fifth-generation platform in widespread use. Though the industry is not dominated by two players, but there are evidences of oligopoly in defence aerospace market. The market share commanded by the four largest firms by value of production and number of units projected results in market concentrations of 91 and 95 percent, respectively. The market, although an oligopoly at present, could be described as one in which there had been until recently pockets of intense competition as noted above (Lockheed Martin, Boeing, and Eurofighter compete to replace Denmark's F-16 fleet, The $15 billion fighter jet procurement deal for Indian Air Force has attracted initial offers from global defence majors, including Boeing, Lockheed Martin and Saab, Lockheed Martin and Dassault have positioned themselves to compete to provide an aircraft to replace Canada's aging CF-18s). It is likely, however, that such competition will soon wane, revealing that although such an oligopoly existed for fourth-generation fighters in the period from 1980 to the 2000s, it is now set to fade in the decade ahead as a shift is made to fifth-generation technology (Aboulafia, 2019).

9. **Globalized Supply Chain:** Though most of the industry is in Europe and North America, but some of the fastest-growing sources of industry demand are in emerging markets (we will see this in the subsequent subsections in this chapter). Trade was also boosted by the industry's increasingly globalized supply chain, with manufacturers outsourcing part and component production to lower-cost countries or ones with aerospace specializations. Moreover, companies are increasingly producing aircraft in rapidly growing markets to better serve their clients and gain market access. During the past 5 years, segments of the industry have been slowly consolidating as suppliers seek to gain scale and product diversification via acquisitions, enabling them to take advantage of growing demand for commercial aircraft. Moreover, original equipment manufacturers (OEMs) have encouraged consolidation to simplify the complex and opaque aerospace supply chain, enabling suppliers to charge higher rates and gain higher profit, but also so that they deal with fewer contracts, have fewer supply chain disruptions and share program risks. We have drawn out a detailed map of aerospace supply chain including all sectors and tiers for key modules and found that, OEMs/LSSIs in every aspect of aerospace production are locating facilities throughout the world (including latecomer nations as India, China, Taiwan, Indonesia, Malaysia, Singapore etc), subcontracting parts and fabrication work to a larger number of suppliers in varying regions through joint ventures and consortiums to increase operational efficiency and reduce costs. In defence, the offset obligations forces OEMs to do production of components in the purchasing country. In general, component suppliers often have higher profit margins than original equipment manufacturers (OEMs). The complexity of the aerospace supply chain and regular lack of price transparency has made it easier for some suppliers to charge more for their components. In some cases, OEMs have provided suppliers with patent rights to certain components, giving the suppliers a monopoly. Moreover, many suppliers compete in the component aftermarket where profit tends to be higher. These trends have all contributed to heightened profit margins over the period. It can be observed that, Although many Asian firms populate the global supply chain but very few except Japan have progressed to OEM/LSSI status. On the other hand Brazil though in

the OEM bracket and currently world's 3rd largest aircraft manufacturer with dominance over regional jet market has absolutely no presence in the value chain (Figure 3.5)! It is observed that, there is hesitation of private equity markets to finance the development of large civil aircrafts. It is mostly limited to lower tiers only. The global sourcing approach below is consistent with the move away from vertically integrated companies (with design, development, manufacturing, and assembly performed in-house), toward a supply network of many companies performing different functions. Though not shown here, these supply networks are categorized into: OEM companies and its suppliers (Figure 3.5) and service companies related to maintenance, repair, and overhaul (MRO) activity (Chapter 8).

	Tier 4	Tier 3	Tier 2	Tier 1/ LSSI	
Airframe & Airframe Systems (fuselage, nacelles, pylon, door, window, seats, interiors and systems)	Alcoa (Arconic Group), Hexcel Composites, AMA, Constelium, Kobe, CTRM, Collins CTG, RTI International Metals, Cytec, Du Pont, Kaiser, Fischer Advanced Composite, Strata, Aries, Jabil, Hexagon, Douglas,	Sonaca, Lisi Aerospace, Weber Metals, Brenner Aerospace (Atlas Group), Safran Zodiac, AviChina, SK10 Andalucia Airbus, Gardener, Fischer seats, Noranco, Mitsubishi, Teledyne, ShinMaywa, Liebherr, Aries, Dynamatic Technologies, Doncaster Bramah, Magellan	Ruag, PZL Swidnik [Leonardo], HAI , Latecoere, LMI, AIDC, L3-Harris, Alenia, Aernnova, Ducommun, Fokker GKN, Penta Aero Vodochody, AviChina, Goodrich, KAI, Kaman, Kawasaki, AvCorp	Spirit, Triumph, Ruag, Elbit, Leonardo, AIDC, Mitsubishi, HAL, Safran Landing, Kawasaki, GKN Aero, SAAB, Latecoere, L3-Harris, AviChina, TAI, Daher Socata, Subaru Fuji	Boeing, Airbus, UAC, Mitsubishi, Embraer, Lockheed, Dassault, BAE, Bombardier, Northrop, Leonardo. SAAB
Advanced Electronic Systems	Exotic Metals, Jabil, Hexagon, Alcoa (Arconic Group), AMA, Constelium, Kobe, CTRM, Collins CTG, Olin Brass, VSMPO, Glencore	Fenwal Safety System, Eaton, Teledyne, Sagem, Tect, Bergen Cable, Lord Corp, Magellan, Barry Controls, Panasonic, Jabil	Eaton, Diel GmbH, GE Aviation Flight Controls, Collins, Sagem, Bergen Cable, Moog, Honeywell	Thales, Collins/UTC, Elbit, China Electronics Technology, L3-Harris, Leidos, Zodiac Safran, Crane Aero, Sagem, Cobham, Telephonics, Parker Hannifin, Honeywell	
Aero-Engine	Doncaster Group, Berkshire Hathaway (PCC), ATI, Warburg Pincus, AMA, VSMPO, Arconic, Aries, CTRM, Allegheny	Barnes , Aries Alliance, BMT Aero, Magellan, Avio, ATK, Asco, AIDC, CTRM, Doncaster, Centrax, Cefival, GKN, MTU, Meggitt, Mitsubishi, Volvo Aero, Triumph, TAE	Aircelle, Alenia, Avio, BAE Systems, Behr, Diehl, Eaton, Goodrich, Harco, Honeywell, LMI, TAE	Rolls Royce, CFM, Pratt Whitney/UTC	
Hydraulic and Pneumatic Systems	Alcoa (Arconic Group), Carpenter, Allegheny, ThyssenKrupp, Smiths, Kobe Steel	Sagem, Tect Aero, Aero Controlex, BMT Aero, Hanwha, Magellan, Aerolia, Ametek, Donaldson, PFW Aerospace, PTI Technologies	GE Aviation, Hanwha, CESA, Microtechnica, Moog, Parker, Premium AeroTec, Ratier, Triumph, Bergen Cable, Goodrich, Circor, Subaru, Meggitt, Lee	Honeywell, Curtiss Wright, Meggitt, Crane Aero, Moog, Goodrich, Messier Doughty, Liebherr, UTC Aero, Parker, Whittaker, Novaer	

US and Canada | Europe | Asia | Brazil | Australia | PE Firm Investment

Figure 3.5: Global Aerospace Value Chain (Source: Frost and Sullivan, Individual Company reports)

10. **Country strategies to join the global aerospace value network:** Global aerospace enterprises rely on each country's policies – export regulation, local requirements, taxes, and technology restrictions, among others – to manage its network of partners. Considering the strong growth for commercial aircraft predicted until 2037, the aerospace sector continues to rely on risk-sharing contracts and the OEMs' system integrator approach, thus, opening up opportunities for new entrants. The potential for socioeconomic development, opportunities for skilled employment, and increased economic value added reinforce the national strategic importance of the aerospace sector. As OEMs face continued cost pressure, they increasingly outsource development and production of noncritical parts to lower cost partners, opening a wide range of opportunities for different countries. Many countries, however, still face difficulties in developing their own aerospace capabilities to increase their share in global networks. Owing to the high entry costs and its inherent technological complexity, the aerospace sector is still considered a risky industry for both OEMs and suppliers. Another problem is the aerospace sector's dependence on country's economy makes it highly cyclical in terms of changes in demand and recurrent crises within the lifetimes of their products. Owing to the number of companies and parts, product development cycles for new aircrafts may take 15 years from an idea and design conception

to the final product. To extend product life cycle, the aerospace industry has adopted several business models in the last 50 years, including government-backed cooperation, build-to-print subcontracting, and risk-sharing partnerships. Thus in such dynamic industrial environment, different countries use different approaches to develop their domestic aerospace industry in terms of strategic importance (globally strong competitive positioning) and financial sustainability (self-reliance through exports and independent of domestic demand).

- Focusing policies for the aerospace sector on right-shoring depending on the country's relative development status - the restructure of global operations through a mix of offshoring, near-shoring, and outsourcing – to achieve the best combination among costs, markets, and resources
- The growing trend for OEMs to offer an array of support packages directly to the airline operators, thus incorporating MRO activities. Some of the services offered include complete packages for maintenance, servicing, and spare parts replacement over a fixed time period. The value network "expansion" strategy undertaken by suppliers of big aircraft producers - encompassing OEMs and MROs activities – has been a catalyst for various countries to position themselves as attractive destinations for hosting aerospace operations. It is important to understand the structure and evolution of aerospace value chains, as it may affect governmental policies for new entrant countries.
- Different countries can be assessed on the maturity of their global aerospace network strategy using the following metrics (adapted from Porter's diamond and Santos et al., 2019):
    a) Related industries: typical profile (turnover, employment levels, etc.) of the companies that operate in the sector; Tier structure of the companies (their structure along the value network, i.e. as suppliers of raw materials, systems integrators, assemblers, clients, research and development (R&D) partners, etc.); Location (are they located in a cluster or specific zone and their collaboration pattern)
    b) Role of national government through regulations or forming local associations/ councils for training, financing and competitive intelligence planning activities
    c) Factors: Historical preconditions (describes how past events and starting conditions have helped in shaping the industry, such as the characteristics of early pioneers, the gradual introduction of management practices to improve design and production performances, and the entry mode in the global value network e.g. through MRO, low cost manufacturing); presence of anchor companies; internationalization processes, either through a multinational corporation, foreign direct investment, or other type of outside action, enabling the transfer of external knowledge and access to foreign markets for local suppliers; local technological and knowledge capabilities in terms of design, manufacturing, and management along with the quality and availability of knowledge generation entities (universities, research institutions, etc.)
    d) Demand: sophistication of customers' requirements and a strong local demand profile creates pressures for achieving higher standards of quality

A sample analysis of three different countries at three different levels of maturity is given below (Table 3.1).

Table 3.1: Comparison of the value network configuration of selected countries (Adapted from Porter, 1998; Santos et al., 2019)

	UK (Class A)	Malaysia (Class B)	Portugal (Class C)
Related Industries	- £31b in revenue in 2016 - 280,000 jobs in 2016 - 3000 firms - Presence of all supply chain tiers from OEMs to Tier 4 - 6 OEMs in design and assembly operations, 10 to 20 Tier 1 companies in assembly and/or manufacture of sub-sections, 100 to 200 Tier 2 companies involved in manufacture of sub-sections, and more than 800 Tier 3 and 4 companies producing machined components and sub-assemblies or specialized in the production of particular components. - Some clustering in regions, mainly South West, East Midlands, and North West. These clusters have benefited from proximity to other manufacturing activities such as automotive and steel making.	- £2.5b revenue in 2016. - 21,200 jobs in 2016. - 200 firms in 2016. - OEM's outsourced design and engineering services. - Build-to-print aerostructures and avionics components assembly - Commercial MRO (mainly) in airframes and engines. - Some clustering in Peninsular Malaysia, mainly in Klang Valley.	- Turnover of €1.7b in 2016. - 18,500 jobs in 2016. - 70 companies, mostly SMEs subcontractors. - Majority positioned in lower Tiers (raw materials, tools, equipment, and make-to-print suppliers). - Existence of 2 Tier 1 suppliers, established through FDI in the country. - Emerging cluster in Southern region, driven by Embraer. - Mould & Die cluster in Central region supplying the aerospace sector.
National Govt. Role	- Formation of Aerospace Growth Partnership in 2011, a joint industry-government effort. - Creation of Aerospace Technology Institute in 2013, representing joint industry-government funding for investment in technologies. - R&D tax benefits. - UK Aerospace, Defense, Security, and Space, a trade organization representing 3000 companies across the UK aerospace supply chain. - National Aerospace Technology Exploitation Program that focus on mid-Technology Readiness Level capabilities through collaborative support in the lower tiers of the UK Civil Aerospace supply chain.	- Malaysian Aerospace Council as steering body to guide industry-government collaboration in implementing the National Aerospace Blueprint since 1997. - Formation of National Aerospace Industry Coordinating Office in August 2015 to implement initiatives identified in the blueprint. - Investment incentives and R&D grants through MIDA. - Aerostructure Manufacturing Innovation Center to carry out R&D relating to aircraft structure manufacturing and also serves as a high-level study and training center. - Asia Aerospace City initiative that offers a complete business ecosystem for industry players in South East Asia.	- 3 associations have formed the AED Portugal to explore synergies and support the Aeronautic, Defense and Space Industry. - 2 “on the job training” facilities created near the 2 Tier 1 established in the country (one in 2010 and the other in 2012) have formed already more than 800 professionals.
Factors for growth	- Turbojet engine was invented by British-born Sir Frank Whittle in 1930, sparking a collaboration with GE in the USA in 1942. - Presence of anchor companies as Airbus, Bombardier, Augusta-Westland, BAE - Presence of Multinational corporations and foreign direct investments. - R&D, design and engineering capabilities.	- Industry began with establishment of MRO operations in 1970s, as part of defense procurement offset programs. - OEMs - Airbus and Augusta-Westland; Tier 1-BAE Systems, GE, Honeywell, and Rolls-Royce. - Multinational corporations, foreign direct investment, and offset programs Component and parts manufacturing, maintenance, repair, and overhaul (MRO) activities, design and development, and the assembly, and operation of light aircrafts and support services. - UniKL's (University of Kuala Lumpur) Malaysian Institute of Aviation Technology wholly owned by the government	- Entry through MRO in the inception of the aeronautic industry in 1918. - Period of expansion in the mid-20th century followed by contraction due to loss of captive markets. - Embraer Portugal, supplier of the parent company in Brazil, installed in 2012, 2 manufacturing facilities. Which resulted in a turnover inflection from 38,5 million € in 2012 to 88,8 million € in 2014. - Presence of French Tier 1 companies: Lauak and Mecachrome. - MRO services to aircrafts of major OEMS. - Foreign direct investments to Tier 1 production facilities. - 9 research institutions with joint projects with the industry.
Local Demand Profile	Local component and parts manufacturers in various aircraft platform development, especially for wings, engine, and landing gear.	Manufacturing of aircraft composite parts for Airbus and Boeing airplane models such as the A320, A350, B737, and B787.	Driven by requirements of MRO and Defense.

Class A: countries whose export share in global aerospace is >1%, Class B: countries with export share between 0.2% and 1%, Class C: countries with export share below 0.2%

11. **Size of global aerospace industry based on country and company level output:** Accepting the limitation of official statistics discussed above in Section 2, that for most countries it is

not possible to disentangle air and space, and civilian from military production, it is still very informative to chart the trends of the aerospace industry. Even if the scale may differ, the cyclical trends are very similar for the largest segment, commercial aircraft. Table 3.2 provides an overview of the evolution of the global aerospace industry between 1960 and 2018. Over these nearly six decades value added increased by a factor 5.5 to 246.3 billion USD, gross output increased seven-fold to over 650 billion USD. The growth of the industry was not linear. This shows a cyclical growth pattern with trough in 1990-1995 followed by periods of continued growth. The most rapid growth in value added took place from 1995 to 2018 (annual average of 10.7%). The difference between value add and gross output became wider due to increased outsourcing of aerospace activities. Also most of the country outputs are delivered to one big supply chain player. Currently aerospace globally accounts for over 5.6 million jobs, which is at its peak.

Table 3.2 Key indicators on the evolution of the aerospace industry, 1960-2018

In $billions (constant 2018 price)	1960	1973	1985	1990	1995	2000	2005	2010	2018
Total Value of Output (GO)	90.1	124.8	189.4	244.98	183.88	255.04	295.6	345.12	650.4
Gross Value Added (VA)	44.4	65.1	87.2	105.7	70.83	89.4	115.4	157.1	246.3
Total Employees ('000s)	953	1075	1680	1839	1669	1531	1357	1324	5619

Source: OECD Stan Database, US Census, IBISWorld, Oxford Economics, Vertesy (2011), for countries as China, Russia, India, Brazil used company databases and press releases

In fact, aerospace manufacturing employment peaked in 1990, at around 1.8 million persons employed, and over 500,000 jobs were destroyed worldwide until 2010. This is the outcome of a combination of factors, including the declining military expenditure after the Cold War, the consolidation of the industry through mergers and acquisitions or outsourcing activities, and the diffusion of information and communication technologies in all areas of design, production, maintenance, or management. For instance, advances in computational fluid dynamics and computer aided design virtually replaced wind tunnel tests and the need for model construction.

12. **Significance of Aerospace Manufacturing Industry in National Economy:** In the leading industrialized economies that produce aircraft, the size of the industry directly accounts for around 0.2 – 0.4% of GDP in 2018 (Oxford Economics). Even larger shares can be observed in Singapore (1.1%), the United States (around 0.53%), France (0.6%). The indirect impact of the aircraft industry is estimated to be as much as three times its direct size, considering its linkages with other sectors of the economy and employment generated. The US shows a declining share of the industry with respect to its GDP following 1990, which is due to the declining defense and space activities after the end of the Cold War. An opposite trend is observable for most other producer countries, including Europe, Canada and China, where the relative size of the industry has been increasing since the 1990s.

13. **Global Trade:** Below are the top 10 countries that posted the highest positive net exports for aircraft and spacecraft during 2018 (http://www.worldstopexports.com/aerospace-exports-by-country/). The aircraft industry is one of the most important positive contributors to the trade balance of countries including the United States, France, Germany, Israel, Canada, Italy and Spain. With the shift of many industrial activities to cheaper locations, advanced economies have experienced increased global competition even in high-tech industries. Aerospace industry remains one of the last industrial powers of the Western world, which is apparent in comparative advantage in aircraft trade, while only emerging country joining them is Brazil in aircraft.

1. United States: US$107.3 billion (net export surplus up 18.3% since 2014)
2. France: $30.8 billion (up 9.7%)
3. Germany: $24.5 billion (up 62.4%)
4. United Kingdom: $7.9 billion (reversing a -$311 million deficit)
5. Italy: $2.9 billion (down -22.7%)
6. Brazil: $2.9 billion (up 104.1%)
7. Spain: $2.5 billion (down -11%)
8. Canada: $2.2 billion (down -52%)
9. Austria: $843.8 million (up 161.7%)
10. Israel: $536.4 million (down -44%)

Among the top exporters, the fastest-growing aerospace products exporters since 2014 were: Malaysia (up 139.6%), Ireland (up 75.1%), China (up 74.2%) and South Korea (up 56.9%). Those countries that posted declines in their exported aerospace products sales were led by: Japan (down -19.7%), Italy (down -18.1%), Canada (down -14.8%), France (down -10.1%) and Germany (down -5.3%).

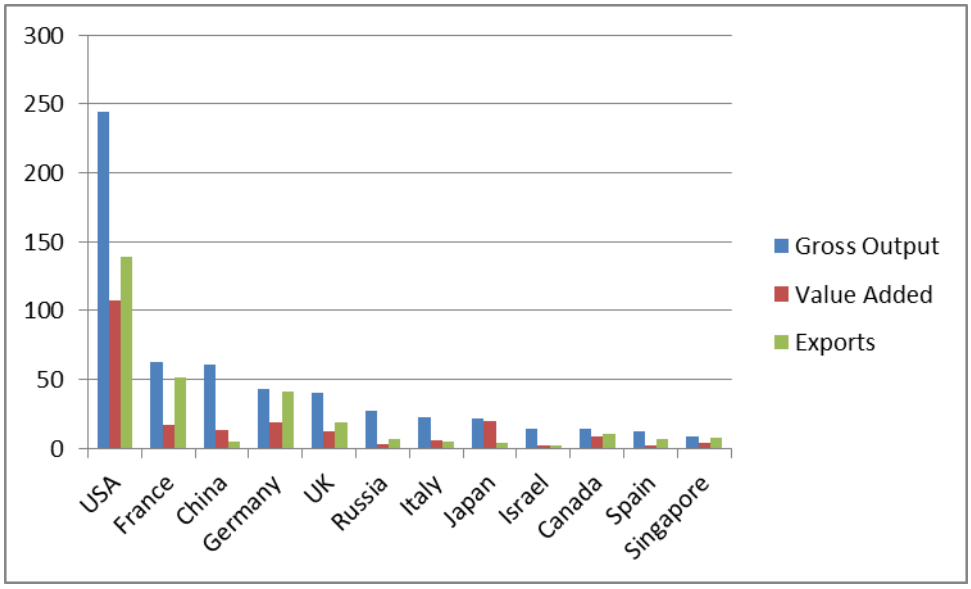

Figure 3.6: Top 10 largest aircraft/spacecraft manufacturers by gross outputs (GO), value added (VA) and their exports (all in current US Dollars) in 2018

Zooming in to the country level, comparing the list of the top 10 exporters and the top 10 producers offers interesting insights into the competitiveness of countries. The US is a leader both in terms of exports and gross output. Four European countries, France, Germany, the UK and Italy feature among the top exporters as well as top producers, but their rank changes significantly if we consider value added rather than export value, which is affected by the strategy of internal collaboration and the pricing of intermediate and final products. Most striking is the position of China among the top producers. Here we have to note that these figures may be exaggerated due to counting Chinese company's outputs based on their main industrial activity, and also including military production. Nevertheless, most of these products are for domestic use, China is yet to establish itself as a major aircraft exporter. The other countries appearing on top lists, Canada, Brazil, Japan and Singapore each have a competitive edge in some segments of the industry. Canada owes to its regional jet and engine industries, Brazil to the regional jets, Japan and Singapore to parts and components manufacturing and Singapore's position as an MRO, warehouse and logistics provider.

14. **A special mention of emerging nations:** Emerging nations, mostly Asian, but also Latin American countries are responsible for a rapidly growing share of global aircraft imports (in 2017, this was around 30% of total world imports, source: UN Comtrade, 2017). Although, as their share in global output of 10% share in global output is relatively small, they show rapid growth through a new kind of export specialization. From many aspects, these countries show little commonality. Some, like Brazil, India and Mexico run a positive trade balance in aircraft, while others, such as Singapore, China, Taiwan, Thailand, Malaysia, Indonesia or Philippines are net importers. Some of these countries have longer tradition in producing aircraft or parts (owing to Embraer in Brazil, HAL in India, ST Aerospace and other transnational companies in Singapore, military and civilian state-owned producers in China or IPTN/IAe in Indonesia) while others are relatively newcomers (such as Mexico or Malaysia). Production has so far not followed demand, but this imbalance provides ambitious governments with some leverage to gain access to technology and production capacity to force sellers/OEMs/LSSIs to source at least some of the value of their aircraft from these countries. Yet changing the international division of labor in such a high-tech industry does not happen overnight, and depends on the successful implementation of policy and business strategies. These strategies show a common pattern, or a new wave of latecomer entry, which can be described as **entry to aircraft industry through the supply chain.**

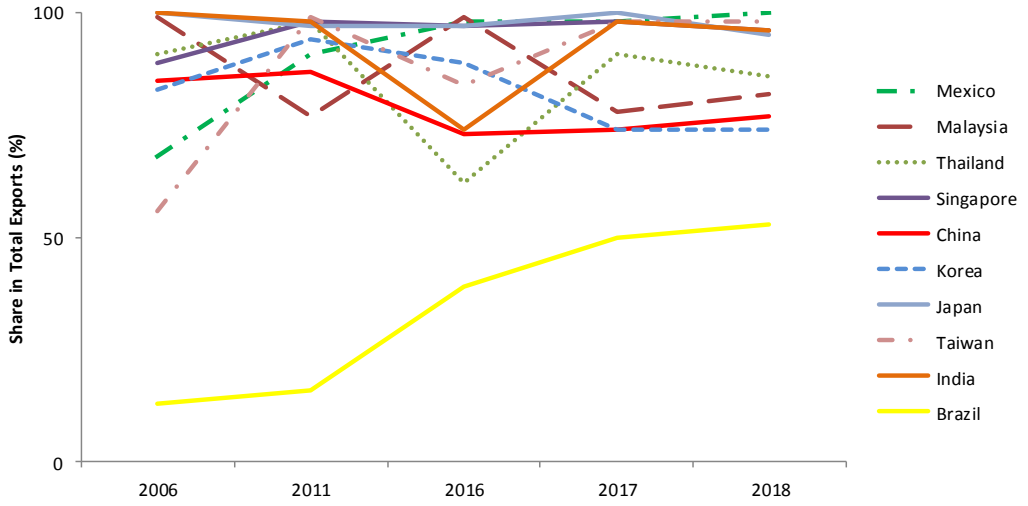

Figure 3.7: Share of intermediate goods in aircraft exports of selected countries (Source: OECD STAN Bilateral Trade by End Use Database)

Data on intermediate trade in aircraft offers interesting insights into ways countries become integrated in the global aircraft industry. Figure 3.7 shows two distinct patterns. One trading pattern is followed by a single country, Brazil, the only emerging market exporter specialized in assembling and selling entire aircraft. In fact, this corresponds to a strategy which we called the “first wave” of internationalization, or which is entry from the top of the supply chain for an “indigenous aircraft” developer and producer – a process in which Embraer of Brazil turned out to be more successful than most others (Vertesy 2011). The other countries have become increasingly specialized as parts and component suppliers, among them China, South Korea or Mexico. They have done so following the model established by Japan, which, after a failed attempt to produce entire airliners (i.e. the YS-11 by Nihon consortium) shifted to parts and components manufacturing, and has become one of the leading suppliers of advanced composite materials. Singapore followed a similar strategy from the establishment of its aerospace industry in the 1970s, when, leaving behind its single role of a trading post, it has become a provider of MRO services and an important producer of parts and subsystems. This graph offers further explanations to the difference

between the size of production and export of China: although it can sell aircraft in the domestic market, when it comes to exports, China's current strength lies in supplying parts and components. If China's other strategy, that is, indigenous aircraft development, comes to fruition and Comac succeeds in exporting the ARJ-21 or C-919 jets, this picture will change. In any case, as for now, Figure 3.7 indicates that most of the aircraft-industry exports of the selected countries are used as intermediate goods by producers in their partner countries.

15. **Limits to globalization:** The relatively slower speed of internationalization of the aircraft industry compared to others can be attributed to a number of economic and political factors.
    - First of all, new entrant companies cannot gain competitiveness overnight, but through the outcome of a longer learning process. This depends on joint efforts done by the company as well as the host governments, by establishing a learning and innovation system, with the provision of specialized human resources, the availability of education, training and research institutes and the availability of linkages to other industries and leading producers. **The provision of specialized labour force is crucial** (Niosi and Zhegu, 2005). Establishing stand-alone institutes is not enough as long as there is a lack of interactions (flow of finance, skilled human resources, ideas, products, etc.) between the key actors of the innovation system (Vertesy, 2011).
    - Second, if the high costs of continuously financing these efforts were not a big enough barrier of entry, latecomers have to reach markets limited by strong standards and political obstacles. The more complex activities latecomers aim for (i.e., an entire aircraft), the higher obstacles they will face. At the same time, posing political obstacles is a double-edged sword, as latecomers can also trade market access to foreign producers for access to technology and localizing higher value-added production activities. It also needs to be emphasized that developing and manufacturing a modern aircraft are extremely complex processes, and so is optimizing supply chains, thus any decisions that are made are affecting the life-cycle of an entire aircraft programme.
    - Third, scale economics favour established trading patterns, and at least in short and medium term, it is much cheaper to buy aircraft and their components rather than make them. To a similar degree, the returns to R&D spent by incumbents is expected to be higher than to recent entrants, making a race against a target that is moving away faster. The largest aerospace R&D spenders happen to be incumbents: the United States, France, Germany and the United Kingdom. US companies are by far the largest aerospace R&D spenders; they spend far more than those of the next ten countries combined. It has to be underlined that even if reported figures include military and space R&D, their outcomes are important sources of new technology used in commercial aircraft. Most of the top-10 companies' self-funded aerospace R&D expenditure is around 4-6% of total sales. But the R&D landscape has also seen important recent changes. China is emerging as a new major aerospace R&D spender as well as an employer of scientists and engineers. At some distance, India has also increased its aerospace research spending (HAL spent 8% of its 2018 revenue in research and development). Direct or indirect public support plays a crucial role in these developments, and in fact a number of American and European companies have made strategic attempts to benefit from these programs. The emergence of world class R&D capacity beyond the traditional locations, and the "competition" by governments to support them also increases the pool of available

risk-sharing partners for incumbent system integrators, which will further increase international specialization along the supply chain.

3.1 Global Commercial Aircraft Industry Landscape and Outlook

Industry operators design, manufacture, overhaul and rebuild planes, helicopters, aircraft engines and various aircraft components and subsystems for the commercial and civil markets. While the industry did initially suffer from the global downturn, the scale of the decline was greatly mitigated by long lead times in aircraft manufacturing. Airlines typically order planes in anticipation of future demand and do not receive orders until months, or even years, later. This production backlog sustains the industry when economic growth is poor. In times of economic expansion, this backlog can bottleneck supply, driving product price upward. In this industry, the platform prices are governed by market conditions as competition, civil requirements and many other factors. The commercial aircraft market continues its strong performance as passenger traffic levels and airline's financial performance maintained impressive levels in 2018 (Bombardier, 2018).

1. Key Drivers: The following key indicators are used to monitor the health of the commercial airline industry in the short term:

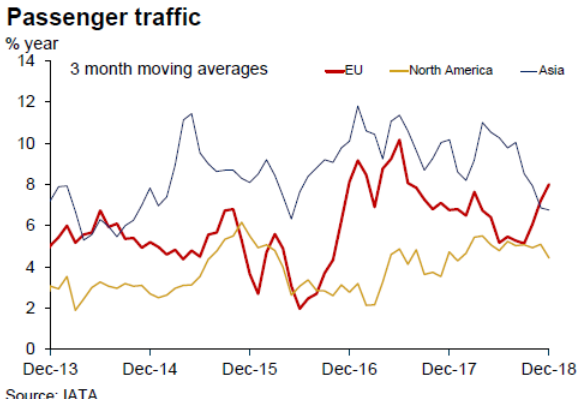

Figure 3.8: Passenger Traffic Trend for past 5 years

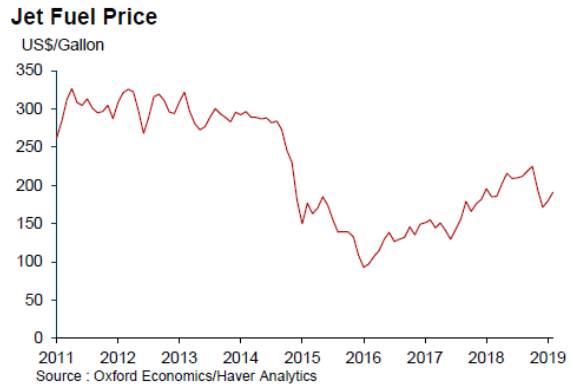

Figure 3.9: Jet Fuel Price Trend for past 5 years

- Airline Profitability: According to IATA, the world's airlines are set to post a ninth consecutive year of positive net profits in 2018.
- Passenger Traffic: As connectivity by air continues to improve and the costs of air transport continue to fall, global passenger traffic, measured by revenue passenger kilometres (RPK), was 6.5% higher for the calendar year ended December 2018 compared to the same period last year (source: IATA, Figure 3.8).
- Fuel Prices: The average annual price of Brent crude oil increased from $54 per barrel in 2017 to $71 in 2018. At the end of 2018, the price dropped to $51 per barrel reflecting an excess of supply, as a result of increased crude oil production and export by the U.S. oil producers (source: US Energy). The price of fuel, one of the largest components of the airlines' operating costs, remains volatile and should result in continued demand for more fuel efficient aircraft. The plunge in global oil prices forced many oil and gas producers to slash investment, especially those in expensive and hard-to-reach fields which typically require helicopter transport. Consequently, demand for helicopters, which are used to reach those fields, has declined. As this report is written the price has gone up slightly to $58 per barrel representing increased demand for rotorcrafts. Figure 3.9 shows the trend in jet fuel price over past 5 years.
- Air transport is one of the preferred transportation means for tourists and business persons. Further, tourism industry across the globe is anticipated to witness significant hike during the forecast period. This is turn, is projected to have high impact over the overall commercial aircraft market by 2022.

- To meet the environment compliance imposed by government bodies people and business entities have started consuming and offering environmental products and services respectively. By 2022, the overall impact of the factor is projected to remain high due to increasing environmental concerns.
- A significant increase in aviation terrorism has a negative impact on commercial aircraft market growth. At present, this factor has high impact in the market, which is anticipated to remain high throughout the forecast period. Major issues include air traffic control error, cabin fire, explosive devices, hijacking of an aircraft, lightning, pilot incapacitation, and others.
- Currently, congestion and delay has had high impact over the market growth. However, the introduction of several initiatives by government and aviation service providers to manage air traffic effectively is projected to reduce the overall impact on the market growth by 2022.

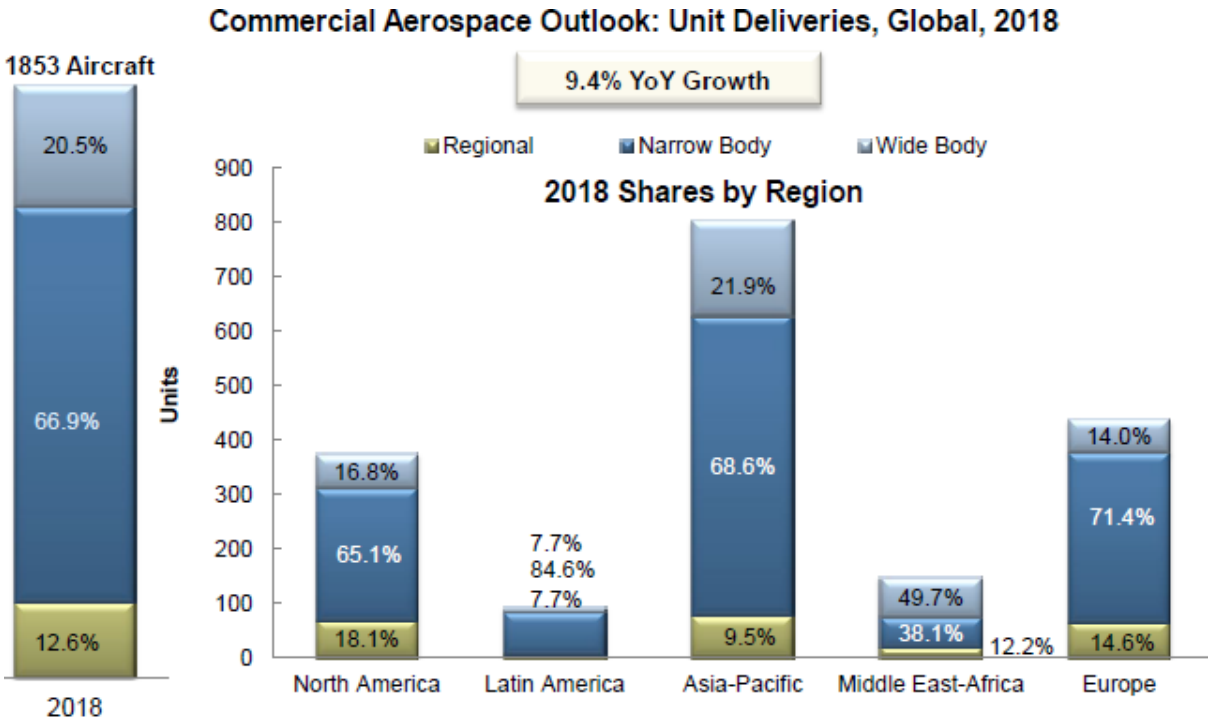

Figure 3.10: 2018 global deliveries of commercial aircrafts (Source: Frost and Sullivan, IBISWorld): [Example: Regional Jets: ATR 42/72, Bombardier Q400/CRJ, Embraer E2 Jets; Narrow Body: Airbus A220/A320, Boeing 737; Wide Body: Airbus A380/A330/A350, Boeing 747/767/777/787]

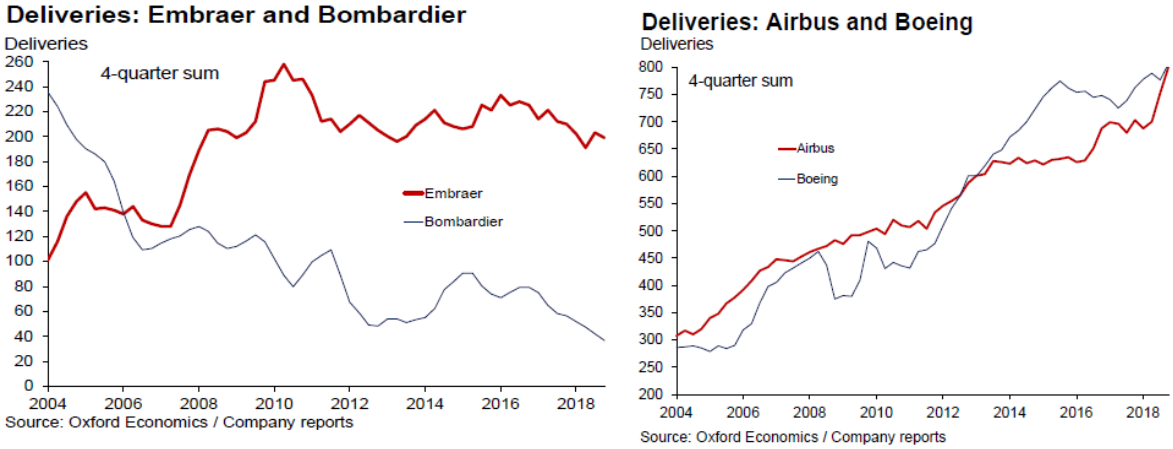

Figure 3.11

2. Industry As Is – Fixed Wing Platform: Rapid economic growth worldwide and increased air travel in emerging markets, combined with the need to replace aging aircraft with new, more fuel-efficient models in developed markets, has significantly increased demand for industry products over the past five years. These trends are chiefly evidenced by the expansion of global per capita income and global tourist arrivals which are projected to grow at an annualized rate of 2.0% and 4.9%, respectively (IBISWorld, 2018). The industry has greatly benefited from emerging markets that have been the primary catalysts of growth during 2018 (Figure 3.10). Rapid economic and income growth has led to a surge in air travel in Asia, the Middle East and Latin America. Consequently, airlines in these regions rapidly expanded, ordering hundreds of aircraft and filling manufacturers' backlogs. Planes such as Boeing's 787 and Airbus' A320neo use more composite materials, advanced avionics and new engines to reduce fuel consumption, increase capacity and reduce maintenance costs, thereby permitting end users to lower costs. Demand for fuel efficiency has been a boon for engine manufacturers because new engines are the largest source of improved aircraft efficiency, benefiting manufacturers as well as MRO operators that retrofit older aircraft. Moreover, the introduction of more efficient aircraft has coincided with established airlines' need to replace aging fleets. Therefore, despite slower economic growth in developed markets, demand for new aircraft has steadily increased as North American and European airlines replace their fleets and attempt to become more competitive. Thus, with an emphasis on emerging markets, industry revenue climbed to **$259 billion** in 2018 (source: Frost and Sullivan, IBISWorld, Company revenues and deliveries), including a 5.8% increase in 2018 alone (This is approximately equal to our estimate in Table 3.1 gross value add calculation). The overall rapid increase in demand and revenue permitted industry profit to grow as well.

Category – Narrow and Wide Body Aircrafts: Figure 3.11 shows the deliveries of aircrafts by the 4 large companies in the commercial segment. Industry giants Boeing and Airbus currently dominate this segment, operating a near duopoly (accounting for approximately **96%** market share). However, several competitors are emerging. For example, Canada-based Bombardier is releasing its CSeries family of aircraft, the largest model of which will come close to large commercial aircraft capacity. Moreover, Chinese company COMAC is developing the single aisle C919, while Russia-based United Aircraft Corporation's Irkut subsidiary is developing the single aisle MC-21. In general, recent developments in commercial aircraft technology has focused on producing more efficient aircraft, with reduced fuel consumption, more passenger and cargo space and lower maintenance costs. Manufacturers have addressed these issues by primarily using more composite materials, installing advanced avionics and integrating a new generation jet engines. Aside from a few completely new models introduced by Boeing (787), Airbus (A380, A350 XWB) and new entrants, most new aircraft being designed are upgraded versions of older generation planes that are being redesigned to include aforementioned technology. Over the past five years, demand for these aircrafts has increased considerably, with new airlines forming in emerging economies, although most demand has been centralized in the narrow body aircraft segments due to their versatility and increasing demand for more frequent but smaller flights.

Category – Regional and General Aviation Aircrafts: Together these account for only **3%** of industry revenue. This product segment is far more competitive than the large commercial aircraft segment (wide and narrow body) due to a larger number of global players and relatively lower barriers to entry. Overall, five companies dominate this segment: Bombardier, Brazil-based Embraer, US-based Gulfstream Aerospace (a division of General Dynamics), US-based Textron (through its Beechcraft and Cessna subsidiaries) and France-based Falcon (a unit of Dassault). However, due to their low price compared with LCAs, this segment's share of revenue is small. Regional aircraft are small, single-aisle passenger aircraft incapable of transcontinental flight and typically have below 150 seats. By far the two largest players in this segment are Bombardier and Embraer. However, Russia's Sukhoi (a unit of United Aircraft Corporation), China's COMAC, India’s NAL and Japan's

Mitsubishi are all currently developing or have already introduced new regional aircraft. As with the narrow and wide body market, rapid economic growth in emerging markets and fleet replacement in developing ones are driving demand for new regional aircraft. General aviation aircraft are mostly composed of business aircraft (which are small jets used by corporations, individuals and government organizations for private passenger transportation) and small personal-use planes. This category is more fragmented, with Bombardier, Embraer, Textron, Gulfstream and Falcon all having significant market shares. In general, the global economic slowdown had a devastating impact on general aviation, with segment revenue below pre-recession levels. In particular, small companies and wealthy individuals have had difficulty buying new and often unnecessary small business aircraft amid financial troubles. Moreover, potentially large markets such as China have been cooled by anti-corruption drives and public opinion which has made business jet ownership a public relations and government scrutiny risk.

Category – Freighters: Finally, logistics companies like FedEx and UPS purchase freighter aircraft to rapidly transport freight. This accounts only 1% of total industry revenue.

Life Cycle: The Global Commercial Aircraft Manufacturing industry is in the mature stage of its life cycle, characterized by slow growth, market acceptance, static product offerings and industry consolidation. Industry value added (VA), which measures an industry's contribution to the economy, is projected to grow at an annualized rate of 5.5% over the 10 years to 2023 (source: IBISWorld). Comparatively, world GDP is forecast to increase at an annualized rate of 3.4% during the same period. Most of the industry's performance can be linked to strong economic growth in emerging markets and the replacement of older aircraft in established ones. While IVA growth that exceeds the rate of GDP expansion is typically indicative of a growing industry, there are other factors that situate the industry in maturity. In general, the life cycle stage of the aircraft manufacturing industry differs between countries and world regions. While mature in the United States and Europe, the industry is only just taking off in other parts of the globe. Many quickly developing countries, such as China and India, also aspire to manufacture their own commercial aircraft; Airbus set up its first facility in China in the past few years. Furthermore, the Commonwealth of Independent States and Russia also revitalized their aerospace manufacturing industry to cater to the steady growth in demand. Overall, commercial aircraft manufacturers benefit from a very wide customer base. Still, commercial aircraft are stable products. Although industry operators invest heavily in research and development, aircraft developed is primarily focused on improving efficiency and lowering operating costs. For instance, new passenger aircraft, such as Boeing's 787, incorporate fuel-efficient technologies like new engines and increased use of composite materials. Plus, industry performance is linked to the health of the global economy, which is further indicative of an industry in maturity. The length of time between all-new civil aircraft programmes has been increasing, from around 8 years in the 1960s and 1980s to 12 years in the 2000s as illustrated in Figure 3.12. Instead of developing all new aircraft, airframers have been able to meet market needs by technology insertion (e.g. new engines, winglets) or creating variants (e.g. stretch fuselages, long-range). This has been made possible by the modular design of the aircrafts (Frigant and Talbot, 2005). Thus Airbus A318/319/320/321 and A330/340 have the same instrument panel, same piloting procedure, same avionics and same systems. There is practically no difference in the cockpits. Wings of the A318/319/320/321 are all identical, only length of fuselage differs (and hence the seats). Same principle applies to A330/340 with number of engines being variable (2 to 4). Based on this the two companies have developed the term family, within which product architecture and various interfaces are shared by all models. This allows development of any sub-system without having to define the entire product. Such a programme can extend for over 40 years which can go through major technological transformations without having to change the initial product design. The development costs associated with these programmes are much lower than all new aircraft. Clean-sheet aircraft programmes typically cost between $10 and $15 billion, whereas variants and

new engine adaptation cost between $1 and $5 billion. The analysis shown in figure 3.12 indicates a trending down of large civil aircraft programme R&D through to 2020, recovering and rising through to around 2026 to support new projects. The analysis also suggests a shift in this programme activity from Europe to North America and Asia that rebalances in 2030. This raises several important implications for commercial aerospace industry such as capability sustainment, increased commercial significance of new programmes, greater delay and risk to realising returns from research, and shift in trade geographies for example.

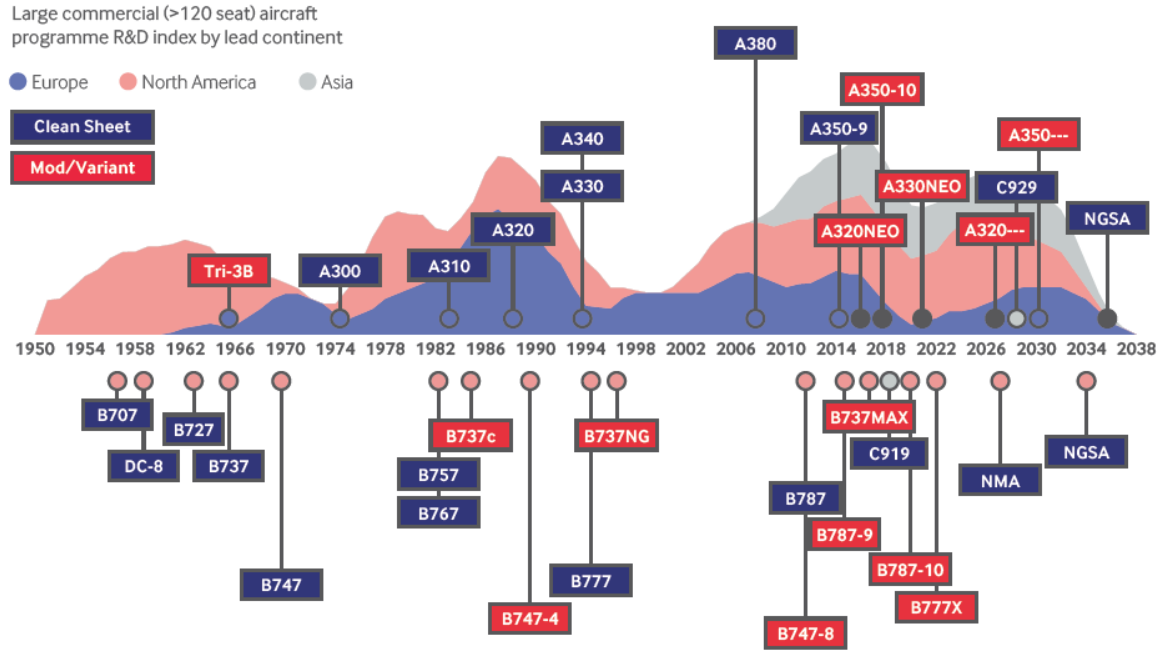

Figure 3.12: Historical large civil aircraft programmes and future market speculation (Source: ATI analysis, 2018) – NMA (New Midsize Aeroplane), NGSA (Next Generation Single Aisle), R&D Index: % of R&D Expenditure in overall continent GDP

3. Parts, Components, Engines and Aftermarket: Aircraft parts and components is by far the most fragmented in the industry. It segments (wings and fuselage) and parts ranging from landing gear to fasteners. The production of this product category has also become the most globalized in the industry (Figure 3.5), with many aircraft manufacturers outsourcing their parts and segment production operations to other industry operators, some of which are in lower labor cost countries. As a reflection of overall industry development, products in this category are increasingly made from composite materials, with aircraft manufacturers and users putting emphasis on component strength, reliability and cost of maintenance. Aircraft engines include turbine, shaft, jet and rocket engines. Engines can be further segmented into takeoff thrust categories, which can then be matched against aircraft classes. In addition, engine manufacturers often derive half of their revenue from providing services like maintenance. Over the past five years, engine fuel efficiency has increased as volatile oil prices and environmental concerns have created demand for more fuel efficient and clean power systems. In addition to improving efficiency, manufacturers have used more composite material to reduce weight, further reducing fuel consumption and controlling maintenance costs by including materials that last longer. This industry product segment is currently dominated by General Electric, United Technologies Corporation (through its Pratt and Whitney subsidiary) and Rolls-Royce. Moreover, these major players often form joint ventures with themselves or other engine manufacturers, such as Safran, to produce tailored engines for a specific aircraft or aircraft category.

Maintenance, repair and overhaul (MRO) services is a significant aerospace sub-sector with substantial industry revenue. MRO services typically involve airframe, engine and component repair and maintenance as well as scheduled maintenance, which is called line maintenance. Currently, engine and airframe maintenance comprise the bulk of MRO services at 42.2% and 24.5% respectively while component and line services comprise 16.7% and 16.5% of MRO Activity (IBISWorld). Most of these services are ad hoc so demand fluctuates with weather conditions and changing technology. Line maintenance is dictated primarily by the country of residence, although global standards on airworthiness also help to stabilize demand worldwide. Line maintenance is on an A, B, C and D schedule based on the number of flight miles an aircraft has undertaken. A checks are regular maintenance services performed every X number of flight hours, which is contingent upon the type of aircraft. B checks are performed approximately every four to six months and are typically more diagnostic in nature more than repair based. C checks are more comprehensive, performed every two years, which often includes replacement parts and engine cleaning services with a partial disassembly. D checks are performed every five to 10 years on average and these are the most comprehensive. D checks include disassembling most of the aircraft for inspection and overhaul, including paint and skins. These typically take up to two months to complete. During the time it takes to complete these checks, an aircraft cannot leave the hangar or maintenance base.

Parts and component manufacturing, which has lower barriers to entry, consists of hundreds of companies and is less concentrated. Still, MRO operators are least concentrated because they typically operate on a local scale, although MRO services are increasingly being undertaken by upstream manufacturers through warranties and service contracts. As noted in earlier sections of this report, the commercial aerospace industry revenue is dominated by the astronomical prices of the completed aircrafts as the components, parts, even engines and MRO services are not included as these are reported as separate segments of the industry. Though a large amount of sales (almost of equal proportion as the total aircraft revenue) are expected to be derived from parts alone, counting them in the overall industry revenue will only result in double counting of revenues and give a wrong picture of the market size. Since the parts go into both the new equipment and the aftermarket, it is also difficult to segregate which part goes to which market and estimate the revenue resulting thereof. So we have reported each individual major aircraft module separately in the next few sections. It can be seen that these parts are generally inexpensive compared with completed aircraft but make up a larger share of industry output by volume. We would prefer to keep MRO business separate from aerospace manufacturing revenue to understand the relative proportion of services to manufacturing in the industry.

4. Future Industry Trends: A key driver of the commercial aircraft manufacturing industry is the technological frontier in aircraft manufacturing. This has been shifted again and again by innovators located in the advanced industrialized economies, creating a moving target for latecomers to catch up with. Aircraft development also continues, albeit at a slower pace. With the exception of the Boeing 777X, and potentially their as-yet un-launched mid-market airplane , there is no other 'clean-sheet' aircraft currently in development by the big two, although a Sino-Russian collaboration to produce a next-generation wide body is in the pipeline.

Engine Technology

- What is also certain, is that engine manufacturers are all investing in research and technology for the next generation of aircraft, and in the mid-term all of them appear to be banking on the current turbofan architecture to improve fuel-efficiency. But any fuelburn savings from propulsion systems will undoubtedly be driven by the employment of increasingly exotic materials – ceramic matrix composites, for example – to allow better thermal efficiency in the hot section of the engine, or the use of a gearing system – as seen on Pratt & Whitney PW1000-series engines – to separate the fan and turbomachinery, allowing each to operate at its optimum speed. On that note, Rolls-Royce is working on its geared UltraFan programme,

coupled with development of a more efficient core as part of its advance research. Engine Technology for Efficiency: Rolls-Royce has entered the geared turbofan race with its UltraFan™ engine project. This project promises a 25% improvement in efficiency using gears and variable pitch, versus Pratt & Whitney's 15%. GE and Snecma are convinced that a geared turbofan is too complex and too heavy. They intend to achieve comparable numbers with other techniques. However, Pratt & Whitney have put plans for a larger engine on hold.

- New Materials: Rolls-Royce will be producing a next-generation engine before its UltraFan geared turbofan. This engine, called the Advance, is a good example of 2 material trends in engine design: composites and ceramics. The Advance will have carbon/titanium (CTi) fan blades, a composite casing, and advanced heat-resistant ceramic matrix composites for efficiency at higher operating temperatures. The ceramics decrease the amount of energy used to cool off engine parts. Current engines divert air from the compressor to create a protective cooling layer, while the ceramic composite does not require this cooling. The GE/Snecma LEAP engine uses ceramic composite materials that weigh far less than metal materials and endure far higher temperatures. The engine also has 3-D printed parts.

Digitalisation

- Digitalization of the commercial aerospace sector includes the use of Big Data analytics, data integration, and Internet of Things (IoT) in every aspect of the business—from passengers to gathering data from onboard sensors during flights—leading to efficient predictive maintenance. OEMs and suppliers are shoring up their digital infrastructure in an attempt to gain a share in the digital market. The current market landscape is convoluted. As Boeing notes in its 2017 technician forecast: "As airlines continue to take delivery of new airplanes, advances in airplane technology will drive an increased need for technicians skilled in avionics, composites, and digital troubleshooting".
- Clearly digitisation will have to play a significant part in helping to address this challenge, for example, technicians using virtual reality will be able to better visualise how components fit together – enabling them to 'step inside' an assembly or view it from multiple angles. And, of course, there are simple cost and time saving improvements, such as paper manuals becoming a thing of the past, and repair staff being able instantly to call-up relevant data on a handheld device. Also, a further strand of competition is emerging as the original equipment manufacturers attempt to capture an increasingly large share of the services and support sector. While original equipment manufacturers (OEMs) have always been present in this sector, for instance in relation to engines or landing gears, airframe manufacturers are also now seeking to provide end-to-end maintenance solutions for their customers. Boeing, in particular, is growing its Global Services division, with an ambitious target of generating $50 billion in revenue by 2025. Boeing – ANALYTX Developed by Boeing Global Services, ANALYTX is aimed at providing flight data analytics to global commercial and defense customers. Services include crew scheduling to supply chain inventorying. Airbus and Boeing are developing interfaces that will permit the retrieval of complete aircraft sensor data. From 2018, Airbus will equip all its A320s with a secure server router that collects aircraft maintenance and performance data and automatically transmits it to ground-based operations via 4G on the ground, and satcom broadband in the air. The new system captures 100% of the available data, or 24,000 touchpoints, or 'health parameters'. This is called Skywise, from Airbus, a data platform targeting airline customers to improve operational performance and business results through the use of Big Data integration and advanced analytics. Rolls Royce launched R^2 Data Labs in 2017, which is a Big Data service offering advanced digital capabilities to customers. GE Aviation developed PREDIX, a cross-industrial IoT platform, that provides asset and flight risk management, network planning and a multitude of related apps. Honeywell's GoDirect suite offers a portfolio of flight efficiency tools including both software, portal and hardware.

Electrification

- With increased demand for power in digitalising commercial aerospace, the generation capacity of the aircraft also needed to grow remarkably. Each 787 can produce around 1,000kVA for its on-board systems, according to Boeing's figures, markedly more than previous-generation models. Electrification: While current propulsion technologies are still wedded to the consumption of fossil fuels, over coming years we will see the increasing electrification of aircraft. And this poses another set of challenges and opportunities for the sector – which can be divided into two strands: more-electric aircraft, for example, the 787 or A350 compared with previous-generation wide-bodies, and electrically-powered aircraft. Hydraulic and pneumatic systems – such as those for actuation or air conditioning – are already being replaced by electrical systems to save weight and improve reliability. the biggest advance most recently was the arrival of the Boeing 787 in 2011. This was the first large passenger aircraft to use electricity, rather than engine-bleed air, to power the cabin air conditioning system. It also featured electrically actuated brakes and an electric de-icing system.
- Another revolution in propulsion technology is currently brewing: driven by both incumbents and start-ups, a large number of programmes with some form of electric propulsion at their heart are currently in development. These vary from small general aviation aircraft and urban mobility designs all the way up to proposed commercial airliners. If an electrically-powered aircraft in the latter category is to be realised, Airbus believes that it would require 40MW of power for the take-off phase, dropping to 20MW during cruise. As a step towards that eventual goal, the manufacturer, along with partners Rolls-Royce and Siemens, is developing its E-Fan X hybrid-electric demonstrator, which should fly in 2020.
- For its part, Boeing is pursuing its interests in the electric propulsion space via an investment in start-up Zunum Aero, which will initially develop an electrically powered 10-seater, with plans for two larger regional jets to follow. In addition, new market entrants such as Wright Electric – which has the ambition of bringing to market an electrically powered180-seat short-haul aircraft by 2027 – are also emerging.
- Although there is considerable research and development activity in this area, making real progress, there remain significant barriers to overcome. These include technological hurdles such as battery performance, notably in terms of weight and energy storage density. The industry will also need improvements to the weight and efficiency of generators and motors to achieve required performance levels in the future for large commercial aircraft. Even if a hybrid-electric system can be achieved as a first step, the required generation and conversion equipment would almost certainly be heavier than the fossil fuel-based propulsion system. Some estimates suggest that to compensate for this, we would need to reduce the airframe mass by around 20%; a huge challenge given the mature state of aircraft design, where significant investment is required for minimal gain.

New Manufacturing Systems

- The 777 production line is a variation of Japanese automotive lean manufacturing methods, using a continuously moving assembly line that moves aircraft from one assembly team to the next. All of the tools, parts, plans, and work instructions are delivered to employees so they have what they need, where they need it, and when they need it. The final assembly line for the A350 was designed to have a highly automated final assembly line. A streamlined aircraft assembly process for the A350 allows teams to work in parallel, reducing the time from the start of final assembly to aircraft delivery by 30%.
- 3-D modeling is rapidly becoming the norm. Models are exchanged with subcontractors and rapid prototype firms, reducing the design-to-build time. Aerospace has high costs of manufacturing due, in part, to the low volume and high costs of inventory. Lean production from the subcomponent manufacturer to the aircraft OEM drives low inventories and just-in-time manufacturing. Companies that have adopted flexible manufacturing, which reduces set-up time and allows small-lot manufacturing at reduced costs, have improved margins.

- Additive Manufacturing (AM), often called 3-D printing, is beginning to make an impact on aerospace. An increasing number of non-critical parts, such as interior components, are being manufactured in this manner. Airworthiness authorities have not approved AM solutions for flight-critical components, which will likely occur over the next several years depending on the validation of conformity and repeatability. The most likely products for AM are single material components. Hybrid solutions will likely grow out of commercial applications from other industries. The legacy spare parts market is the best low-hanging fruit, as AM could eliminate the need for casting molds and forging dies, and could help replace legacy manufacturers that have gone out of business. The uptake of 3D printed parts will be rapid: by 2020 engine manufacturer GE Aviation estimates it will be producing 100,000 individual components via 3D printing. AM and other automated processes could eliminate complete tiers of manufacture. Using 3D printing, Airbus has enabled small-batch manufacturing that is quicker and produces components that are around 15% lighter than earlier versions. Similarly, manufacturer ATR is using 3D printing to produce low quantities of cabin parts for out-of-production variants of its turboprop airliner family.

Supplier OEM Relations

The fundamental elements which will define 2019 for aircraft OEMs are not primarily associated with their internal ability to continue ramping up production but rather the ability of their tier 1 and tier 2 suppliers to:

A. fully ramp up themselves ahead of an increase in the production rate

B. work with their own respective supply chains and second source with other suppliers if required

C. handle personnel issues associated with possible shorter-notice rate increases

Both of the major OEMs have engaged new programs to improve internal efficiency and increase the competition between suppliers. As a result, they have made the supply chain more competitive. These programs include:

- Airbus Scope + Program
- Boeing Partnering for Success (PFS)

Boeing and Airbus are engaged in a price war, particularly for single aisle aircraft and older platforms, to enable the bridging of new programs such as 777-300ER, A330-200 and A330-300, and A380

- Suppliers will benefit from these renewed relationships, especially while Boeing supports its suppliers' own rationalization efforts.
- Therefore, suppliers need to help. They represent 65% of the total aircraft cost.
- Airbus and Boeing are no longer accepting excessive margins from some suppliers. For example, Airbus has asked its supplier for the A320 to decrease their price by 10% until 2019 to increase program profitability.
- Boeing's 787 risk-sharing partnership, although very innovative, needs to be tweaked to keep better control of production schedules.
- The Boeing buying process was chaotic and dissociated between sites, which is an important internal coordination issue.

Size of the Market

The International Air Transport Association (IATA) forecasts that global passenger numbers will almost double in the period to 2036, rising to 7.8 billion annually. To match that demand, the aviation industry is continuing to raise output to historic levels. In July 2018 Airbus announced that nearly 37,400 new aircraft – valued $5.8 trillion – are required over 20 years, doubling the world's passenger fleet to more than 48,000 aircraft. Driven by that forecast, the two big aircraft manufacturers – Airbus and Boeing – are both looking at taking narrowbody production to unprecedented levels and challenging the supply chain to meet the demand. This is a significant issue, bearing in mind engine and interior manufacturing have both proved to be recent production bottlenecks – then we could see a monthly output of a combined 130 aircraft from 2020 onwards.

Narrow-body aircraft will see a surge in production during the middle term (2021-2024) of this period, while wide-body platforms will see a production spike in the later years (2025-2028) (Figure 3.13).

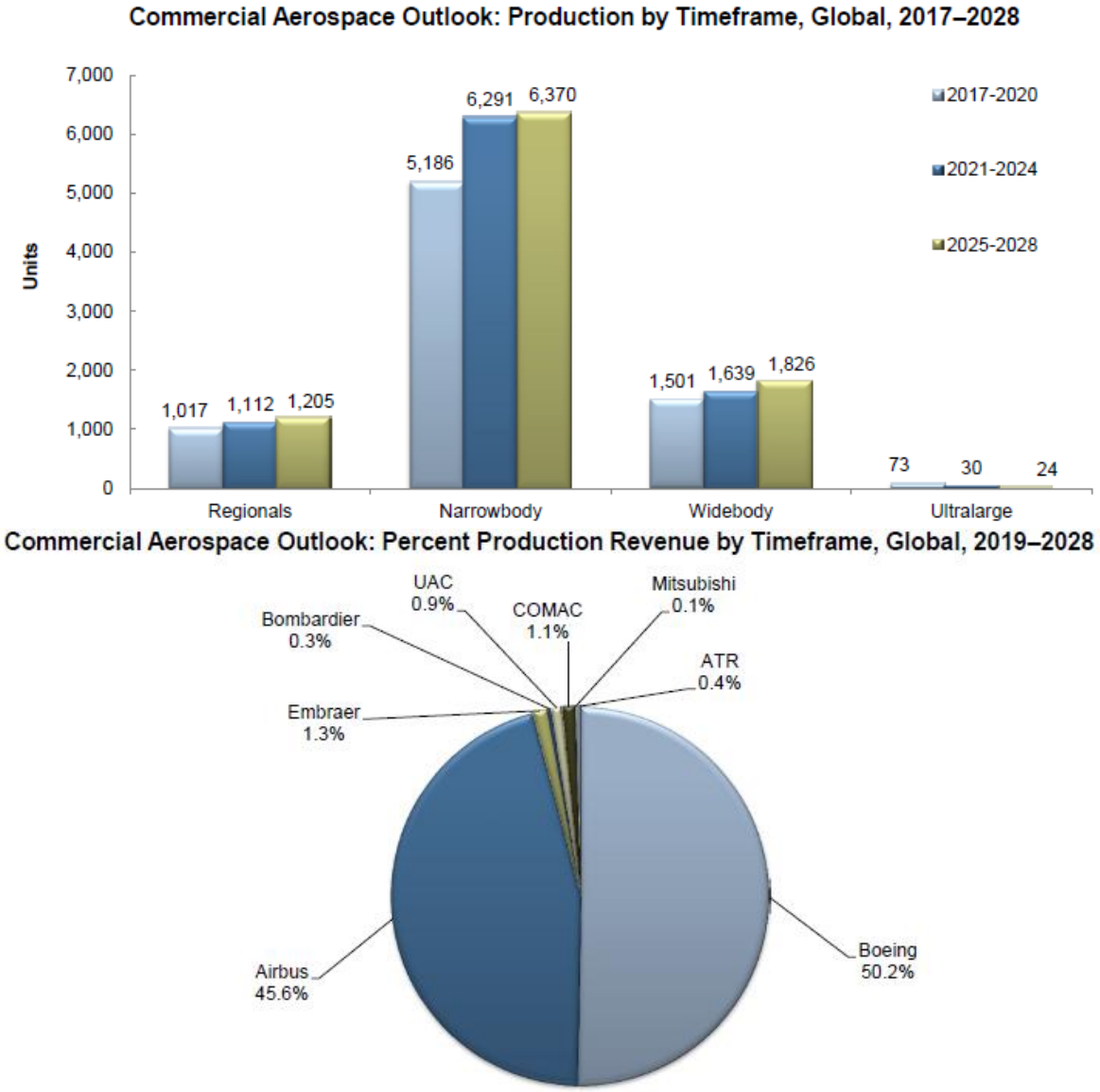

Figure 3.13

Boeing and Airbus will maintain their leading revenue share during the forecast period as well, despite the presence of new market participants. The COMAC C919 narrow-body aircraft, currently dredging through the flight test phase, faces certification challenges relative to sales for international travel, but will sell well for travel within China. The overall market size will grow at a CAGR of 5.5% (Airbus, IBISWorld) to **$350b in 2024** and $450b in 2028 as per combined forecast by Airbus and Boeing. This is largely driven by increased demand from Asia Pacific markets but tapered due to the mature phase of the industry with no new platforms coming into picture within the 10 year period of 2019-28. Unit production count will start to flatten after 2022. The key to Boeing's future will be its ability to transition to new versions of the 737 and 777 in the short term and investing in bringing out NMA and NGSA. As per Boeing's 2018 outlook, production of wide-body aircraft will continue to remain at around a third of Boeing's delivered aircraft. Airbus will continue to increase its production over the next 4 years (until 2022) and will have will only have a modest change in product shares.

5. Industry As Is – Rotary Wing Platform: While helicopters account for a very small proportion of the total aerospace industry revenue, they are among the most common commercial aircraft in the world, with the world fleet at around 22000 in 2017 (source: JetNet). This is primarily due to the lower per unit costs of helicopters compared with commercial planes. The nature of helicopters enables them to carry out a broad range of tasks, including passenger and cargo transport and search and rescue missions. Currently, the civil helicopter segment is dominated by Europe's Airbus Helicopters, a division of Airbus, and AgustaWestland, a unit of Leonardo; US-based Bell Helicopters, a unit of Textron, and Sikorsky, a unit of Lockheed Martin; and other operators, such as Moscow-based Russian Helicopters. Figure 3.14 shows the market share of different companies in global civil helicopter market in 2018. The total market size (source: Airbus helicopters) is **$6.5b in 2018**. The recent plunge in global oil prices has forced many oil and gas producers to cut their investments, especially into expensive and hard to reach fields which are usually navigated via helicopters. Consequently, demand for helicopters which are used to reach those fields has declined. North America the USA and Canada included does have the greatest number of active civil and commercial helicopters (42%). This is followed by Europe then, Asia, South America, Australia and Africa. Fleet renewal and expansion are another indicator of how active the region happens to be at a given time; done by comparing the % change in regional fleet size each year. In this count, Asia ranks first in the past 10 years registering the highest fleet growth rate. In 2017, the Asia fleet of civil rotorcrafts increased by 3%, compared to only 1.5% in US. The greatest proportion of helicopters are in the General Utility and Corporate/VIP sector, Emergency Services/Search and Rescue plus Oil & Gas take up a little more than a quarter of all active helicopters. News and Television hold onto 1% share of the active fleet.

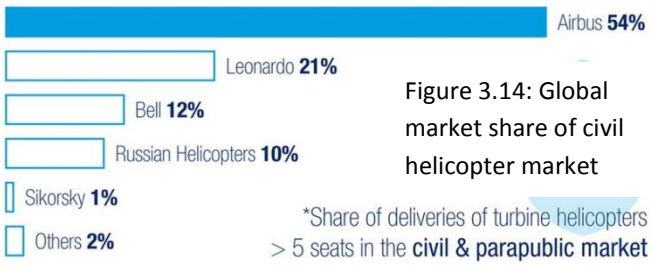

Figure 3.14: Global market share of civil helicopter market

In its 21st annual "Turbine-Powered Civil Helicopter Purchase Outlook," Honeywell forecasts 4,000 new civilian-use helicopters will be delivered from 2019 to 2023, marginally lower than the 4,200 cited in the five-year forecast from 2018. The operational fleet today has an extended 'aviation' lifespan. Approximately 1/3rd of today's operational fleet of helicopters are greater than 25 years in service. Though this is a promising enough factor to boost rotorcraft sales in coming 5 years, Heath Patrick, president, Americas Aftermarket, Honeywell Aerospace, said - "Despite positive impacts of U.S. tax reform on new helicopter purchase plans in North America, an inconsistent economic outlook for international markets has resulted in lower purchase plans worldwide from fleet managers when compared with a year ago". Purchase plans for North American market show that 18% of the customers would expand their fleet with a new helicopter over the next five years. Close to 65% of planned North American purchases were identified as light single-engine models, while roughly 22% of new planned purchases were for intermediate and medium-twin product classes. In Europe nearly 15% of the customers would either replace or expand their fleet with a new helicopter over the next five years. Intermediate and medium twin-engine classes captured roughly 30% of new helicopters. Meanwhile, 25% of indicated plans are to purchase light single-engine helicopters. Latin America had the lowest rate of new aircraft purchase plans globally (only 9% would either replace or expand their fleet with a new helicopter over the next five years). Latin America favored light single-engine models, which represent about 70% of their planned purchases. Middle East and Africa had the second highest new purchase rate globally, with 15% of fleets expected to get a new helicopter replacement or addition. Close to 70 percent of planned new helicopter purchases were medium twin-engine models. Light single-engine models would be the second-highest. In Asia Pacific close to 13% of the fleet would either be replaced or expanded with a new helicopter over the next five years. Light single-engine and medium twin-engine helicopters were the most popular classes, both

capturing near 30% for new helicopters. Based on such estimates, new platform procurements will grow at a compound annual growth rate (CAGR) of 2.0% and will present a 2024 market size of around $7.5 billion globally. The law enforcement segment will sustain the market as other roles are outsourced. The reduction in spending for oil and gas platforms will continue for several years. Still growth will be more for commercial sector, light single engine helicopters (<2.5t). There is a growing appetite for high-speed and long-range helicopters, with green efficiency being a key requirement. Demand for manned and unmanned police units will increase in the medium term for better response to urban warfare. Crime prevention and surveillance missions will grow in the long term. Smarter vehicle systems will emerge with the rise of Big Data analytics for platform maintenance and system status monitoring, which will positively affect the industry. Substantial safety, operational, and supply-chain improvements will benefit future helicopter programs.

The main restraints for commercial helicopter market penetration in transitioning regions are a lack of infrastructure, skilled personnel shortages, and complex regulations. The advent of urban air mobility (UAM) services though in its infancy (Daimler-backed Volocopter and Chinese startup Ehang have already demonstrated their aircraft) is attracting attention of governments worldwide as a substitute for traditional helicopters with many operational constraints (noise, space, infrastructure etc). Government are planning for a proof-of-concept up and flying within the next two years. The whole commercial/civil rotorcraft industry is going for a shakeup, as Uber, Google and traditional rotary wing aircraft manufacturers such as Bell and Airbus Helicopters are trying out electric vertical take-off and landing (eVTOL). Although there is a marked difference between the various technological configurations being planned, all are consistent in proposing designs which use Distributed Electric Power, with multiple rotary wing configurations and cutting- edge battery technologies. The Big Data revolution will affect avionics and mission systems of the helicopters in the form of on-board use of smartphones and tablets. In order to operate such future rotorcrafts, training and skill development is a key factor in all regions.

3.2 Global Military Aircraft Industry

The Global Military Aircraft and Aerospace Manufacturing industry develops and manufactures military aircraft and aerospace products, such as fighter jets, transporters, tankers, missiles and intelligence satellites. Over the past five years, the industry has lost some altitude due to initially shrinking Western defense budgets. The wind-down of large-scale combat operations in the Middle East, combined with budget pressures caused by economic underperformance, forced many Western countries, such as the United States and most Western European nations, to cut military spending. As a result, demand from the industry's most significant markets declined, leading to reduced revenue. Moreover, because a significant portion of industry revenue is earned in foreign currency, the appreciation of the dollar reduced industry revenue in dollar terms. However, rising spending on defense by emerging economies helped offset some of the drop in demand for industry products and even helped many Western industry operators maintain revenue via exports. In this section we will cover the key aspects of military fixed and rotary wing aircrafts mainly. Missiles, satellites are left out of scope for this report.

1. Key Drivers

- *The Security Environment*: This includes examples such as the fall of the Soviet Union, or the more recent expansion of China into the South China Sea, or Russia assertiveness in Ukraine. In the Middle East, the uprising by Houthi rebels in Yemen and gains made by ISIS in Iraq and Syria are being tackled through a coalition format with the extensive use of precision air strikes. Events such as these are driving investments in the procurement and modernization of combat aircraft. Despite the recent improvement in relationships between North Korea, Republic of Korea and the United States, the affected nations maintain high operational readiness and have plans to introduce a large number of 5th generation combat aircraft to

the peninsula to ensure air superiority and maritime strike capabilities. These changes will influence governments to either increase or decrease defense budgets. The latest SIPRI data from 2018 global defence spending shows 2.6% increase in 2018 of around $1.8trillion.

- *Global, Technological Competition in A&D*: This captures the pressure that technological advancements place on governments, firms, and markets. Examples include new air defenses, stealth etc. Future air combat environments will present challenges to older generation combat aircraft in the face of new air and ground based sensors and weapons capabilities. Proliferation of advanced weapon systems such as MANPADS among terrorist groups, improved air defence systems, longer range radars, BVR missiles, complex EW systems and others can be countered mostly by only Generation 4+ aircraft or heavily modernized Gen 3+ platforms. With increased digitalization of battlespace and forces moving towards collaborative network-centric operations, upgrades or new-generation aircraft are necessary to fit into the theatre of operations. Installation of new-generation ECM, Electronic Warfare Self Protection suites, AESA radar, improved targeting pods, precision weapons, and sensor fusion-oriented mission control systems will be the minimum requirements to survive in these combat environments. (source: http://www.defenseworld.net/news/18074/Israel_Retires_F_16_A_B_Fighter_Fleet__Puts_Up_40_Of_Them_For_Sale#.WpPI0FpuYdU)

- *Commercial Market Trends*: The military aerospace sector often lags what has happened in global commercial markets. Examples include global supply chains, outsourced manufacturing, global capital flows, and the import of finished products. It also includes modern business management and organizational theory. The Global Military Aircraft and Aerospace Manufacturing industry is highly regulated. While some regulations protect domestic manufacturers from foreign competition, others prevent companies from exporting their products, thereby limiting their revenue growth. Regulation for the industry is expected to decrease in 2018, as governments soften trade laws to encourage exports. However, regulation will remain high, posing a potential threat to the industry.

- *Ageing Platforms*: The increasing age of combat aircraft fleets around the world (average >25 years, source: Frost and Sullivan, Aviation Week) will drive the need to upgrade or replace programs during the forecast period. In many cases, life extension and upgrade programs will be pursued due to budget constraints and the need to provide enhanced capabilities in the face of new threat environments. Eastern European and African countries that currently operate vintage Soviet origin fighters will seek modern combat aircraft solutions, possibly through new procurement or second-hand surplus supplies, such as Romanian F-16s (ex-Portuguese) and Croatian F-16s (ex-Israeli). Countries like India and Russia will also be replacing ageing platforms during the period. Modernization and life extension programs are expected to stem from less developed countries such as Algeria, Chad, Gabon, and Namibia to name a few, whilst most life extension contracts have already been allocated to vendors by more developed countries (the vast majority being F-16 life extensions). Central & South American countries such as Colombia, Chile, Brazil, Ecuador, and Venezuela operate Gen 3.5+ combat aircraft whilst the vast majority is made up of ageing Soviet era and older US fighters (such as the F-5 and A-4). These are costlier to operate than many new variants in the market. For example, the older A-37 engaged in strike roles is more expensive to operate as compared to the relatively more advanced EMB-312 Super Tucano. The need to phase out obsolescent aircraft and reduce operational costs drives combat aircraft procurement and modernization.

- *Geopolitics of Sourcing*: Geopolitics plays a strong role in procurement of fighter aircrafts – when a country buys a fighter, it also buys a strategic relationship. Increasingly customer countries are seeking multiple such sourcing contracts perhaps to hedge against the risk of arms cutoffs due to diplomatic relationship strains. Egypt has broken its three decade streak of US fighter reliance by sourcing Rafales from France and MiGs from Russia. Qatar has become the first export fighter customer to order 3 twin engine heavy models (F15s, Typhoons and Rafales) at the same time.

- *Lockheed Martin's F-35:* This is the single biggest market driver, with long awaited production ramp finally seeing results. Last year deliveries jumped to 91 aircrafts from 66 in 2017 and 46 in 2016. 2019 expectation is 130 deliveries. This growth is going to continue till 2023 with a peak of 164 in 2023. F-35 lines will be capable of reaching 180 deliveries with currently planned facilities.

These factors and other small ones (as material prices, new participations, research and development, FDI policies, MRO) will drive the fighter aircraft market.

2. Industry As Is: The modern fighter aircraft market as it is currently structured is on a trajectory toward market failure in the long term if we analyse using Porter's five forces. The Global Military Aircraft and Aerospace Manufacturing industry is in the mature phase of its life cycle. Industry value added (VA), which measures of the industry's contribution to the global economy, is expected to rise at an annualized rate of 1.0% over the 10 years to 2023. Comparatively, global GDP growth is expected to reach 3.4%. In general, the industry's contribution to the world economy has slowed primarily due to the end of major wars and reduced military spending in the western world. Capacity for further sales is dependent on the threat of war and new products released into the market. The huge amount of research and development that goes into this industry spurs some new product development. Recently, the emphasis has been put on developing unmanned aerial vehicles, new missile systems, stealth technology and surveillance systems. Establishment growth in this industry has been minimal due to the high barriers to entry. In addition, players in Europe are continuing to undergo consolidation. Businesses felt the need to combine resources to meet the challenges of global competition and to respond to orders for transnational projects, in both the civil and defense sector, which are increasingly being undertaken on a pan-European basis. In Europe, mergers and acquisitions between state-owned companies and private enterprises have led to an increase in privatization, hence the ability to compete on a global scale. In the United States, however, mergers between civil and defense contractors provided the basis for players to use economies of scale and technology transfer to maintain their lead in the industry. Substitute products in defense aerospace for now appear implausible. No weapon system now in use could cover the range of mobile offensive and defensive capabilities that fighter aircraft offer. Buyers have substantial bargaining power - countries are not monopsonistic price makers, the combination of their legal power, taken together with the limited competition that exists in the market now, positions them to have a strong influence on price. The intricacies of working in the defense industry – particularly in the United States and certainly elsewhere as well – means that to work in the defense aerospace sector requires a familiarity with the same array of policy, practice, and accounting requirements that systems integrators/prime contractors face. This creates a barrier to entry for suppliers, many of which at the same time have the alternative of supplying the less fraught civilian aerospace market. The broad technological complexity of military aircraft also means that many suppliers also have the alternative of repositioning to compete in not only other defense industries, but also in a wide variety of non-defense manufacturing and software industries, giving them exit opportunities.

Generations	Technological features	Relevant fighters
Generation 1	Jet propulsion	F-80, German Me 262
Generation 2	Swept wings; range-only radar; infrared missiles	F-86, MiG-15
Generation 3	Supersonic speed; pulse radar; able to shoot at targets beyond visual range	"Century Series" fighters such as F-105; F-4; MiG-17; MiG-21
Generation 4	Pulse-doppler radar; high maneuverability; look-down, shootdown missiles	F-15, F-16, Mirage 2000, MiG-29
Generation 4+	High agility; sensor fusion; reduced signatures	Eurofighter Typhoon, Su-30, advanced versions of F-16 and F/A-18, Rafale
Generation 4++	Active electronically scanned arrays; continued reduced signatures or some "active" (waveform canceling) stealth; some supercruise	Su-35, F-15SE
Generation 5	All-aspect stealth with internal weapons, extreme agility, full-sensor fusion, integrated avionics, some or full supercruise	F-22, F-35
Potential Generation 6	Extreme stealth; efficient in all flight regimes (subsonic to multi-Mach); possible "morphing" capability; smart skins; highly networked; extremely sensitive sensors; optionally manned; directed energy weapons	

Figure 3.15: Generation of fighters (Source: Lee and Yoon, 2015)

The market is rapidly approaching a fundamental shift with the advent of hyper-expensive fifth-generation fighters and the unmanned platforms that will follow them (Figure 3.15). Individual countries like France and Sweden have struggled to sustain national champions and even joint efforts are reaching the stage at which European defense budgets are insufficient to support R&D costs in light of relatively low production runs. Advanced fourth-generation platforms are already so expensive that marketing them in large numbers to states outside the Euro-Atlantic market has yielded few sales for the Eurofighter, Rafale, and Gripen. Sales of fourth-generation Euro-Atlantic fighters are so anemic that most, if not all, of the production lines face the prospect of closure or very low production at best in the next decade.

At the same time, Lockheed Martin is the only Euro-Atlantic producer currently working to develop or produce a fifth-generation platform. Without another Western firm or consortium ready to enter the fifth-generation fighter market, Euro-Atlantic states that require state-of-the-art fighters may soon have no realistic alternative to the F-35. These customers would be unwise to turn to products theoretically available from potential adversaries (Russia and China) and are unlikely to see products in development by other states (Japan, Turkey, and India) come online soon, if ever. As Lockheed Martin F-35 production increases in scale, development issues are resolved, and per-unit price falls, the airframe's reportedly clear superiority to fourth-generation fighters could well expose fourth-generation alternatives as expensive as well as largely obsolete, although they may serve usefully in concert with fifth-generation assets. A transitional phase may ensue during which some Euro-Atlantic states such as Bulgaria, Canada, Finland, Slovakia, and Switzerland acquire further and more advanced fourth-generation fighters, trading capability for lower cost. This may make it appear as though the Euro-Atlantic fighter market has fragmented into two distinct markets – one for fifth- and another for four-generation platforms, which are not genuinely comparable products, even though their use together in a mixed force may be effective. Euro-Atlantic states are only likely to face Russia, or in the case of the United States, China, as genuine adversaries. This has the effect of limiting the long-term combat utility of fourth-generation platforms, which might need to face those two states' most advanced aerospace products. Some Euro-Atlantic states may nonetheless choose to acquire fourth-generation aircraft, but such choices are more likely to be made for symbolic defense or economic reasons apart from pure military effectiveness. Export purchases of fourth-generation fighters may prolong this transitional phase, but as fourth-generation technology is mastered by outside competitors – in part as a result of co-production and licensing arising from offsets – the market viability of Euro-Atlantic products outside Europe will decrease. This should cut

into orders, reinforcing pressure on whichever fourth-generation production lines survive into the next decade. In the meantime, Russia and China have attempted to create and cope with their own market dynamics.

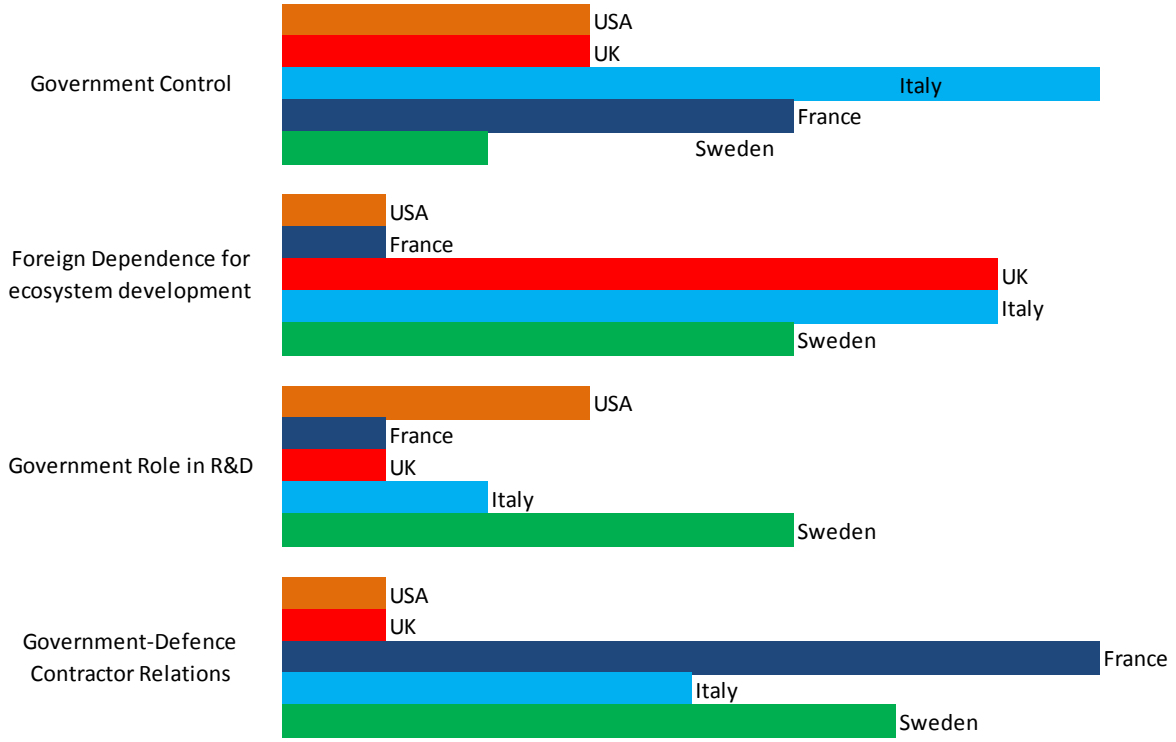

Figure 3.16: Comparison of leading Military Aircraft Exporters

Industrialised Nations Defence Industry Base

In this report we have compared the key ingredients of developing powerful industrial base for aerospace and defence sector in industrialised nations (US, UK, France, Italy and Sweden). All of them are developed through years of consolidation and solid history of government supported capability development. Figure 3.16 depicts the catalytic role government plays in these countries along with dependence on foreign market for exports and capability building. The military policies are decided very informally in France through 100% involvement of the entire defence ecosystem. Compared to all other nations, Italy is the least transparent and most controlling of its defence base. It holds 30% equity in Leonardo. France not only holds ownership in defence companies through multiple modes but also does not allow any foreign firm to acquire or work jointly with French firms. USA though a proponent of competitive market and free market economy with hands off approach towards defence industry but has built multiple monopolies in different specialisations (Lockheed for aircrafts, Northrop for bombers, aircraft carrier producers Huntington Ingalls). On the other hand, Sweden and Britain have allowed foreign participation to develop their industry. Britain though allowed foreign firms to take over British firms, but still maintained golden share (a say in management) in core defence contractor or a national champion BAE Systems. Sweden has privatised all the defence companies but developed only one powerful national champion and maintained good relations with the owner Wallenberg family of Saab. UK has gone far to privatise its defence R&D establishment as well. However, all other countries have retained some government function in R&D. Out of which Sweden's FMV, France's DGA, Italy and US government's roles in developing top quality engineering and research skills for indigenous industry are path-breaking. Appendix 1 compares different industrialised nation's aerospace and defence industry using Porter's Diamond.

Emerging Nations Defence Industry Base

Lee and Yoon (2015) compared three emerging economies in terms of their technology acquisition capability in military fighter jet manufacturing. Whereas "buy" is more aligned with countries with heavy production experiences, "make" is preferred by countries with the focus on basic research and technological knowledge. From the case of Brazil, the important **role played by universities and government research institutes** is observed in developing complex military equipment with a focus on design capability. This phenomenon is similar to the catching-up of Korea and Taiwan in mass-produced goods (i.e., semi-conductor, electric products) that fostered the spin-offs and commercialization of the research outcomes from their universities and government research institutes. However, the institutions of the latter two East Asian countries have focused on production capability. In addition, they discovered that the role of **foreign partners** is crucial in acquiring highly-sophisticated technology through coproduction, co-development, and reverse engineering. Although literature in catch-up adopted the Vernon's (1966) view that "production competence is routine or tactical and thus can be exported", the researchers showed the **importance of manufacturing capability for latecomers in aerospace industry to gain bargaining leverage in various joint venture schemes**. As evidenced from the case of Korea, latecomer with higher accessibility to a foreign knowledge base tends to take advantage of their relationship with a foreign partner by running a close level of cooperation. In this sense, Korea has focused more on supporting existing export industries by producing related capital goods for foreign system integrators. Furthermore, as evidenced from the case of Korea and Brazil, the co-development programs such as **T-50 and AMX** have been effective in acquiring core and advanced technologies. However, co-development programs are the most difficult forms of cooperation to carry out owing to their high cost. In particular, since the countries with less advanced aviation industries typically pay a premium price or commit to purchase significant quantities, latecomer countries need to possess relatively well-developed aviation industries to gain a bargaining advantage in co-development programs. This is the reason why many latecomer countries arrange co-production programs before entering into co-development programs (Saunders and Wiseman, 2011). Meanwhile, latecomers with a low level of accessibility to a foreign knowledge base due to political and diplomatic constraints, tend to make **purchases from their diplomatic allies and conduct autopsies** in a bottom-up mode. In fact, the bottom-up mode occurs as China sees to support strategic and high technology industries for national purposes with the seeds of "techno-nationalism" (Hobday et al., 2000).

There is no doubt that such development requires strong government interventions along with relevant policy initiatives. In this sense, latecomer governments should play a significant role in innovation. Specifically, achieving the status of an indigenous developer requires government initiatives in three areas: strategic, functional, and project. The first step requires having a strong strategic intention to create a viable indigenous industry not to be over-dependent on imported goods. For instance, **it is important to select a strategic industry and establish a national innovation cluster to spearhead and support relevant R&D** activities. Although the government of these latecomer countries recognizes the importance of R&D, their research funding is still increasing slowly and are often not sufficient to stimulate and support the institutional reforms for industrial development. Secondly, **groundwork for basic and applied research should be prepared in academia to train potential scientists and engineers**. Also, **incentives to attract and secure well-qualified human resources from abroad** should be designed to promote the culture of technological innovation and entrepreneurship (Yoon and Lee, 2013). These two are important steps in securing a core knowledge base required for large scale defence projects. Lastly, **international collaboration** through various mechanisms should be pursued to improve access to external knowledge, thereby fostering the transfer of core technology. Latecomer countries show their weaknesses in low degree of involving externalities in their innovation projects, due to closed organizational culture. Involving external parties into the development of platforms could provide the latecomer firms with

opportunities to receive investment and technical assistance. The policy initiatives taken by three countries are discussed in Table 3.3.

Table 3.3:

Latecomers' organizational capabilities for technological learning.

Policy dimensions	Brazil	China	South Korea
Strategic initiatives	Formation of aerospace cluster to construct efficient R&D platform	Lavish investment in national R&D projects with top-down support	Transitional approach from "buy" to "make" by acknowledging the importance of self-defense
Functional initiatives	Establishment of research and education institutions for basic research	Attraction of human resources with advanced degrees in science and engineering from developed countries	Involvement of Korean conglomerates with their reputation as world-leading exporters in manufactured products
Project initiatives	Implementation of various incentives via export, alternate financing, etc.	Management of multiple projects with various suppliers	Skillful use of offset orders and negotiation to arrange joint venture agreement with foreign suppliers

Size of the market

The global market of military aircraft is divided into three different platforms: fixed wing, rotary wing and military transport aircrafts. In any period the market revenue is computed using individual company deliveries and prices thereof.

Combat Aircraft: A total of around 15000 combat aircrafts are operational in 2019 (source: Aviation Week). 2018 saw Lockheed, Boeing, Dassault dominating the defence aerospace market with nearly 52% market share. A look at the in-service age of the top three prolific solutions in each segment indicates that the average age of the fighter and strike segments is approximately 29 years, whilst that of the multirole segment is 22 years, implying that many combat aircraft will need to be replaced or upgraded in the forecast period of 2019-2024. The total market size in 2018 is **$51b** (Source: Frost and Sullivan, Individual company revenue and delivery figures)**.** The market is characterised by three different segments: Strike[1] (Su-24/25, JH-7), Multirole[2] (F-16, Su-27/30/33, F/A-18) and Fighter[3] (Mig-21/31, F5).

- Strike aircraft such as the A-10 and the Su-25, extensively used in Syria against ISIS, are vital to supporting advancing ground forces in urban areas. More advanced defense forces such as those of the United States and Russia also maintain strategic bombers, such as the B-1, B-2, H-6 and Tu-160, for strike roles. There have been a number of technology upgrades to strike aircraft to improve precision strike, targeting capabilities such as installation of optical laser remote thermal imaging systems and survivability. Dedicated strike aircraft will continue to be used in the coming 5 years, albeit with upgrades that enable advanced weapons and with active protection systems.
- Majority of the fighters in use today are either MiG-21 or F-5 variants which were produced between the 1970s and 1990s, designed for air-air combat and as bomber escorts. These aircrafts are still deployed by air forces which are less advanced, budget-constrained, and/or face no or less threats. Most still rely on technology from the 1980s, whilst some are undergoing modernization and life extensions.
- Multirole fighters in operation today are capable of seamlessly switching between different combat roles and are able to utilize actionable intelligence from multiple sources for improved combat effectiveness. The roles played by multirole combat aircraft seem to have broadened with advances in technology. For example, with increased networking between airborne and land-based assets, combat aircraft tend to rely on a large number of data points and, thereby, may receive a larger stream of real-time mission objectives and modifications. Multirole fighter requirements also include high operational availability and cheaper maintenance costs and high sortie rates. Multirole fighters are increasingly being used to carry out strikes on terrorist strongholds beyond enemy lines. New hypersonic super

[1] Strike aircraft are primarily deployed for ground attack missions and to provide close air support to troops on the ground.

[2] A traditional air superiority attack aircraft or interceptor aircraft primarily deployed for air-air missions, with a limited secondary air-ground capability.

[3] A combat aircraft that excels in both air-air and air-ground roles, and can switch between roles in a single mission.

maneuverability, advanced sensors, digitalization, artificial intelligence, and stealth technologies are influencing multirole fighter designs. This is the largest segment with nearly 80% share.

Military helicopters: Helicopters come in various forms and usually carry out attack, scout/utility, surveillance and transport missions. In general, combat aircraft outnumber other fixed-wing aircraft types by a wide margin, while helicopters are the most common military aircraft. Table 3.4 shows the different types of helicopters used globally.

Table 3.4: Market Segmentation and Definitions

End Users	Roles	Definitions	Examples (Non-exhaustive)
Military *(armed forces)*	Attack	Rotorcraft with weapons and reconnaissance capabilities	*AH-64 Apache, AH-1Z Cobra, Mi-28 Ne, EC-665 Tiger, Mi-24/35*
	Maritime	Rotorcraft with maritime surveillance, anti-submarine warfare and weapons capabilities	*Westland Lynx, MH-60R/S, AS-565 Panther, AW-159 Wildcat, Ka-52K, NH-90 NFH, AW -101 Merlin*
	Utility	Rotorcraft designed to fulfil a wide range of missions (combat search and rescue-SAR, Medical Evacuation-MEDEVAC, observation, training)	*UH-60 Black Hawk, H-145M/UH-72A Lakota, AW-139M, H-125M, UH-1 Huey, H-225M Caracal, AW-109 Power, Bell 407*
	Transport	General-purpose rotorcraft used for troops, cargo and logistic transport missions	*Mi-8/17 Hip, H-215M Super Puma, CH-53 King Stallion, CH-47 Chinook, Mi-26 Halo*

Total market size in 2018 is **$40 billion** (Source: Company Reports, Frost and Sullivan). This is mostly considering new procurement/manufacturing and remanufacturing/modifications. After almost 10 years of stagnation and delayed programmes in key regions, the market for military and public services helicopters is facing a slow recovery globally, driven primarily by dynamic economies such as Asia-Pacific and Central & South Asia. However, recent political uncertainty among leading economies over international trade agreements and subsequent actions leading to economic sanctions and reissuing of trade barriers could impact helicopter production lines and exports. Original equipment manufacturers (OEMs) need to consider new strategies for international competition and retain traditional export customers. Military customers are continually facing fleet shortages primarily due to: low-paced replacements on account of budget constraints; more operational requirements and deployments increasing attrition rates and growing lack of skills, particularly in transitioning economies. The market is fairly concentrated with top players Boeing, Leonardo, Russian Helicopters, Bell, Airbus and Sikorsky accounting for 90% share (company reports) in 2018. 2018 was particularly a good year with Boeing making around 70 Apache and Chinook helicopters, contributing to 50% of the industry revenue. Attack segment is found to be the biggest fraction of output of military helicopter industry worldwide.

Military transport aircrafts: Airbus's A400M Atlas is set to dominate the transport market as program participants take deliveries, while most of the remaining market is expected to be controlled by Lockheed Martin's C-130 and Boeing's KC-46A tanker/transport. A total of 4,772 transport and tanker aircraft are in operation across the globe in 2018 (Source: frost and Sullivan). A look at the in-service age of solutions shows that the average ages of medium and light transport segments are 29 years and 25 years, respectively, and could provide market opportunities during the next 10 years. Frost and Sullivan forecasts the market size in 2018 to be **$12b.**

2. Future Trends

Economic upheavals in the recent past have shown that their ramifications are geographically dispersed, affecting nations across the globe. Most nations are wary about aftershocks and have refrained from making large increases to their defense spending budgets. New procurements have been deferred in many cases and planned procurements have been replaced with more economical

lifespan extension programs. Nations are being cautious about outright large-scale procurement and many of those affected by crises are aiming for slow and steady defense budget growths only after their economies show signs of sustained stability. New multirole fighters not only require high capital investments on platforms, but also high components of operational expenditure and sunk costs. As the new-generation multirole combat aircraft are complex platforms, the effectiveness of which often depends on the ability to work with other equally or more expensive assets, they require substantial investment in terms of ISR platform links, sensor fusion, and integration with network-centric systems. Sustainment of such aircraft requires specialized infrastructure, tools, air crew, and maintainer training, which in turn translates to higher costs. Often, sustenance and support costs for a 10-year period equal 60+% of the platform cost. In spite of this Aviation Week's Fleet Data Services has forecasted that, over the next decade the world might see deliveries of 3164 new-built combat aircrafts. This will include 1771 F35s. The decade until 2029 will see retirement of 1835 fighters, 2/3 rds from two families 584 F-16s and 574 F/A-18s. The retirement of so many 4th generation fighters will create opportunities for countries with less sophisticated equipment to cheaply acquire aircrafts though heavily used, will represent a level of capability previously out of their reach. Figure 3.17 shows the distribution of aircrafts in the coming decade.

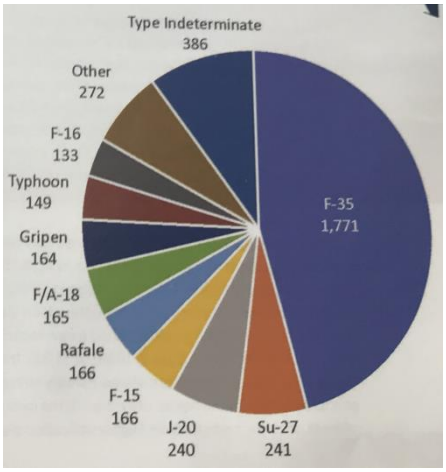

Figure 3.17: Top Fighter New Builds 2019-2029 (Source Aviation Week)

Over 50% of the segment valuation in next 10 years, will be directed towards modernization and upgrades led by programs such as the US's A-10 re-winging and life-extension and possible light attack/ armed reconnaissance program, as well as the Su-35 and Su-25 upgrades by Russia and other nations. The low flying capabilities and high sortie rates of trainer aircraft, combined with low operational costs, make the platform a suitable baseline for counter insurgency oriented modifications. KAI's T-50/ FA-50 and Embraer's Super Tucano are examples. Budget-constrained nations are increasingly turning to these examples for counter insurgency deployments. The coming decade will also see strike aircraft deployed in war zones are being upgraded with active protection systems to ensure protection against heat-seeking warheads. Strike aircrafts are being upgraded to carry smart bombs, missiles, and improved targeting systems. Russia has started arming strike aircraft with independently mid-course correctible cruise missiles. Certain nations have upgraded strike aircraft to share and receive intelligence data from UAS deployed in war zones for greater command and mission efficiency. Most solutions in the market today are multirole fighters, and new procurements in fighter segment will be limited. The market will witness a dip after 2018 as MiG-31 modernization in Russia and F-50 deliveries to Iraq are concluded. Majority of nations today are adopting multirole fighter aircraft solutions as standard as opposed to mission-specific fighter/strike aircraft. Economically well-off markets are adopting Generation 4 and 4.5+ solutions and the segment is getting increasingly competitive. F-35 will remain the sole Gen 5 solution for most of the forecast period. Economically strained countries requiring fleet recapitalization have also started looking at cheaper solutions such as the Chinese JF-17. Multirole fighters are increasingly being

connected with multi-frequency data link systems to improve situational awareness. The mission systems are seamlessly integrated with avionics and sensors, supporting targeting for intelligent weapons. Built-in network-centric capabilities ensure better coordination and collaboration with ISR platforms and systems. The inclusion of artificial intelligence and new haptic interfaces into cockpit designs is complementing new digital cockpit layout with large colour Multi-Functional Displays and Helmet Mounted Display (HMD) to provide aircrew with situational awareness support and minimize information overload. The adoption of integrated multifunction AESA radars, electronic warfare suites, and IRST is standard to provide multispectral information and operational flexibility. The F-35, J-20, and the upcoming solutions for 5th generation aircraft use advanced stealth technology using meta materials that are fine-tuned to absorb certain wavelengths to evade radar detection. Both France and Germany have agreed initial requirements for a new combat aircraft to replace the Rafale and Typhoon, respectively, beginning in 2040. In pursuit of this, Dassault Aviation and Airbus Defence have signed an agreement to work together through a consortium to bring a new-generation fighter into operation by 2035. In the United Kingdom, a consortium consisting of the UK government, Leonardo, BAE Systems, Rolls Royce, and MBDA is planning to come together to develop a new 6th generation fighter Tempest by 2035 to replace the Eurofighter Typhoon. A joint development program with Indonesia, the KF-X will replace F-16 variants currently in operation in both countries. Korean Aerospace Industries (KAI) is the lead developer, with Dirgantara Indonesia (PTDI) having a 20% share. Production deliveries will be in the mid-2020s. Su-57 is a 5th generation fighter being developed by Russia incorporating stealth, internal weapon bays, N036 Byelka AESA radar system, and the L402 Himalayas ECM system developed by Tikhomirov NIIP Institute, SA. India was also a participant in the joint development of the program but has withdrawn in 2018 due to delays and conflict with regards to the capability mix. TFX program is underway at present in Turkey, where Turkish Aerospace Industries (TAI), with assistance from BAE Systems, is developing the TAI-FX, which is a stealth capable air-superiority fighter. This fighter will be operational towards the end of 2030 and will eventually replace the Turkish F-16 fleet.

Based on these assumptions, 2019 will be a good year for the military fixed wing platforms. The industry is going to expand 10% globally on F35 production and deliveries to $55b. After that sales will taper off as new platforms are not going to appear before 10 years. So most of the market, as predicted by Aviation week, will depend on F35 programme and more affordable J20. Frost & Sullivan estimates $101.4 Billion worth of potential opportunities until 2026. Using current pricing and aircraft production forecasts, this will be around $160b until 2029. About 35% of the opportunities presented are modernization programs whilst the rest are procurement. Modernization opportunities will include AESA radar, active protection system, ECM, and electronic warfare oriented upgrades. New procurements will be dominated by the purchase of 4.5+ and 5th generation aircraft. The market size in the end of 5 year forecast horizon in **2024 will be $60b**.

In military helicopter manufacturing whilst **fleet renewal and modernisation opportunities** will remain quite significant during the forecast period, a **slow decline is foreseen in the long term**, especially across new procurement opportunities, as the renewal cycle will progressively reach its end. Territorial disputes and porous borders strongly drive market demand for helicopters, which are unmatched for their VTOL capabilities, strongly sought for **amphibious and ship-based** operations, especially in Asia. Emergence of conflicts in the Middle East and Eastern Europe also trigger substantial interest in helicopters for **armed reconnaissance, ISR, and close combat** support to assist troops on the ground. However, such opportunities dictate more of an important list of operational requirements to be considered **in the very short term whilst replacing existing** fleet, rather than translating into fleet build ups due to budget constraints and personnel shortages. Part of “fit to need fleet” requirements essentially focuses on multiplying helicopter capabilities to make it more survivable and lethal. This notably includes progressively converting helicopters for MUM-T operations (current operational assessments in the US and South Korea with AH-64 and MQ-1C) and

better collaboration with RPV, especially with UAS swarm for better force projection. **Gradually converting existing platforms into optionally piloted** ones is also part of this trend, as illustrated by the on-going trials with K-MAX, MATRIX (Lockheed Martin), and Rotary Unmanned Aerial Systems-RUAS (AgustaWestland). As the **strong interest for light utility and scouting helicopters** gathers in the market **in the short and medium terms** (5-10 years time), new operational requirements and fleet renewal trends will focus on **heavy-lift capabilities in the long term**. In the **medium term, market demand will be also influenced by the shift to maritime operations**, driven by new military warfare doctrines such as in Southeast Asia where anti-submarines warfare and mine-countermeasures capabilities are strongly sought. Fulfilling existing capability gaps in the Middle East for ship-based operations and ISR (in Qatar, Saudi Arabia, Egypt and the United Arab Emirates) is also foreseen but at a much lower volume. With the exception of the US, the Russian Federation, and China, the increasing lack of heavy lifting capabilities—which is considered 15 tonnes plus MTOW—and/or ageing units are challenging the forces' ability to engage in distant areas. With a **limited number of available models and new joint programmes being put on hold in Europe, replacement options are quite narrow**. Instead, end users are considering either upgrades to existing platforms, off-the-shelf or second-hand platform acquisitions, or outsourcing military missions to commercial operators. **Concerns regarding existing training capabilities and MRO centres** have been voiced amongst military end users. On one hand, procurements require heavy financial investments in building or upgrading existing infrastructures in emerging economies, often requiring a complete change the existing supply-chain. On the other hand, mature markets are about to face an imminent and progressive decline in skilled technicians capable of performing platform and systems support on old legacy platforms going through lifecycle extensions. Furthermore, the high level of **complexity of new, on-board mission and weapon systems will have a strong impact on fleet management knowledge and operational readiness**. **More time is required not only to define precisely the training need analysis, but also to train the trainers** and have enough instructors in the pipeline to start training future operators and crews. As a result, these diverse obstacles are slowing down new platform adoption, with customers scrutinizing new platform integration costs, availability and delivery timeframes to meet their renewal, and operational targets. The impact is expected to diminish in the long term, as training and MRO infrastructures will progressively be adapted to new needs. As military end users are planning to **operate reduced but optimised helicopter fleets**, there are strict requirements in terms of **multi-role platform capabilities**, where mission and weapon systems are perceived as the force multiplier. However, fleet size constraints, budget allocations, training pipeline, logistic footprint, and safety standard priorities are challenging specific mission requirements, resulting in programme delays as witnessed with the NH90 programme of Germany. Instead of having cost-affordable 'Swiss knife' helicopters, multi-role platforms tend to become '**mission neutral'** to keep the platform-systems price ratio down. Therefore, the question arises: is **customising platforms off-the-shelf the only solution to preserve tactical warfare assets?** Furthermore, stretched fleets due to on-going deployments, modernisation programmes, and retirement of ageing units are actually creating a **market need for mission-centric helicopters being multi-terrain**, from mountainous areas to maritime environments. Unless helicopter OEMs and systems integrators can provide **more agility and resilience to existing platforms**, market opportunities will remain on-hold through the forecast period. In spite of the progressive adoption of UAS amongst most of the countries, the roles of **helicopters and UAS** have so far been quite diverse, **acting more as complementing assets** rather than cannibalising each other. Current technical challenges (endurance, payload, resilience, and safety) have limited UAS market adoption. Currently, UAS play a more supporting role for helicopters in their traditional missions. Besides, helicopters are also perceived as important assets for countering hostile UAS, especially small ones, with on-board lasers and/or automated machine guns. In the long term, manned helicopters being converted into Optionally Piloted Helicopter (OPH) or fully unmanned aircraft, like the MQ-8 Fire Scout or the South Korean KUS-VH/ AH-6i, will impact future demand for manned helicopters and similarly this will also help retain market growth across

VTOL UAS opportunities. It will be more about converting existing platforms into smarter ones and/or making distinctive assets interoperable instead of actually procuring new capabilities. Thus longer term (beyond 10 years) prospect of the military helicopter industry would see a sea-change in terms of capabilities, demand and manufacturing/maintenance. The market will remain stable and growth will be near zero in the coming 10 years due to reasons explained above. So as per different forecasts, the military aircraft market will increase marginally to **$45b in 2024** before declining until 2029.

Apart from military mission roles, the transport aircraft must be suited to handle more civil roles such as disaster relief and must be able to carry large lifting devices, rescue boats, and mobile cranes. High degree of modularity is being sought after to quickly switch between operational roles such as troop transport to medevac and vice versa. Tankers such as the A-330 MRTT solution can also be deployed for troop transport, VIP transport, and medevac roles. Tactical airlifters may need to be swiftly switched between operational modes in case of contingencies. For example, the C-295W solution can be easily converted from a tactical light transport to a convenient and user friendly roll-on/roll-off water bomber solution capable of carrying 7000 liters of fire retardant during emergencies. A more rapid response to crises situations is being sought after, and this indicates greater distances being flown during a crew duty day. Advanced operation-based computerized fuel management systems are being incorporated by OEMs to increase fuel efficiency and maximize operational range. With new platforms such as Xi'an Y-20, Kawasaki C-2, and Embraer KC-390, the market will become increasingly competitive. OEMs will have to offer competitive prices and rely on ancillary product solutions such as extended support and training to win contracts. Chinese platforms could potentially undercut product prices to compete with Western suppliers. There is a growing need for indigenization and collaborative production, especially in emerging markets such as Saudi Arabia and India. Defense majors will have to vary their market strategy accordingly to access emerging opportunities in these markets. Future operational requirements would demand short-field take-off capability, high fuel efficiency, lower operational and maintenance costs, and higher engine lifecycle. The competitive advantage of OEMs will be highly determined by these factors, apart from the unit cost of platforms. Unless these products are brought out in the next ten years, the industry will only remain in replace and modernise mode and will stagnate in the next decade with marginal increase to **$15b in 2023**.

4.0 Aerospace Parts and Components Global Supply Chain

This chapter covers the entire supply chain of aircrafts manufacturing. Many secondary market research databases have studied the supply chain of global aerospace industry and included them in the total industry size of the aerospace industry. As we have already discussed the difficulty of considering suppliers in the industry size calculation will distort the result due to double counting and VA gives a much accurate measure for the industry. Hence in our report, we are reporting these as separate standalone industries as we would try to evaluate the opportunities for new entrants or late comers in the respective subsectors of global aerospace supply chain. Though we had separately studied different platforms as military and civil, rotary and fixed wing, for the supply chain and due to the presence of almost all players in both segments of the industry, it is of no use to separately consider military and civil sectors. IBISWorld reports the total size of this industry in 2018 to be of $350 billion approximately. However, the break-up of the industry into its constituent elements is not provided. Similarly, Teal group computes the same size as $227 billion approximately without giving any break-up. We have included key constituents in this report and analysed the size, growth prospects and opportunities for latecomers/new entrants willing to join the global value chain.

4.1 Engine Manufacturing

Global market size in 2018 was **$67b** and is going to reach $125b in 2028 at a CAGR of **5.2%** (source: Technavio, IBISWorld, Frost and Sullivan). The global aircraft engine market is controlled by three companies, with many others contributing to the efforts that enhance the overall technology advancement. GE Aviation, Rolls-Royce, and Pratt & Whitney or a combination of the three manufacture or are involved in manufacturing every current aircraft jet engine in defence and commercial segment. Joint ventures, partnerships, and alliances dominate the industry segment and allow commercial aircraft engine manufacturers to share engineering expertise and most importantly, the risk involved. Allegiance to an engine manufacturer by airlines is common yet risky. Additionally, a power plant option on each airframe is no longer always available. France-based Safran, while not responsible for any standalone products, is a 50/50 partner with GE Aviation in the CFM International venture which has created the most popular commercial jet engine of all time, the CFM56. CFM International is currently producing the LEAP engine, the exclusive power plant used on the new Boeing 737 MAX, and the successor of the CFM56. Some of the next generation engines such as Rolls-Royce's Trent 1000, Pratt & Whitney's Gearted TurboFan (GTF), and the CFM LEAP have suffered design flaws grounding fleets of new aircraft while engineering resolutions are incorporated. In military engines market a notable player is Honeywell International which manufactures T55 engines for US army's Chinook helicopters. Pratt & Whitney designs and manufactures engines currently in use by 34 militaries worldwide. In the U.S. military, the F-22 Raptor, F-16, and F-15 fighter jets, as well as the C-17 Globemaster III, are just a few of examples of military aircraft powered by Pratt & Whitney engines. China recently developed indigenous WS-10 Taihang engine to enable spectacular maneuverability of J10B fighters. From the legendary T700 turboshaft engine and F110 jet engine to the revolutionary Adaptive Cycle Engine (ACE) and GE3000 turboshaft engine, GE Aviation's military aircraft engines deliver unprecedented speed, power, fuel efficiency and reduction in costs. Rolls Royce is the second largest provider of defense aero-engine products and services globally. In commercial sector demand will be more for narrowbody engines. Extreme noise reduction, unprecedented fuel efficiency, and performance enhancing weight reductions are the expectations of all new engines (be it civil or military). Military engines, customization and mission specific requirements along with affordability will play the key role in deciding the industry winner. Asia Pacific will remain the largest market for growth. Engine manufacturers who can avoid design flaws will capture market share. Those who cannot will lose. The coming decade will see emergence of new players. Introduction of COMAC C919, which is a new commercial narrow-body aircraft, would channelize substantial investments from the country and other regions for the procurement of this aircraft. The developments of such indigenous engines are being backed by strategic collaborations between the Chinese aerospace industry and foreign stakeholders. One such example is the collaboration between Germany-based MTU Aero Engines and China's AVIC Commercial Aircraft Engine for the development of the CJ1000 engine.

The engine development process requires substantial investments. Aircraft engines are required to undergo stringent testing and approval processes following their development. Not many countries have shown positive results in terms of gathering enough expertise in aircraft engine development. Hence, aircraft OEMs and airlines rely on a few trusted suppliers. This restricts the entry of new entrants in the market. Thus opportunities are **low** in this subsector for new entrants although the sector is growing during the next 10 years due to increased sale in emerging markets. The presence of a few established vendors of aircraft gas turbine engines has limited the options for buyers in the market. In addition, most of the engines are developed for specific types of aircraft and cannot be used in others without design revisions. The long term contract with OEMs and lack of interchangeability literally shuts out the new entrants from this highly specialised sector. Only opportunity is to become a supplier to the engine OEMs or LSSIs.

4.2 Advanced Electronics Systems and Components Manufacturing

The market for advanced electronics devices and components manufacturing includes equipment as flight management systems, cockpit electronics, integrated avionics system, avionics communications router, AFDX switch, avionics data network, core network & common data network, onboard computers, integrated modular avionics, communication systems and many more electronic devices. Military aircrafts have more advanced requirements than civil/commercial segment, which include cryptos, armament management systems.

Flight controls and autoflight systems have become central to the avionics systems on aircraft. Key among the pieces is the flight management computer. Honeywell, Thales, and GE aviation provide these systems for air transport aircraft. These will be increasingly important as new air traffic management systems are installed.

Communications has been an avionics mainstay for many years. In general, most of the suppliers have remained the same with some consolidation. The one major change has been the addition of satellite communications. This technology has brought several newer names into this category. Honeywell and Rockwell Collins are primary systems providers and integrators. HR Smith, EDO and Cobham are major providers of Antennae.

Indication devices are the domain of the three prime avionics providers: Rockwell Collins, Honeywell, and Thales. However, many of the components and parts are provided by the other companies on this list. This area contains the items usually described as surveillance systems and display systems by avionics companies. Although the technology is evolving, the suppliers are likely to remain the same. There may also be opportunities for smaller suppliers as avionics systems become more integrated. This can allow the system to be essentially “plug-and-play” compatible, allowing anyone to provide a complementary piece of equipment. Many names are placed in the advanced electronics systems (Figure 3.5) in Section 3.

Navigation systems have experienced significant changes over the last 20 years. Increasingly, satellite-based navigation is the norm. The traditional land-based radio aids to navigation are being marginalized and the sales of the receiver radios is declining. Honeywell, Northrop and Rockwell Collins provide both types of radio navigation devices as well as inertial navigation units.

The aircraft OEMs have retained most of the integration portion of integrated information systems area. This area has the greatest number of new market entrants. These have come from the IT and telecommunications industries. As aircraft are increasingly interconnected and digitally driven, the trend is likely to continue. IDD, Honeywell, and GE Aviation are the current leaders in this area.

The total market size in **2018 is $70b** (Source: Technavio, Individual Company Reports, Frost and Sullivan). By platform, the commercial aviation segment is expected to be the largest contributor to the avionics market during the forecast period (60% of the share is from commercial segment). By system, the hardware segment is projected to lead the avionics market during the forecast period. The global avionics market is expected to value US$115.0 billion in 2028, and will grow at a CAGR of 5%. The military market consists of five categories: surveillance and detection, mission systems, communication, display systems and navigation and control. The surveillance and detection segment is anticipated to account for 56.5% of the market, followed by the mission systems and communication segments with shares of 28.5% and 6.2%, respectively. North America is projected to dominate the sector overall with a share of 34.3%, followed by Asia-Pacific and Europe respectively.

The need for technical expertise, high investments, and the process for regulatory acceptance of these products deter new entrants to some extent, particularly in the hardware segment, however

the **opportunities are really high in the software segment** where the need of big data analytics is need of the hour. Currently, the complexities related to data associated with avionics is being addressed with advances in technology. Big Data has gained momentum, through which any dataset of 20 terabytes or higher can be accessed. Full motion video and constellation of platforms, each of which carries a number of sensors, help in collecting a massive amount of high-resolution data, which confronts the challenge to some extent. With aircraft manufacturers innovating aircraft models and emphasizing on advanced cockpit technology, the commercial aircraft flight management segment is expected to thrive during the forecast period. This opens up opportunities for new entrants in the segment. In March 2019, Honeywell developed a new communication technology, the Aspire 200 satellite communications system, for use on the Bell B429 helicopter. In April 2019, UTC received a contract from the US Coast Guard to provide aircraft avionics for maritime law enforcement. In March 2017, Thales received a contract from AirAsia to supply avionics such as FMS, T3CAS, Low Range Radio Altimeter, and Emergency Location Transmitters for A320neos aircraft.

4.3 Pneumatics and Hydraulics

Hydraulic systems are used on aircraft to move and actuate landing gear, flaps and brakes. ... The reason to use hydraulics is because they are able to transmit a very high pressure or force with a small volume of fluid (hydraulic oil). The hydraulic area is being restricted by the number of designs that are more electrical. Military designs are replacing hydraulic systems with electrical actuation, and commercial designs are following that lead. Boeing's 787 has significantly reduced the miles of hydraulic tubing and numbers of actuators. Certain applications such as landing gear will largely remain hydraulic markets, but flight controls are increasingly electric. Eaton, Parker and Liebherr are the leading suppliers of hydraulic systems and act as integrators on several aircraft. The tier two suppliers are perennial suppliers that design engineers turn to for off the-shelf components. Thus the hydraulics pneumatics market mostly covers landing gears, actuators (for flights), valves, pumps. Within the airframe flight control actuators include inboard & outboard ground spoiler actuators, leading edge slat actuator, horizontal stabilizer trim actuator, stabilizer trim actuator, precision control valves for trailing edge flap, flow control valves. The landing gear supply chain has been dominated by landing gear for many years. After many consolidations, the prime manufacturers are effectively limited to Goodrich (UTC), Messier-Dowty (Safran), and Liebherr. These primes work with the OEMs on design details, but their choices for sensors and actuators often become the OEMs choice. Brakes are also one of the landing gear primes areas, but Crane, Honeywell, Meggitt, and UTC are all major suppliers in that space. The other items in this area are the gear doors and their actuators. The design and selection of these items is generally the OEM's decision, but it is heavily influenced by the landing gear manufacturers. The fuels component area is almost completely dominated by Goodrich and Parker as integrators. All the tier II suppliers play significant roles in the market. Until recently, the OEMs made virtually all of the fuel component decisions. Recently, there has been more collaboration with the suppliers. Pneumatic systems power and provide air for an array of aircraft functions. Best known are cabin pressurization and air conditioning, main engine start and anti-icing, but other functions include fuel tank pressurization, fuel tank inerting, avionics cooling and engine pneumatics. A pneumatic servo actuation system is a low-cost alternative to mechanical and hydraulic actuation systems for some low-power applications. Though the systems are cheaper and lighter but their use is limited to low pressure activities as door opening closing, emergency door opening and the functions outlined above. Moog, a major vendor in the market, still develops pneumatic servo actuator systems primarily for aerospace applications. The systems were designed to meet the high performance requirements while operating in extremely harsh environments. Such developments fuel the market growth during the forecast period. However industry is moving from pneumatic control to electro pneumatic actuators and valves. Liebherr is investing in new technologies after Boeing's thrust on all electric planes. Liebherr MD said (source:mro-network.com), "Aircraft OEMs have been striving, and still strive, for substantial

progress in cost, weight, reliability and maintainability. All those aspects have been driving them to rely more and more on pneumatic power, at least as long as electrical technologies have not reached the sufficient level of performance." The industry size in 2018, using the key players revenues and deliveries, and assuming the supply chain participation is **$30b** (Source: Technavio, Individual Company Reports, Frost and Sullivan). This is going to grow at a CAGR of 5.5% in the next decade and is going to reach **$51b** by 2028. Since the actuators contribute significantly to the overall safety factors of the aircraft, the buyers (aircraft manufacturers) tend to engage only the suppliers with a prominent history of failure-free product supply. There are hardly any new entrants in the industry and the buyers engage the suppliers in short to mid-term contracts. Since the industry is consolidated by few large global players with facilities worldwide, there is very little scope for new entrants in the segment. As any new development needs certification from the OEMs and various regulatory bodies before full fledged revenue generation, the **opportunities are in Tier 2 and 3 only, where the industry is fragmented**.

4.4 Electrical Systems

The aircraft electrical systems market is projected to grow from **$29 billion** (Source: Frost and Sullivan, Technavio and Individual company reports) in 2018 to $42 billion by 2025, at a CAGR of 5.67% during the forecast period. Optimized aircraft performance through the use of more electric technology is a major factor driving the growth of the aircraft electrical systems market. In a conventional aircraft, the majority of non-propulsive systems are driven by a combination of pneumatic, hydraulic, mechanical, and electric power sources. By platform, the commercial aviation segment is expected to be the largest contributor to the aircraft electrical systems market during the forecast period. By component, the generators segment is projected to lead the aircraft electrical systems market during the forecast period. With the 787, Boeing replaced the traditional bleed-air control with electric-motor-driven compressors that feed the rest of the aircraft's environmental control system (ECS), and changed its wing de-icers from pneumatic to electric. In comparison with an Airbus A320, which can generate up to 270 kVA of electrical power, the 787's alternators can generate up to 1,500 kVA—enough to power the homes of a small town. Major vendors in the aircraft electrical systems market include AMETEK (US), Safran (France), Astronics Corporation (US), Amphenol Corporation (US), Esterline Technologies (US), Honeywell (US), Meggitt (UK), Thales Group (France), and United Technologies Corporation (US). Safran, which specializes in aircraft electrical systems, has introduced new power electronics for aircraft, such as ETRAS (Electrical Thrust Reverser Actuation System) and EBAC (Electrical Braking Actuation Controller). These major technological advances, along with its expertise in engine and electrical wiring, will enable the company to offer innovative electrical systems to aircraft manufacturers in their forthcoming programs. Thales is among the world's top three suppliers of electrical aircraft power-generation and conversion systems. The company has been working intensively in this field for more than 60 years. Thales provides major innovative electrical solutions for commercial and military aircraft. In February 2019, Safran signed a contract with AVIC to provide the main and auxiliary electrical generation system for MA700, a regional turboprop aircraft. In April 2018, AMETEK signed an agreement with AAR to provide power distribution units, starter generators, generator control units, primary and secondary power distribution for commercial aircraft, regional transport aircraft, and helicopter markets. In November 2018, Honeywell received a contract from the US Air Force worth USD 1,036.0 million to provide logistics support for secondary power systems and ground-based auxiliary power systems for multiple aircraft types. Here also the concentration and technology development capability **lowers** the opportunity for new entrants

4.4 Aerostructures/Airframe Manufacturing

This is the most fragmented segment of the global aerospace industry. The OEMs are responsible for the majority of the airframe activities, but there are a number of companies that specialize in providing major assemblies or subassemblies. Many of these companies were previously OEMs themselves or were divisions of the OEMs that were spunoff from the OEMs. Doors are one of the more challenging pieces of an aircraft to design and manufacture. As a result, most OEMs contract with specialists for door manufacture. The most difficult doors to manufacture are the passenger doors. The undisputed leaders are Latecoere and Vought (Triumph) for the passenger doors and PZL Swidnik for the door mechanisms. The two tier I suppliers also routinely use many of the same tier II suppliers for specialty products such as PZL Swidnik for the door mechanisms. By comparison, manufacture of the cargo doors and landing gear doors are divided among a number of different companies. The fuselage manufacturing is a highly fragmented area. Some OEMs prefer to contract for fuselage components and manufacture the major assemblies themselves. However, OEMs are **increasingly contracting for major assemblies from suppliers and performing only the final assembly themselves**. This is especially true with composite structures. The tier I market leaders are Spirit Aerospace, Alenia (Leonardo). Nacelles are a distinctly specialized manufacturing area. The leading suppliers of nacelles are Goodrich (now UTC), Spirit Aerospace, and, for certain engines, Aircelle. Supply of pylons varies according to OEMs. The leading suppliers are Spirit, Goodrich, Vought (Triumph), and Daher-Socata. The complex curved surfaces of these major structures requires considerable expertise and some highly specialized equipment to manufacture these assemblies. Often, the supplier companies are also the design engineers working with the OEMs and the engine OEMs to design the optimum assemblies. Stabilizers have also traditionally been designed and assembled by the OEMs. That trend is changing, especially with the move to composite empennage. Some of the traditional suppliers have been scrambling to provide a full composite stabilizer manufacturing capability. The market leaders are Aernnova, Alenia, Spirit Aerospace, and Vought. Wings remain the OEM's manufacturing area. Virtually, the only primary assemblies in the wing area produced by someone other than the OEM are the winglets. However, that adds increased importance to the work of the tier II suppliers. Notable in this group are Spirit Aerospace and Vought. In general, the airframe area has a significant number of suppliers. A number of these suppliers provide products at the tiers I, II, and III depending on the structure area. There are a few standouts within the differing areas. Spirit Aerospace, as part of the former Boeing Wichita, is the structures leader followed by Vought (now Triumph). The difference between the two is that Spirit is almost exclusively a Boeing supplier and is almost exclusively a tier I supplier. Vought supplies to Boeing, Airbus, and Embraer as both a tier I and II supplier. RUAG, LMI, and Alenia round out the top five. Alenia and RUAG primarily supply into Airbus; however, Alenia is now also a major supplier for the Boeing 787. LMI provides into both Boeing and Airbus aircraft. All three of these tier I supplier build most of their own structures and use tier II and III suppliers sparingly. The overall market is driven by key factors as use of new lighter and durable materials as composites in both military and civil aircrafts; modernisation and procurement of aircrafts; new platform; new manufacturing technology as additive manufacturing (The A350 XWB aircraft will employ 1,000 of such 3D-printed parts and will exhibit advanced manufacturing techniques); stringent rules and regulations; challenges regarding material crashworthiness, lightning protection, fire resistance, endurance and debris protection. The global commercial airframe component market is highly competitive, and vendors compete on the basis of cost, quality, reliability, and aftermarket service. To sustain in such an intensely competitive environment, it is crucial for vendors to provide cost-effective and high-quality service with latest technology and materials. The growth of the new suppliers depends on factors such as market conditions, government support, and industry development. Therefore, vendors must expand geographically while reviving domestic demand to achieve sustained growth. Vendors can boost profitability by practicing efficient production techniques that minimize product costs and mitigate the associated risks. Vendors should also stay abreast of emerging technologies that could affect the continuing competitiveness of their product lines in the market. The

competitive environment in the market is likely to intensify further due to an increase in technological innovations, product/service extensions, and M&A. The share gathered by top 5 companies in the market is only 40% leaving the industry wide open for competition. The opportunity for new entrants in this market is **HIGH.** Already this market (Figure 5) has seen entry of many new firms in this segment (HAL, AIDC, KAI, CTRM, Dynamatic). The industry size globally (eliminating OEM participation) is **$65 billion** in 2018 (Source: individual company reports, Frost and Sullivan, Technavio) and is expected to grow at a CAGR of 6% (due to increasing participation of new companies) in the next decade. The industry size in 2028 is expected to be approximately $111billion.

4.5 Aerospace Materials

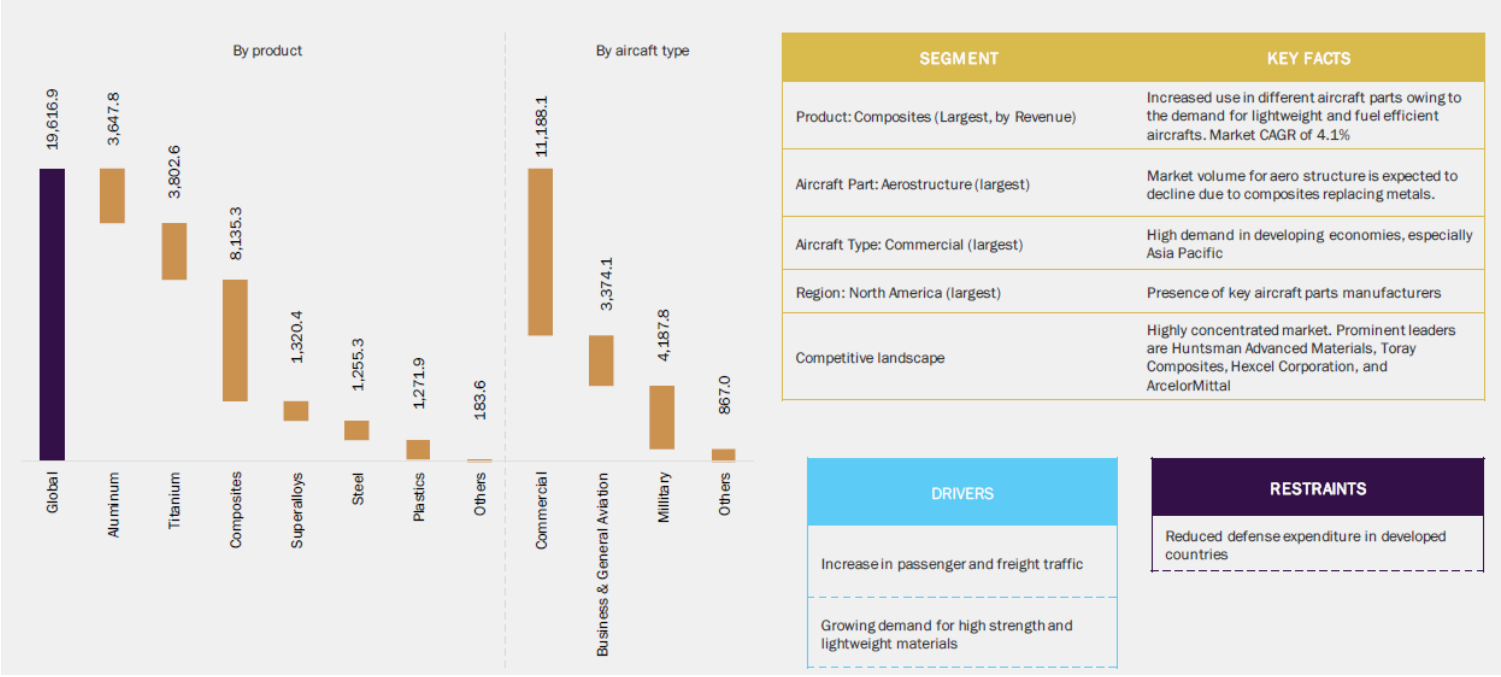

Figure 4.1: Aerospace Materials Industry 2017 Snapshot (Source: Grand View Research)

The major raw materials used in aerospace & defense materials industry are aluminum, titanium, steel, and carbon fiber. Aluminum is the most widely used raw material used in the market on the account of its superior characteristics. Aerospace materials market size as seen from the Figure 4.1, in 2017 is nearly **$20b.** The CAGR for composite materials is assumed to be 4.1% in the report due to its uncertain performance and certification issues. However, we are using the same rate of growth as commercial aircrafts of 4.8% for the entire materials. This will result in the size of the industry in 2028 to be $33b.

Aluminium Alloys (Ti-Al for engines to retain strength at high temperature, Al-Li for commercial air frames) are used to reduce weight and fuel consumption, particularly where composites are unsuccessful or cost prohibitive. They are preferred due to ease of machining, corrosion resistance. Use of composites in aircraft components is increasing, which is predicted to boost the utilization of titanium for fasteners etc owing to its excellent compatibility with composites. Pure titanium is used for airframes where formability is considered as an important parameter, whereas titanium alloys are used in engines where heat resistance and strength are considered important. Titanium is also used in many mission specific critical pneumatics or hydraulic valves. The use of composite in this industry helps in reducing part count, reducing cycle time, enhance fatigue life and improve the case of upgradability. However, composites exhibit weakness at very high-temperature, which makes the aircraft vulnerable to fire hazards and toxic fumes. Extensive R&D on next-generation composite

materials aimed at developing lightweight and high-temperature resistant materials is expected to aid in designing high-performance and economical aircraft. Superalloys are the group of nickel-, iron-nickel-, and cobalt-based alloys, especially used in jet engines. These are very heavy though! Copper, Magnesium, Barium, Molybdenum etc are used for aircraft electronics and electricals. Steel is still used for its many favourable properties. The interiors of an aircraft particularly require plastic materials that have rigid standards for heat release, flammability, toxicity, and smoke generation. Table 4.1 shows the vendors in global materials supply chain carrying out different functions.

Table 4.1: Vendor Landscape

Company Name	Presence in Value Chain	Product
Glencore	Raw Material Supplier	Copper, Cobalt, Zinc, Nickel, Ferroalloys
US Sillica Company	Raw Material Supplier	Silica sand,
Albemarle	Raw Material Supplier	Lithium
Norsk Hydro ASA	Raw Material Supplier, Mfg	Bauxite, Alumina, Low-carbon aluminium
ArcelorMittal	Raw Material Supplier, Mfg	Bauxite, Steel, Aluminium
Alcoa Corporation	Raw Material Supplier, Mfg	Bauxite, Alumina Aluminium
Rio Tinto	Raw Material Supplier	Iron ore, Copper, Aluminum
Huntsman Corpn	Manufacturer	Composites
Toray Composites Inc.	Manufacturer	Composites
SABIC	Manufacturer	Composites
Tata Advanced Materials	Manufacturer	Composites
Hexcel Corporation	Manufacturer	Composites
Hadco Metal Trading	Distributor	Aluminum, Steel, Aluminum & alloys
Sigma Aerospace	Distributor	Aluminum, Titanium, Steel, Superalloys
Aviva Metals	Distributor	Brass, Bronze, Copper Alloys
Scope Metals	Distributor	Aluminum, Copper, Steel, Titanium, Plastics
Midhani	Raw Material Supplier, Mfg	Titanium
Godrej Aerospace	Manufacturer	Composites, Inconel, Titanium, SS

5.0 Indian Aircraft Manufacturing

Indian aerospace manufacturing market is concentrated around military fighter jet (mostly strike segment) and helicopter manufacturing. From the moment of India's independence there was a thrust on building self-reliance in defence industry. In aeronautics, the self-sufficiency model was pursued at a more ambitious level at Hindustan Aeronautics Limited (HAL), which was brought under the control of MoD in 1951. During the 1950s, HAL made a significant stride in aircraft assembling under licence. Since then HAL has made significant progress and has many success stories. Presently it is ranked in the top 100 Defence Companies of the world (source: Defensenews.com). In recent years, the Indian aeronautics industry has seen a veritable enthusiasm in Indian large, medium and small companies from India's private sector to participate in the industry. The Tata Group, Reliance, Larsen & Toubro (L&T), Godrej, Bharat Forge, Mahindra and a host of others have tied up with foreign vendors such as Boeing, Airbus, Thales, Dassault, Lockheed Martin, Rolls Royce among others, to bid for government contracts and to secure a place in the global aeronautical value chain. India's aeronautical industry thus in 2018-19 constituted of aircraft design and production by defence PSUs as DRDO, HAL, NAL and supply of parts, components, systems, sub-systems, services by a growing indigenous private sector supply base (involving large organisations as Tata, Reliance, L&T, Godrej, Bharat Forge, Adani group, Mahindra, Wipro; relatively smaller emerging players as Dynamatic, Cyient, Vem, Amphenol and hundreds of MSMEs). The total size of the aeronautics industry in 2018-19 is approximately **Rs.30000 crores** (major contributors being HAL [19000cr], L&T [4000cr], Cyient [1500cr], Tatas [1000cr], Table 5.1 below shows the distribution of revenues in 2018 which includes only domestic companies). In the coming 5 years this industry is going to attract more companies (both global and domestic of different scales, industry sectors) due to certain positive policy interventions taken and mulled by the current Indian government. In this section, we will analyse the Indian aircraft manufacturing industry's "AS IS" condition using SWOT analysis. We will then identify the areas of weaknesses and potential threats to recommend countermeasures/policy interventions in the end. First we will report the findings from our workshops on aerospace manufacturing involving HAL supply base, customers and other government stakeholders.

Table 5.1

HAL	18624
TASL	342
TAML	399
VEM	178
Dynamatics	400
Bharat Forge	300
Aequs	600
Mahindra	200
L&T	4000
Godrej	300
Cyient	1500
MSME Supply Base*	2100
TAL Manufacturing	200
Wipro	300
Midhani	660
Total Size (Rs crore)	**30103**
(Assuming 600 tier 3 suppliers with average revenue of Rs 3.5 Crore)	

5.1 Findings from Primary Research

1. Supplier Survey Results

In total 21 suppliers filled out the questionnaire and 17 supplier representatives participated. We interviewed 11 of them individually. We had asked HAL to rank their suppliers based on some parameters as suited to them. HAL's outsourcing manual based definition is used for defining the supplier base. Also as per our interaction with HAL senior management we could understand the status of supply base tiers. We have defined Tier 1, 2 and others as per international definitions before to understand the global market. As per HAL, in India, currently there are no suppliers who can be categorised as Tier 1 suppliers. For being a tier 1, parties must be capable of partnering/sharing across the spectrum of project design and development and execution, have ability to explore and generate common business interest in aerospace sector. As per HAL, there are currently 40-50 tier 2 vendors who are capable of manufacturing and supplying complex/major parts and assemblies with capability for tool design and development and potential to procure raw materials on their own. Most of HAL subcontractors are Tier 3 vendors and they are capable of manufacturing components/sub-assembly, detail parts/ providing support systems with HAL support for technical inputs. The suppliers are assessed by HAL annually to give them a rating over a score of 100 (60% assigned to quality performance as a fraction of items accepted out of received and 40% assigned to delivery performance as a fraction of items received on time against total items received). The sub-contractors are then classified into three categories – Class A as those having performance rating of 80% and above, Class B with performance rating of 60-80% and Class C below 60%.

General Characteristics: In a sample of 21 companies, 17 were A class suppliers, 2 B class and 2 C class suppliers. 10 were Tier 2 suppliers and 11 were Tier 3 suppliers. On average, Tier 2 suppliers had 66% of their employees receiving professional training and 13% of total employees are being trained in foreign facilities/platforms/academia. In comparison Tier 3 suppliers had only 43% with professional training and less than 3% receiving foreign training. Class A suppliers had 58% receiving professional training, while only 35% of class B and C on average are being trained. In the sample 8 suppliers had annual revenue less than Rs 10crores, 6 companies had revenue of Rs.10-50crores, 3 had revenue between Rs.50-100 crores and rest 4 were above Rs.100 Crores (which are either part of larger domestic or global conglomerates). All of them reported on average revenue growth of 30% in the past 3 years (2017-2019). On average, 40% of the revenue of the supply base is from exports. Most of the companies (including those in Class B/C category and in Tier 3) have global aerospace companies in their customer list. Except for one company, all suppliers have clients in domestic (both private and public) or foreign aerospace industry. Many companies have transitioned from different industry sectors – hydraulics, textile, gear manufacturing for automotive and railways, telecom. All of them have one or more certification from ISO, AS, NADCAP, NABL, CEMILAC etc. The nature of capabilities in the sample involved mostly in built-to print component manufacturing for engine, actuator, LRUs, supply of flaptrack beams, structure, fasteners, gears, jigs and fixtures, landing gear parts, castings, Aero engine Precision Components (Compressor, Turbine blades, NGV's; HP/LP Turbine/Compressor Discs; Compressor Casings; Flame Tube Rings; critical components such as flap tracks, fan blades, shafts, landing gear components, rings and discs for engines etc, manufacturing of aerospace grade Ti alloys, steels and inconel super alloys, minor subassemblies. Most of the vendors are suppliers to military platforms (70% of the sample).

Identifying key success factors: According to the supply base, the key order winning capabilities are:

- Resourceful Machinery, **Manufacturing Capability**, Capability to manufacture the products required by customer

- **Product / Component Quality**, Quality first time right and every time, Quality systems, Advanced in-house inspection, test facilities and chemical laboratory for chemical process or special process
- **Technical Capability/Skill Set of Manpower**, Knowledgeable Design and Development team on Aerospace standards and Approvals, Technical expertise, Weightage to be given for prior expertise and experience of being a supplier to Primes and OEMs, Capable of understanding specific requirements and capable to develop the new process, registration with DGAQA and process design approval with CEMILAC
- Required to have all **certifications** related to Aerospace Industry, Perfect Documentation,
- **Delivery Commitment**, Commitment to deliver the quality products in a time bound way
- **Cost competitiveness**
- Financial capability, **Capital to have the infrastructure required**
- Comprehensive technical and commercial evaluation for bid selection: **L1's capability on technical competence and commercial viability to be assessed**
- Execution and supply of end product as per customer requirements, **Market Analysis**
- More involvement from customer to work as a team to resolve issues and avoid rework and ambiguity in decision making, **Good relationship with customer and discussion**

HAL, the customer, states the key success factors for OEMs delivering to Indian military are:
The important key factors to win the contracts in the aerospace market are:

- Good track record of commitment to **delivery** schedule
- Acquisition and operating **cost** of the platform
- High maintainability of the platform (**Min AOG or High Serviceability**)
- **Compliance to regulatory standards**
- **Customer flare** for using **Indigenous** Products and Platforms
- **Proximity of Governments** in case of export orders
- **Response time** to customers
- High **user and influencer level interaction with customers** for analyzing the requirements

Managing resources to achieve the success factors:

- **Machinery and Good Processing Team** managed with proper QMS activities, **Proper Documentation** at every stage of Process, **Quality Checks** at each stage of operations
- **Sales and Design Team in interaction with customers** update of documents periodically
- **Vertically integrating** to set up a one stop shop for various metal cutting, forming and finishing technologies
- **Process engineering, manufacturing, sourcing**, quality assurance, competence and skill mapping, training, career growth opportunities, key skill retention programme, supply chain management and distribution
- **ERP systems** customized to special functions as testing or manufacturing; system installation for data back up in main server at regular intervals
- **Software for virtual manufacturing** and specialized preform design software, product development team uses CAD, CAM and CAE infrastructure for 3D modelling, NC tool path generation and FEA analysis software

Coordinating and Integrating operations: It is observed that small and medium sector service providers do not have chance to get trained and share latest technology to upgrade and update. They either lack capital or exposure to global best practices due to lack of coordination in integrating their operations to deliver complete solution to the customer or build their capabilities.

- Strong **quality management system**
- Local operations prepare **process sheets** as per drawing requirements and machine accordingly. This serves as coordinating mechanism with the customer as the process sheets

are certified by customers before manufacturing. This gives 100% insight into their requirements

- **Sales engineering and marketing offices worldwide** are coordinated to provide embedded solution to customers
- One Tier 2 Class A supplier described, "**We have complex 5 axis machining facility, global sourcing from UK for raw materials, skilled manpower to build the final products**. It benefits to have coordinated capability available at both the locations and this gives confidence to end customer while delivering quality products"
- Another Tier 2 Class A supplier noted, "We follow **APQP (Advanced product quality planning)** methodology for product development, lean manufacturing practices, Business excellence drives, Team approach of problem solving". The company generates value through on time product development, matured serial production, increases in OEE, OLE, on time delivery, reduction in waste generation. These are learnt from the supplier's past experience from automotive industry. **A transitional capability**
- Another Tier 3 company developed **joint venture with foreign partner** to gain technical knowhow and global market presence
- **Strong coordinated Engineering and Development Team** increase orders and improve customer satisfaction
- Planning and execution related to **full utilisation of resource**
- One Tier 2, class C supplier said, "As an MSME we maintain a good supply chain with close **proximity to our industry cluster**. Other operations are done in house to reduce costs and delays". The cluster helped them reduce cost and delivery time.
- To develop **3D model from the customer drawing** and establish the process to interact and meet the customer product requirements
- A common platform of **CRM** (Customer Relations Management) across the entire organisation, where a common database is maintained: a) Plant details; b) Demand and Stock Sheet; c) Business Projection d) Report generation for analysis. This helps them understand the overall business with rate of growth, customer preferences, business focus areas better in order to decide strategy ahead
- **Attending conferences** conducted by Indo French, Indo German and Indo Canadian aerospace consortiums of manufacturers, **attending seminars** conducted by SIATI, AESI, vendor development program, getting exposed to different manufacturing requirements both **international and domestic registration, bidding process** and requirement of customers

Learning mechanism to generate value: It is observed that, across tiers and classes of suppliers there is urge to implement learning mechanism to generate order winning capabilities. Not only that, some suppliers are found to learn practices which are ahead of current requirements. They are getting equipped with advanced process improvement, investing in digital manufacturing to meet futuristic customer requirements.

- **By Internal and External Training:** exposure to employees about new techniques and thinking in a different way. Adopting new practices in manufacturing techniques and adapting to changing customer requirements
- To be **updated with respect to customer drawings and latest technology** to meet customer requirements with on time delivery
- **1) Capturing, 2) Creating and 3) Disseminating internal and external engineering knowledge and distributing work to the shop floor.** Result is improvement in quality, minimised mistakes and achieving end product as per drawing with approved processes
- **Lean, Six sigma, TPM, IoT, Industry 4** enabled us to become a preferred choice for our global customer

- **Knowledge transfer from OEMs/customers, Skill trainings** - Understanding the technical know how has helped to increase customer base and improve business
- **TGW, TGR, PFMEA based risk management,** Proactive risk management, prevention of failures, risks in first time product development reduced, cost effective solution
- **AS 9100D** helped in finding new customers
- **Modern Manufacturing Processes** - Latest machines for manufacturing and inspection improved productivity with assured quality
- **Internal interactions for knowledge sharing** and moving progressively to more complex parts
- **On the job training and provide corrective actions** for the issue – learning to go through document
- **Free consultancy through OEM and government**
- **Coordination with academia and institutions**
- knowledge gained through **experience with the industry during transition** from other industry
- **Technology transfer** helped produce critical products
- **Internal process** improvement as ACME and ADME (Accelerating competency for manufacturing and design excellence), TQM, 5S
- Through **training in existing skills, capturing new/advanced metal cutting technology** one MSME has, in a short span of time converted itself from “Iron & steel Trading” to Aero Engine Precision Manufacturing for Leaders in Aviation field.
- **Internal training and skilling procedure is used to learn new skills**. Upon hiring personnel, a skill matrix is mapped and gaps are identified to formulate annual training plans. Aside from this, key personnel have succession plans defined. Personnel are also encouraged to attend seminars and conferences. Internal training material is continuously developed through knowledge base of the experienced employees. The learning mechanisms detailed above allow for quick skill upgradation of new personnel and ensure that knowledge gained by the organisation stays within the organisation.
- **Learning of assembly of critical aerostructures**, machining of titanium parts, assembly jigs and fixtures, MRO activities through **current expertise in local operations provide exposure to global operations**

Technological Absorption and Manufacturing Capability in the Supply Base: The suppliers were asked to rate technology absorption capability of Indian supply base in aerospace industry sub-sectors. The scoring was made between 0 to 10 (10 means high, 0 means non existant). The suppliers felt that aerostructures is the area where our supply base has the highest capability. Access to capital and international technical and commercial information though is limited. Though there is fairly moderate ability to learn advanced knowledge in engines, managerial knowhow, level of tech. development has been lower. Ability to process materials scores high in labour skills but falls behind in technology development and access to international technologies. Avionics, adhesives, hydraulics and pneumatics and devices and systems technological capabilities are low in almost all the areas for Indian supply base. This makes us vulnerable to import substitution for these equipment. So we need to develop these capabilities and build access to materials and engine global technology and infrastructure.

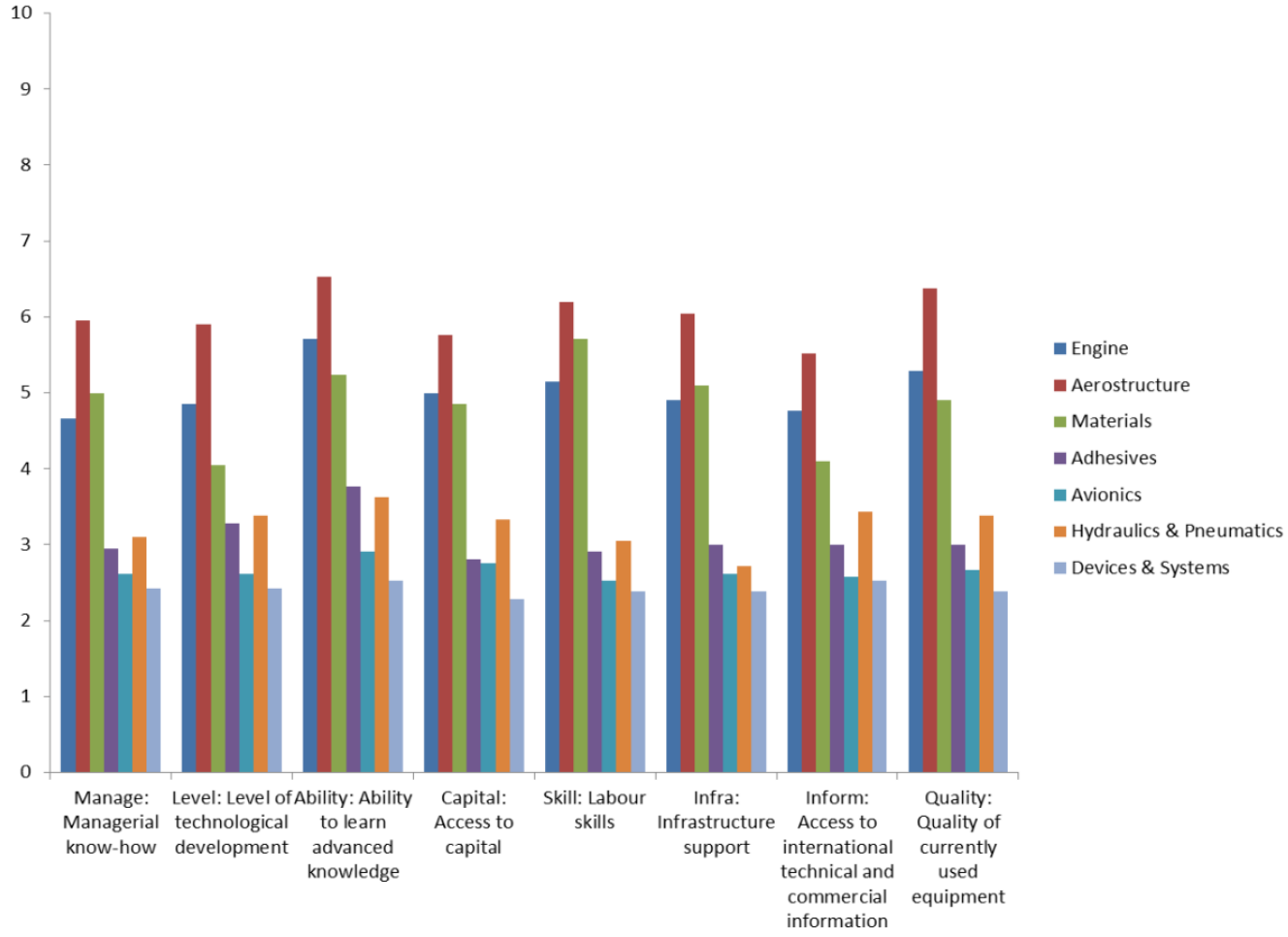

Figure 5.1: Technology absorption capability of the Indian supply base

Table 5.2 gives the ratings provided by the suppliers for self-evaluation of their manufacturing capability.

Table 5.2:Manufacturing Capability comparison of the supply base across tiers

	Tier 2	Tier 3	Difference
Manufacturing practice — production planning (PP)			
1: Use technology that integrates different manufacturing processes	7.70	7.00	0.70
2: Conduct work schedule planning	8.40	7.33	1.07
3: Improve work environment with ergonomics	7.90	6.75	1.15
4: Implement just-in-time (JIT) materials management policy and procedures	7.10	6.33	0.77
5: Implement an inventory management system	8.40	6.89	1.51
Manufacturing practice — quality management (QM)			
1: Use Six Sigma to improve production quality	6.20	6.43	-0.23
2: Implement the quality control tools (Pareto chart, SQC etc)	7.70	7.00	0.70
3: Execute the 5 S activities (sorting, straightening, systematic cleaning, standardizing, and sustaining)cleaning, standardizing, and sustaining)	7.90	7.75	0.15
4: Conduct quality control	8.90	7.78	1.12
5. Conduct process control activities	8.80	7.67	1.13
Manufacturing practice — human resource management (HR)			
1: Improve the team members' skills and expertise	8.40	7.33	1.07
2: Conduct continuing education trainings that involve team members	8.70	6.90	1.80
3: Develop a reasonable reward and punishment system	7.89	6.44	1.44
4: Conduct continuing education trainings that involve managers	7.10	6.22	0.88
Manufacturing practice — capacity management (CM)			
1: Manage production schedule effectively	7.90	7.20	0.70
2: Vigorous pursuit of quick setup and changeover	7.50	7.11	0.39
3: Reduce machine setup time for the manufacturing process	8.10	7.44	0.66
Manufacturing capability — cost control (CC)			
1: The manufacturing process capable of significantly reducing production cost.	6.70	7.33	-0.63
2: The manufacturing process capable of significantly reducing material cost.	6.80	6.90	-0.10
3: The manufacturing process capable of significantly reducing overhead cost.	6.80	7.44	-0.64

Table 5.2: Manufacturing Capability comparison of the supply base across tiers

	Tier 2	Tier 3	Difference
Manufacturing capability — flexible manufacturing			
1: Manufacturing process had distinctive technological competence.	7.40	7.50	-0.10
2: Manufacturing process involved high levels of automation.	6.90	6.00	0.90
3: Manufacturing process involved high levels of process integration.	6.80	6.67	0.13
4: Manufacturing process capable of promptly providing new products.	7.30	6.44	0.86
5: Manufacturing process capable of providing various products	7.70	6.78	0.92
Manufacturing capability — continuous improvement			
1: The manufacturing process is stable.	8.00	8.30	-0.30
2: The manufacturing process is capable of promptly responding to requirements related to the product.	8.00	7.78	0.22
3: The manufacturing process has a very low rework rate.	7.70	7.67	0.03
Manufacturing capability — quality control (QC)			
1: All machinery and equipment in the manufacturing process subject to routine preventive inspection and maintenance procedures.	8.50	8.80	-0.30
2: The manufacturing process involved reliable delivery of products and materials.	8.00	8.33	-0.33
3: All products underwent a rigorous quality control process.	8.60	8.67	-0.07
Project manufacturing goal — delivery goal (DG)			
1: The project deliverables delivered quickly.	7.60	8.10	-0.50
2: The project provided reliable delivery of goods.	7.60	8.11	-0.51
3: The project deliverables delivered in good condition.	8.30	8.56	-0.26
4: The customer order fulfilled on time.	8.00	8.44	-0.44
5: The project delivered on schedule.	7.90	8.33	-0.43
Project manufacturing goal — quality goal (QG)			
1: The project deliverables did not contain a defect.	8.70	8.78	-0.08
2: The project provided quality products that have durability.	9.22	8.89	0.33
3: The project deliverables were highly reliable.	9.11	8.89	0.22
4: The project deliverables were safe for use.	9.33	8.89	0.44
5: The project deliverables were of high quality.	9.33	8.78	0.56
Project manufacturing goal — cost goal (CG)			
1: The project provided low price products which achieved economic profit goals.	7.80	7.75	0.05
2: The project provided products with competitive prices in the market.	8.20	8.11	0.09
3: The production cost was low on this project.	8.00	6.89	1.11
4: The inventory cost was low on this project.	8.00	7.00	1.00
R&D/Innovation manufacturing goal —			
1: Relationship building with customers and OEMs	9.22	8.00	1.22
2: Relationship building with research institutions	6.56	6.63	-0.07
3: R&D Expenditure	6.89	5.88	1.01

Few key observations from the above analysis are:
- Tier 2 suppliers are way ahead of the Tier 3 in terms of manufacturing practices as human resource development, production planning, R&D and innovation, quality management and control. This sets an opportunity for cross learning across industry tiers on best practices or building some sort of consortium to share challenges and opportunities for capability development
- Capacity management, cost control, delivery commitments, project based manufacturing capability the two tiers are literally inseparable. There is very marginal and insignificant different between the different tiers in these areas.

Other stakeholders' perspective: We also requested the service staff, HAL senior management, DGAQA (from IAF, Navy, Army, Coast Guard service personnel) to share their views on Indian aerospace industry. Everybody acknowledged the efforts and initiatives taken by the current government in rejuvenating the Indian aerospace and defence sector through DPP 2016 and subsequent revisions, Make in India and indigenisation programme, however they also mentioned few crucial observations which will help us understand the threats and weaknesses of Indian aerospace industry. The key responses are summed up below:

- **Strategic partnership** though stressed upon by the government, Indian aerospace is still struggling in getting proper strategic partnership with global aerospace majors or countries.
- Military R&D is staggering with only 0.9% of total spending. It is very difficult to motivate research spending from private sector. Consequently we are still "at the stage of **screwdriver technology**". This is particularly true for western equipment and HAL still buys modules from them (Mirage etc).
- **Critical components have not been given away by foreign OEMs**. Indigenisation in helicopters is 40% on average.
- We are **good at structures**, structural components whether it is done by HAL or ancillaries through ecosystem or themselves in Banglaore (MSMEs). This capability is maturing**. Most of the composites that are built here is (alloys made in composite workshop) for ALH is a big success story**. To make the composites we have to import materials.
- **Avionics, electronics devices and systems mostly are imported**. There are some success stories in HAL's **LUH – foreign component less and indigenous components more – DataPatterns Chennai** made glass cockpit or IADS (integrated architecture and display systems). The company's product development culture is **no profit no loss initially**. Data Patterns is one such vendor who would develop the product without thinking of costs – later he will spread the cost over large orders. The respondents lamented that it is very difficult to get **NCNC (no cost no commitment)** vendors nowadays. Someone who will develop the product (even prototype) and absorb the cost, is very rare to find as promise of larger orders is difficult. Orders are related to the ASQR and user cannot select a product which is detrimental to his war fighting capability. So there are lot of adjustments in supplier developing the product to meet the customer requirements. As there is no time for experiments with such indigenous products, in the mean time to meet immediate warfront requirements the customer imports materials. **We need to keep the equipment going by keeping powder dry and ready**, **at the same time we need to support indigenisation and OEM has to develop the MSME sector**.
- In **aero-engines**, HAL has got licensed technology but **not all components are indigenously** developed or manufactured. Materials are also as per design specifications given by the foreign OEM. To succeed in engine sector – metallurgy has to be looked in to for standards development, **continue to depend on foreign OEMs**.
- **ALH Mark 4** – 267 flying, more than 2 lakh flying hours over 25 years– list of MTBF is quite creditable. **LUH – segmented blade** development are HAL's success story
- HAL's maintenance capability is also creditable. Earlier 270 odd maintenance requests came down to 108 in ALH and in LUH to just 30. **HAL has addressed maintenance very well**.

- **No synchronisation between industry, armed forces and within industry and finance department**. IAF's procurement of a single aerospace grade bolt for ground maintenance is not properly understood by finance staff and time is wasted in justifying the high price.
- **Lack of environmental testing facilities.** MSMEs cannot access the HAL, DRDO, BEL, Midhani Laboratories. Initially the development cost quoted by MSME for a clock was Rs 30k, however IAF needed to carry out vibration test – approached RCA Hyderabad and cost quoted was Rs. 8 Lakh. Finance states the project needs to be re-tendered as others might quoted lesser. MSME vendor loses interest and indigenization opportunity lost. In this manner currently due to inadequate testing facilities, many such opportunities are lost.
- **Aviation grade Raw materials** – When a MSME is given order for 100 nuts a year of particular raw materials (take around 5-10kg) he cannot get it made in a cost effective manner. Midhani produces/melts in tonnes. IAF not able to provide the raw materials – Midhani cost is too high for 100 nuts. As aviation grade is identified – solely by process of manufacturing. There are so many other processes involved which are not available in India and particularly to small timers. MSMEs thus only get the raw materials from OEMs and sell the products after machining or processing. This acts as an entry barrier for other organisations who do not get any such support from the Prime. As whenever we purchase raw materials we have to ask for the certificate and particularly the source from where they got the raw materials.
- **Quality is always compromised for L1 part in defence sector**. A vendor says he will give me aerospace grade raw materials. He might quote very low to become L1 and fool the customer. Before finalising L1 there is no option to check his raw materials. Once L1 is finalised the customer is stuck. Certifying vendors who can participate in the bidding is also difficult as any defence procurement must go to open marketplace in website GEMPP so that tender is open to all players and ensure fairness to all.
- **Design for maintainability** to avoid maximum time maintaining. LUH conveniently designed for maintainability perspective. That makes us competitive globally also
- Airforce or Army's **low requirements** (minimum order quantity) prevents MSMEs to come to aerospace. This also deters investment and naturally the vendors they go directly to for routine maintenance, have **unsophisticated manufacturing processes** where accuracy and tolerance has no place.
- Most vendors are facing **certification** problems. Technology is available in market but cannot fit in the aircraft due to staircase approach of approval and finally when it is ready for market it is obsolete.
- For DGAQA Delhi there are many success in **developing ground support equipment for the airforce**. DGAQA is a small setup (with inadequate financial and infrastructure support and running from pillar to post to resolve such queries) supporting all queries regarding ministry, user and contractor. Its primary role is that of a Quality Assurance agency – it developed International aeronautical standards along with IAF. 3rd party inspection/TPI is used by government. Raw material to assembly (TPI) concept is introduced to reduce the overburdened DGAQA. DGAQA also **studies OEM processes for quality improvement**. BEL has given technology to a vendor. Failure was 15%. DGAQA studied their process and brought down the failure to 5%. This is acknowledged by Airbus.
- Established vendors (public or private sector) will always be coming forward and **no second line is developed** as there is no volume, costs are huge and technology barrier is higher.
- **HAL's focus has been mainly production of aircrafts. There is a separate design establishment.** They have developed LRU level technologies in India. Electronics items are developed through private, HAL which are exported – vision computers, radio alternators. Development of engines – business jet/trainers and helicopters.
- **Materials supplier difficulty –** Midhani's aerospace and defence orders do not come from original product designer, but from a licensed producer who uses a borrowed design and

wants to match the designer's material to be developed inhouse. **Indigenisation currently is limited to just a copy of foreign technology**. **Use of local culture, talent, facilities is true indigenisation**. Borrowing technology and doing it in India (govt offset policy also says that we buy technology and vendor needs to manufacture it here) is the biggest fallacy of indigenisation. If true designer is there Midhani don't have to copy Timet, or Russian brands. Even if it is copies and given a name under Midhani XXX, RCMA, Cemilac, DGAQA say it is a different component and it has to go through duplicate certification. In defence and aerospace Midhani does not know what the exact material requirements are. It is developed through lot of experiments to emulate the property. Sometimes works and sometimes not. **Only when the original design is there knowledge of the loads, design parameters is high– design of material gets accurate. Designer should drive the material development – this is a deficiency of borrowed technology.**

Though there are many success stories in Indian aerospace industry, however from the above analysis of primary data, we can understand the gaps in capabilities for building world class self reliant aerospace and defence industry.

5.2 Summary of Findings and Analysis: Strengths

Based on our primary and secondary data, Indian aerospace industry's SWOT analysis is done.

1. HAL – the national champion of Indian aerospace and defence industry:

- India does have full scale aircraft manufacturing capability except for turbine engines. **It has had production capability since the 1950's**. Tracing its roots back to 1941, HAL now builds military trainer aircraft and has **manufactured indigenously developed brand new fighter jets in 2018-19. It has also built helicopters, agricultural aircraft and has one of the largest maintenance depots and engineering services in the world.**
- India could build an airliner if it chooses to do so. However, the amount of investment is significant. HAL management has correctly assessed that entering into competition with Boeing, Airbus, Bombardier and Embraer would be a high-risk venture with no guarantee of profitability. India has made reasonable attempts to build its own aircraft through substantial investments in infrastructure, capital and skill development. For example, the state-owned Hindustan Aeronautics (HAL) has manufactured indigenously in large numbers, the multi-purpose light transport aircraft - Dornier 228 aircraft. HAL bought the production licence for this aircraft from the German firm Dormer GmbH in 1983. The 19-seater aircraft is being currently used by defence forces. Recently, the Directorate General of Civil Aviation (DGCA) has given 'certificate of airworthiness' to this aircraft paving the way for its civil use. It is envisaged that the aircraft has substantial role to play in enhancing regional connectivity under the ambitious UDAN scheme.
- HAL has the capability to cater a large spectrum of aerospace business which includes D&D, manufacturing and MRO of the Fixed Wing, Rotary Wing, Aeroengines, LRUs and airborne systems.
    - HAL has good track record in aircraft upgrade for its defence customers which includes major changes like reengining, avionics upgrade, and weapon system integration.
    - HAL has good knowledge and understanding of Russian platforms. It has successfully absorbed the transfer of technology (ToT) and produced MiG-21, MiG-27 and Su-30MKI.
    - HAL has developed expertise in D&D of utility and combat helicopters. We have developed a wide range of helicopter platforms like ALH, LCH, Rudra and LUH to offer to our customers.
    - HAL has been a trusted partner of IAF for providing support to its aging (some of which are more than 40 years) and obsolete fleets.

- HAL's corporate strategy is mainly driven by its unique position due to virtue of its ownership and industry of operation. HAL is a DPSU under direct administrative control of Ministry of Defence. The corporate strategy of HAL is collective outcome of various strategies which HAL has adopted over the time. Some of the important contributing strategies to HAL corporate strategy are:
    a. Diversification
    b. Licensed Manufacturing to acquire technologies
    c. Self-reliance
    d. Lead Integrator
    e. Outsourcing: Development of Defence ecosystem
    f. Indigenisation
    g. Thrust on R&D

  To be competitive in market and provide superior product and services to its customers HAL has cost leadership with differentiation as strategic approach. HAL products are at parwith its competitors' in their class and category. HAL also provides life long after sales service to its customer along with mid-life upgrade services. HAL has a broad range of products which caters to its Indian Defence customers in Trainer, Fighter and small size military transport aircraft segments. HAL also caters to 3 to 5.5 ton utility and combat helicopter segment.
- HAL's core competence (in order of strength) lies in a) state-of-the-art weapon system integration and avionics upgrade of the existing Defence aircraft, b) Managing lifelong aftersales service support to customer platforms some of which are even obsolete by the OEMs, c) Design and Development of Fixed and Rotary wing aircraft, Systems and accessories.

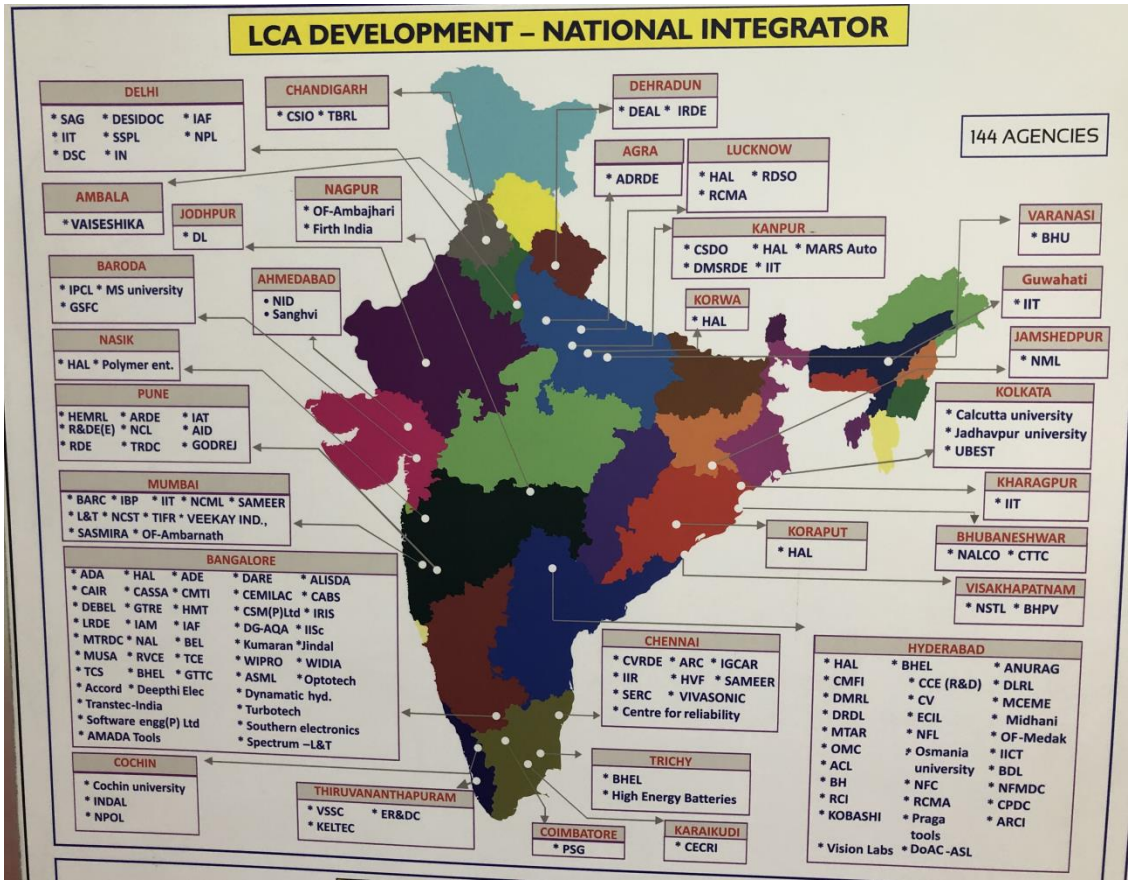

Figure 5.2: LCA Tejas integrating academia, industry and government across entire India (Source: HAL)

- LCA is a success story for HAL to emerge as a LSSI/OEM with private companies undertaking much of the manufacturing ' Larsen & Toubro (wings), Dynamic Technologies (front

fuselage), VEM Technologies (centre fuselage), and Alpha Design & Dynamics (rear fuselage). HAL only undertook final assembly. As a result, the Tejas' production rate will increase to 24 aircraft a year. It took 14 years to complete the production run with the private companies in partnership. Importantly, this helped private industry acquire skills like prime-contractorship and systems integration, and to someday make aircraft of their own design for India (Source: Assam Tribune, 15 March 2019). Figure 5.2 shows the involvement of the entire Indian industry, academia, research institutions in producing India's first indigenous LCA Tejas.

- Indian government's positive steps have helped achieve industry breakthrough in aeronautics design and development. The most notable achievement was of NAL during 2018 was the new upgraded versions of SARAS, the indigenous transport aircraft developed by NAL, "successfully" made its maiden flight on 24th January 2018 in Bengaluru.

2. Highly Capable Ecosystem:

- On our interaction with HAL, it is mentioned, "we have developed and created the entire eco system for Defence Aerospace". HAL has developed all the Tier-II and Tier – III suppliers, who are today exporting their structures and other components to global aerospace companies (one example is Dynamatic Technologies). Even in all projects viz. LCH, LUH, HTT-40, HAL has been interacting with potential private partners from design & development stage to turn them into long term reliable partners over time, establishing long term business agreements to ensure their support through the entire product life cycle
- Due to the availability of skilled expertise and competitive pricing, both top tier and lower tier Indian suppliers are migrating slowly but steadily, into tapping the export markets in the segment besides catering to domestic markets. However at global level, the top tier suppliers slightly fare better owing to availability of capital/ equity, access to better financial avenues, branding which provide them with the much required risk appetite and market resilience when competing with other global players. A few of the top tier suppliers have already established themselves as sole suppliers for global OEMS. A snapshot of Indian supply base is shown in Figure 5.3. The yellow area shows that, there is very little presence of Indian suppliers in the aerospace adhesives and coats market domestically or internationally. Also there are cluster Formation around Bangalore, Hyderabad, Pune, Nashik, Chennai, New Delhi area (Ghaziabad, Faridabad, Gurgaon, Noida).

	Design, Engineering, IT, Training, Quality, Testing	Tier 3	Tier 2	Tier 1	OEM	MRO
Aero-Engine	**HAL,** Turbo-Tech AD, Wipro, TCS, HCL	Titan, VEM, Ravilla, SEC, Dynamatics, SKM, Avasaria, Unipol, UniMech	LMW, Godrej, Maini, Quest, Cyient, TASL, Turbo-Tech, Bharat Forge, LMW		**HAL**	**HAL,**
Aerostructure	**HAL**, AvioHeliTronics, Axiscades	Aequs, BEML, AvioHeliTronics, BevelGears, Bliss, EC Blades & Tools	LMW, Godrej, Taneja, TAML, Maini, Quest, Mahindra, Adani, BEML, AEPL, Wipro, Aequs, Adani, Tata Lockheed, Cyient, Reliance, Wipro, Sansera, Dynamatic	**HAL**	HAL,	HAL, Carlisle, Airworks
Adhesives & Coating	Hexcel, Bostik, Henkel	Bliss, Atul, Tentacles	Atul, Bliss		Hexcel, Bostik, Oerlikon Balzers, Star Hentzen	Star Hentzen
Materials	Composites India	Godrej, Avdel, Thyssenkrupp	TAL Mfg	Midhani	DRDO	Avdel
Avionics and Electronics	**HAL,** Assystems, Axiscades, Samtel, Mahindra	Comavia, Kaynes, Advancetech, Aitech	Sika, L&T, TASL, Cyient, Data Patterns, Apollo Microsystems, MKU	BEL,	HAL, Captronic, BEL, Accord, Samtel	**HAL**, ATMSI, Sika
Hydraulics & Pneumatics	**HAL,**	Amado Tools	VEM, Amado		HAL,	HAL, Sika
Devices and Systems	**HAL,** Ananya Technologies, Centum, Alpha Design	AMPL	AMPL, Sika, Data, Patterns, Trident, Centum, Veer AnanthCentum, Veer Ananth		HAL, Captronic, Centum, Apollo Microsys	HAL, Sika

Figure 5.3: Indian Aerospace Supply Base Snapshot

- In its relatively short history, the private sector has made some significant progress with a number of deals being awarded and executed by it. Until the year 2001, it enjoyed a limited

role as a supplier of raw materials, semi-finished products, parts, components and limited services to India's DPSUs. Government has issued 439 licenses covering 264 companies till March 2019. In addition, for a large number of defence components, no license is required. There are more than 600 MSMEs which are among the vendor base of HAL supplying various components to them. 31 out of 34 joint ventures in the defence industry are led by private sector companies. Aero-components export from the country approximately falls in the range of Rs 20000 crores in 2018-19 (https://commerce-app.gov.in/eidb/ecom.asp).

Figure 5.4: Major Aerostructure Players in India

- Over 160 suppliers contribute or provide parts and assemblies covering aerostructures, wire harness, composites, forgings, avionics mission systems, and ground support equipment for some of Boeing's most advanced defence platforms (boeing.co.in). **Boeing counts TCS, Cyient, HCL America and HCL Technologies, and TAL Manufacturing** Solutions among its IT and engineering services providers. Quest has won the Wing & Pylon Design Centre offshore contract from Airbus (https://timesofindia.indiatimes.com/business/india-business/indias-engineering-footprint-in-airbus-boeing-is-growing/articleshow/67188524.cms).
- **A teaming agreement between Cyient and Triumph Aerostructures** – Vought Aircraft Division, a wholly-owned subsidiary of Triumph Group, Inc. with operations in Dallas and Cyient India collaborate to provide aerospace engineering services throughout the product lifecycle from design and analysis to manufacturing engineering, build, test and aftermarket services. These solutions span aero structures, interiors, mechanical systems and avionics. Cyient is the preferred engineering service provider for Triumph Aerostructures.
- **TAML** acquired the A320 business from CTRM Malaysia, in early 2014 and are currently manufacturing Aileron Sharklets, Trailing edge & Aileron Composite Panels. They are partner to **CTRM**. A320 is Airbus's best-selling aircraft globally with a monthly rate of 42 shipset currently and showing a healthy outlook on increased demand in the coming years.
- Expanding its partnership, **Rolls-Royce** has awarded a Rs 200-crore ($30 million) contract to **Godrej** Aerospace, spread over the next five years, the company said. "Under this contract, Godrej will manufacture unison rings, complex fabrication and external brackets which will supply as many as 600 different parts to the various Rolls-Royce civil aerospace engine portfolio,"
- **Safran Aircraft Engines** has taken a significant step forward in its commitment to the Indian government's "Make-in-India" initiative by choosing **Maini Precision Products** (MPP) to

manufacture the low-pressure turbine (LPT) guide vanes for LEAP engines. Since 2015, MPP has also become a supplier on Safran's LEAP engine, successor to the CFM56, and the Silvercrest business jet engine. With this contract Maini expands its contribution to the new LEAP engine, which has gotten off to a very successful start, with more than 14 000 orders.

- Capability for **manufacturing engine parts** like turbine fans and engine cores through casting and forging Titanium alloys has also been achieved by **HAL, Bharat Forge** as component suppliers for Rolls Royce
- **UniMech Aerospace** have been manufacturing precision tooling assemblies for Aircraft Structures, Aero engines and Ground Support functions that adhere to stringent International safety standards. They have delivered **MRO tooling** which are used in CFM, Leap, GE, Rolls Royce, Boeing, and Airbus products.
- **TurboTech Defence and Aerospace** that **designs, builds and maintains aviation and defence equipments**, will produce, at its newly set up Bangalore plant, the Oil Cooling System and components for **the Safran Helicopter Engine** (Ardiden 1U Engine), for the use of European and Indian market from 2019.
- India's core area of strength is the presence of its supply base in the aerostructures market. Figure 5.4 shows the big and small players in India.
- **Atul Limited** manufactures world leading epoxy resins in its state of the art facility near Mumbai
- **Tentacles India** signed distribution agreement with one of the largest specialised aerospace tapes OEM PPI Adhesive Products
- **Star Hentzen Coatings** Pvt. Ltd. (a leading player in Indian market) a joint venture between Hentzen Coatings Inc. USA and Star Paint & Oil Industries, India. Having its registered. Office in Mumbai, India. The JV is created to manufacture and trade to cater the emerging Aviation Sector with state of the art Aerospace & Defense Coatings (low emission of VOC).
- **Genser Aerospace Pvt Ltd** provides design Support for Airbus E2S organizations (specification level design covering: systems integration, specification coding of FCS & FWS, aircraft's Electrical Load Analysis; external CFD analysis on wing-body-nacelle configuration etc.)
- **Exa Thermometrics** leads the way in the design and manufacture of high quality thermistors for advanced temperature sensing. Exa Thermometrics has pioneered the development of a vast range of material systems, meeting all global RT curve requirements. This State-of-the-art polycrystalline semi–conductor fab facility manufactures NTC thermistor chips, discs and ring/polos, a variety of glass encapsulated chips, lead frame coated devices, microchip based catheter thermistor probes and OEM customer specific temperature probes.
- Over 400 aircraft sets per annum of actuator gears are being supplied by **Zensar** to European Commercial Aircraft Programme through a specially developed product-specific-supply-chain across India.The delivery volume is expected to double in two years.
- **Amado Tools** supply precision aerospace valves: servo valves, solenoid valves, lock valves, and other valves as per specifications
- **Servocontrols** offers Custom built Electromechanical Actuator setup for mass production. Setting up Test Rigs for Business Jet Systems simulation and Design of Test algorithms for one of Top Most Aerospace Tier 1 supplier. Setup of New Hydraulic/Electronics Systems and Test Rig Test Facility at Udyamabag Facility; Executed 1000HP Hydraulic System(including SKYDROL) along with Onsite Plumbing/ Erection/ Installation/ Commissioning for Premier Aerospace Company.
- **MPS** Precision Engineering (formerly Microprecision Solutions Pvt.Ltd). is a precision engineering company involved in the manufacture of high precision gear metering pumps, transmission components, assemblies and other high end engineering products. It is a joint venture between Micro Corporation Ltd, UK, and Uniflo Engineering, India, a precision

engineering company in India with over three decades of experience in the area of precision metering pumps.

- **Sika Aerotek** Aviation has secured a contract for the design, development, qualification and certification of the landing gear retraction actuator for a 2 ton medium-altitude long-endurance unmanned aerial vehicle, which has already completed the critical design review milestone and commenced prototype manufacturing.
- Bangalore-based **SATTVA** Aero Accessories and Systems Private Limited (AASPL) has designed, developed, certified and supplied the Main and Nose Landing Gear Actuators and Flap Test Rig for the **SARAS** aircraft developed by National Aerospace Laboratories (NAL), Bangalore.

3. Government Policies:

- India has made several attempts at skill development in areas of strategic or national importance. For example, to build capabilities in the defence manufacturing segment - aircraft, helicopters and missiles, the Government of India has hand-held defence public sector units for forging partnerships with global aerospace and defence majors. In some cases this has been achieved via licensed production of trainer aircraft, while in other cases, by manufacturing sub-systems, components and spare parts for helicopters and fighter aircraft. Domestic firms have contributed notably, gradually increasing their learning curves. As a result, the country today has built capabilities in important segments such as production of fourth generation fighter aircraft, advanced helicopters (Dhruv and Light Combat Helicopter) and best-in-class missiles (BrahMos).
- DPP -2016 focuses on institutionalising, streamlining and simplifying defence procurement procedure to give a boost to 'Make in India' initiative of the Government of India. In the last four financial years i.e. from 2015-16 to 2018-19, out of the total 210 contracts, 135 contracts have been signed with Indian Vendors including Defence Public Sector Undertakings/ Public Sector Undertakings/ Ordnance Factory Board and private vendors for capital procurement of defence equipment. Government has issued 439 licenses covering 264 companies till March 2019 (http://pib.nic.in/newsite/PrintRelease.aspx?relid=190654). In addition, for a large number of defence components, no license is required. There are more than 8000 MSMEs which are among the vendor base of OFB &Defence PSUs supplying various items to them. Out of these around 600 MSMEs are associated with HAL.
- DPP has been revised in 2016 wherein specific provisions have been introduced for stimulating growth of the domestic defence industry. A new category of procurement 'Buy {Indian-IDDM (Indigenously Designed, Developed and Manufactured)}' has been introduced in DPP-2016 to promote indigenous design and development of defence equipment. It has been accorded top most priority for procurement of capital equipment. Besides this, preference has been accorded to 'Buy (Indian)','Buy and Make (Indian)' & 'Make' categories of capital acquisition over 'Buy (Global)' & 'Buy &Make (Global)' categories.
- Government has notified the 'Strategic Partnership (SP)' Model which envisages establishment of long-term strategic partnerships with Indian entities through a transparent and competitive process, wherein they would tie up with global Original Equipment Manufacturers (OEMs) to seek technology transfers to set up domestic manufacturing infrastructure and supply chains. The 'Make' Procedure has been simplified with provisions for funding of 90% of development cost by the Government to Indian industry and reserving projects not exceeding development cost of Rs.10 Crore (Government funded) and Rs.3 Crore (Industry funded) for MSMEs.
- Separate procedure for 'Make-II' sub-category has been notified wherein a number of industry friendly provisions such as relaxation of eligibility criterion, minimal documentation, provision for considering proposals suggested by industry/individual etc., have been introduced. Till date, 36 proposals for development by industry have been given 'In-principle' approval under Make-II.

- The Prime Minister launched a historic support and outreach programme for the MSME in November 2018 (https://pib.gov.in/newsite/PrintRelease.aspx?relid=184578). The Prime Minister said that the success of economic reforms launched by the Union Government, can be gauged from the rise in India's "Ease of Doing Business Rankings," from 142 to 77 in four years. The Prime Minister said that there are five key aspects for facilitating the MSME sector. These include access to credit, access to market, technology upgradation, ease of doing business, and a sense of security for employees. Loans upto Rs. 1 crore can be granted in-principle approval through this portal, in just 59 minutes. This facility is being used by all the MSMEs we spoke to during data collection. There will be a 2 percent interest subvention for all GST registered MSMEs, on fresh or incremental loans. For exporters who receive loans in the pre-shipment and post-shipment period, the Prime Minister announced an increase in interest rebate from 3 percent to 5 percent. Public sector companies are asked to compulsorily procure 25 percent, from MSMEs. All public sector undertakings of the Union Government must now compulsorily be a part of GeM. He said they should also get all their vendors registered on GeM. 20 hubs will be formed across the country, and 100 spokes in the form of tool rooms will be established. A mission will be launched to ensure that MSME employees have Jan Dhan Accounts, provident fund and insurance.
- Government has decided to establish two defence industrial corridors to serve as an engine of economic development and growth of defence industrial base in the country. These are spanning across Chennai, Hosur, Coimbatore, Salem and Tiruchirappalli in Tamil Nadu and spanning across Aligarh, Agra, Jhansi, Kanpur and Lucknow in Uttar Pradesh (UP).
- An innovation ecosystem for Defence titled Innovations for Defence Excellence (iDEX) has been launched in April 2018. iDEX is aimed at creation of an ecosystem to foster innovation and technology development in Defence and Aerospace by engaging Industries including MSMEs, Start-ups, Individual Innovators, R&D institutes and Academia and provide them grants/funding and other support to carry out R&D which has potential for future adoption for Indian defence and aerospace needs.
- Government has notified a Policy for indigenisation of components and spares used in Defence Platforms in March 2019 with the objective to create an industry ecosystem which is able to indigenize the imported components (including alloys & special materials) and sub-assemblies for defence equipment and platform manufactured in India7.
- Defence Investor Cell has been created in the Ministry to provide all necessary information including addressing queries related to investment opportunities, procedures and regulatory requirements for investment in the sector.
- FDI Policy has been revised and under the revised policy, FDI is allowed under automatic route upto 49% and beyond 49% through Government route wherever it is likely to result in access to modern technology or for other reasons to be recorded.
- The Defence Products List for the purpose of issuing Industrial Licenses (ILs) under IDR Act has been revised and most of the components, parts, sub-systems, testing equipment and production equipment have been removed from the list, so as to reduce the entry barriers for the industry, particularly small & medium segment. The initial validity of the Industrial Licence granted under the IDR Act has been increased from 03 years to 15 years with a provision to further extend it by 03 years on a case-to-case basis.
- The process for export clearance has been streamlined and made transparent & online.
- Offset guidelines have been made flexible by allowing change of Indian Offset Partners (IOPs) and offset components, even in signed contracts. Foreign Original Equipment Manufacturers (OEMs) are now not required to indicate the details of IOPs and products at the time of signing of contracts. 'Services' as an avenue of offset have been re-instated.
-

- Government has set up the Technology Development Fund (TDF) to encourage participation of public/private industries especially MSMEs, through provision of grants, so as to create an eco–system for enhancing cutting edge technology capability for defence applications.
- In a major boost to Mission Raksha Gyan Shakti, a Memorandum of Understanding (MOU) was signed between the Intellectual Property Facilitation Cell (IPFC), Department of Defence Production, Ministry of Defence and National Research Development Corporation (NRDC), Ministry of Science and Technology on 09 July 2019. The partnership between IPFC and NRDC is expected to bridge the capacity shortfall and provide a major fillip to the ongoing efforts of MoD towards promoting a culture of Innovation and Intellectual Property Rights (IPR) in Indian Defence industry. It may be recalled that Mission Raksha Gyan Shakti was launched with the aim to inculcate IP culture in Indian defence manufacturing ecosystem. Under this mission, an Intellectual Property Facilitation Cell (IPFC) has been established under the aegis of Directorate General Quality Assurance (DGQA) which has within a short span of a year achieved challenging target of training more than 12,000 personnel on IPR and facilitating filing of more than 1000 new IPR applications. The Action Plan 2019-20 of MRGS has also been approved by Raksha Mantri Shri Rajnath Singh, which includes training of additional 20,000 personnel from Public / Private Sector Industry and Armed Forces on relevance of IP Culture to Indian Defence manufacturing industry and to institute a framework which enables full utilization of new ideas and innovation towards achieving self-reliance in defence sector.
- Not only the above initiatives by Central government have helped in rekindling the Indian aerospace industry but several states as Guajarat, Maharashtra, Odisha, UP, Tamil Nadu have announced very industry friendly aerospace policies for their states. Most of these states (Appendix 2) have accorded special status to aerospace industry and have announced setting up aerospace, defence parks in specified areas within the state for MRO/component/assembly/ research and development activities. Special incentives for anchor units and MSMEs are also announced in terms of land, utilities, taxes, labour, clearance,skill development, R&D, certification, patents etc. States are also keen to become equity partner if a major public/private OEM starts building aircrafts which would life the global status of the industry in the world.
- DPE has initiated development of a Knowledge Management Portal (https://samanvay.cpse.in) on which all the CPSEs can share their best practices, case studies, tacit knowledge, breakthrough innovations, etc. in their respective functional domains. The proposed portal also has a separate section on infrastructure facilities such as R&D, training, equipment, etc. which can be shared with other CPSEs. The portal has been launched and in first phase executives of 54 Maharatna, Navratna and Miniratna CPSEs have been given username and password to access and upload information in the portal. In the second phase, 115 more CPSEs are being covered. The executives of these CPSEs can use the portal for uploading relevant information and accessing available information.
- **Tzar Aerospace** Research Labs (a startup which is direct beneficiary of government's startup India initiative) and CTTC, Bhubaneswar. With this important collaboration state of the art facilities at CTTC shall be used for design and manufacturing of high precision components and assemblies. An IIT Bombay startup Zeus Numerix is providing end to end design solutions to aerospace industry.

4. Transition of capabilities:

- Twenty three years ago, QuEST Global, an outsourced engineering services company decided to foray into manufacturing products for the aerospace industry, mostly for commercial jetliners. Its goal was to be a one-stop provider of aerospace services and products. It was also a time when many Indian automotive parts manufacturing companies were looking at the aerospace vertical and QuEST, too, wanted to make use of India's labour arbitrage and offer clients precision engineered products at a 30 to 40 percent discount as compared to

manufacturers in Europe and the US. The 250-acre SEZ is unique for a company as young as Aequs (started in 2009) and they have steadily built their expertise in the aerospace services in a way that has attracted global aerospace industry giants. With their acquisitions in US and France, they have been able to establish the first global aerospace ecosystem in the world, of this scale. They also have the distinction of being India's fastest growing aerospace company, with a CAGR of 50% year-on-year for 5 years. At present, the Belagavi SEZ houses 25 aerospace entities, including Aequs companies and its JVs, with nearly 70 acres still to be developed. "Aequs managed this transition [from services to products] in QuEST superbly (http://www.forbesindia.com/printcontent/52805).

- Maini Precision Products, a well-known automotive and aerospace manufacturer from Bengaluru, Karnataka. In 2005, the company forayed into the aerospace vertical, which today is a Rs.100-crore-plus business that focuses on products for aircraft engines.
- Cyient, which gets nearly 50% of its revenue from aerospace and railways, works on solutions ranging from aero engines and aero systems to avionics and aero structures.
- Many players as Mahindra, Sansera, Dynamatic, Mainin, Aequs have shifted from automotive industry (ranging from cars to car component making) to the aerospace industry. This has seen Indian aerospace ecosystem with players (small and big) inheriting very good systems and processes. Structured approach to timeplan help them to meet deadline and reduce development time. Visual management, daily management systems, employment recognitions boost their growth. Cross interaction between different businesses, bring values and adapt to create business excellence. TAL Manufacturing is a wholly owned subsidiary of Tata Motors and significant contribution to the Indian aerospace industry.
- This also releases pressure on the ecosystem to depend only on one particular customer or demand volumes. Bharat Forge, L&T, Godrej, Reliance, Adani – all established players have brought their expertise in running business in engineering and other areas to aerospace industry. Though the aerospace business for all these companies are still at nascent stage. At the same time we saw companies as Lakshmi Machine Works from textile spinning machinery manufacturer entering the industry based on dynamic capability of advanced machining of complex parts.

5. Presence of foreign players in India:

- **Thales**, an European technology major, said it would be using India to export some products. It will double its annual sourcing from India, to $740 million in coming years (https://www.business-standard.com/article/companies/defence-major-thales-targets-1-23-billion-revenue-from-india-118041000869_1.html). Thales, which accounts for 25 per cent (in value terms) of the Rafale aircraft, also has JVs with **Samtel and L&T Technology** Services.
- According to a joint report by IESA, Nasscom and Roland Berger the outlook for the Aerospace and Defence Industry in India is positive and expected to reach $70 billion by 2029 (https://www.maiervidorno.com/foreign-strategic-partnerships-transform-indian-aerospace-defence-industry/). There are immense opportunities for forming JVs and collaborating on a range of technologies, ranging from small arms, tanks, artillery guns, air defence systems to radars, missiles, fighter aircraft and ships, in the Defence Sector. Several major foreign defence companies are actively looking for partnerships with Indian companies and/or outsourcing of defence products' manufacturing. Numerous OEMs **(Elbit-Adani (UAVs), Cyient-Blue Bird (UAV), Saab-Aequs (aerostructures), RR-HAL (Engine components), Thales-BEL (radars), Thales-L&T, Reliance, Samtel, IAI-Wipro (composite aerostructures), Dassault-Reliance (aircraft components), Rafael Advanced Defence-Astra microwave (tactical radio communication), Telephonics-Mahindra (radar), BAEs-HAL (aircraft), CAE-Wipro (Simulators), Rosoboronexport-Axis (avionics), Lockheed Martin-TASL (Aerostructures), Safran-HAL (engine parts))** have formed JVs with Indian partners

(Chander, 2018). In capital acquisitions under the “Buy Global” category, contracts will be awarded to these JVs by foreign partners/OEMs.

- As part of the 'Make in India' initiative, Saab has identified a number of Indian companies for collaboration in various areas including software development. The JV partners would help creating a defence eco-system which would involve hundreds of Tier 1, 2 and 3 partners, vendors and suppliers. They can incubate partnerships between its global supply chain and Indian suppliers. It would also foster R&D partnerships for next-generation platform, system and sub-system design and development across the industry. **Safran** Aircraft Engines has taken a significant step forward in its commitment to the Indian government's "Make-in-India" initiative by choosing **Maini** Precision Products (MPP) to manufacture the low-pressure turbine (LPT) guide vanes for LEAP engines. Capability for manufacturing engine parts like turbine fans and engine cores through casting and forging Titanium alloys has also been achieved by HAL, **Bharat Forge** as component suppliers for Rolls Royce. **Saab’**s MoU with **Dynamatic** is a starting point to explore future joint opportunities in commercial and defence-related aerostructures work, including Gripen. As an ongoing commitment to the JV and partnerships with local vendors, Thales focus on creating jobs. They have a strong workforce of over 1,500 people working both directly with as well as indirectly through the supply chain partnerships built with Indian companies. They plan to triple this number in the next two-three years looking forward to developing capabilities for local engineering,
- Aequs Special Economic Zone in Karnataka has expanded by bringing Toulose based **Latécoère Groupe**, ranked 2nd worldwide in onboard aircraft wiring, to set up its production facility in Belagavi, Karnataka. Aequs SEZ is a full-fledged aerospace ecosystem, hosting separate facilities for Machining, Surface Treatment, Assemblies, Fabrication Warehousing, etc., supporting the entire manufacturing process, thereby reducing time-to-market on projects. The company is planning to construct a brand new 4000 sq. m. manufacturing facility within the SEZ to benefit from the existing aerospace ecosystem at Aequs (https://mfgtechupdate.com/2018/06/aequs-sez-facilitates-latecoere-enter-india/).
- With a fully owned in-country subsidiary, **Selex ES** (part of **Leonardo**) brings to the Indian market its state-of-the art portfolio of products and solutions for a wide range of requirements. Active in India since 1972, Selex ES has collaborated first with HAL (Hindustan Aeronautics Limited) and currently with BEL (Bharat Electronics Limited) to supply the country with radar systems and control centres for military Air Traffic Control (ATC) including the 2080C Precision Approach Radar (PAR) system for the Indian Navy and Air Force. The company has also provided a complete Communications, Navigation, Surveillance / Air Traffic Management (CNS/ATM) turn-key system for the two new airports at Bangalore and Hyderabad. More recently Selex ES has been awarded a contract to supply the Indian Navy with its 3D L Band Air Surveillance Radar (RAN-40L) which will be installed on-board the new aircraft carrier at Cochin Shipyard. Through partnerships with **HAL and BEL** Selex ES has also supplied the HF radios (400W, 1 KW and 5 KW) for most of the platforms and coastal stations operated by the Indian Navy and that are manufactured in India by HAL under licence. In addition, the company can provide the Indian Armed Forces with integrated combat systems for naval units, C3I and C4I systems based on network-centric architectures, and radar systems for naval, coastal and land applications. **Data Patterns and Selex ES** are in the process of forming a Joint Venture. This will include the production of high performance electro-optical seekers suitable for a range of different guided weapon programmes. These include Infrared Imaging seekers (both cooled and uncooled), Semi-Active Laser (SAL) seekers, dual and multimode seekers. These are all based on proven Selex ES designs, many in service with international missile systems, customised for the Indian market by Data Patterns (https://www.leonardocompany.com/en/press-release-detail/-/detail/selex-es-in-india).

- India's **Bharat Electronics Limited (**BEL) announced on 5 March the signing of an agreement with Israeli company **Elbit Systems** to produce helmet-mounted display systems and helmet-pointing systems for the Indian market. BEL said through the new technical collaboration agreement (TCA) it will licence-manufacture and integrate the Elbit-designed systems onto rotary-wing platforms in operation with the Indian armed forces. The company added that the TCA was agreed by the two at the 2019 Aero India exhibition in Bangalore. The TCA expands already strong ties between the two companies, with much of the collaboration geared towards meeting Elbit Systems' defence offset obligations within India. **Alpha Design Technologie**s Pvt. Ltd, today announced the signing of a $30 million contract with Elbit Systems for IAF'S MI-17 helicopter upgrade programme. The programme involves upgrading of 90 Mi-17 helicopters and Alpha Design, as the major offset partner, will be manufacturing all key sub-units at its Bengaluru factory, the company said in a release (https://www.janes.com/article/87028/india-s-bel-signs-licence-production-deal-with-elbit, https://economictimes.indiatimes.com/news/defence/alpha-design-signs-30-million-deal-with-elbit-for-iafs-mi-17-helicopter-upgrade/articleshow/57187813.cms?from=mdr).
- India's **Mahindra Aerospace** inaugurated a 270,000-sq-ft aerostructures manufacturing plant last week at the Narsapura Industrial Estate near Bangalore. The plant opening accompanied an announcement by Mahindra that it signed a technology partnership agreement with Spanish Tier 1 supplier **Aernnova** Group, the first for Aernnova with an Indian aerostructures manufacturer. The facility can make large, complex sheet-metal parts using CNC routing, stretch-forming, bladder press, heat treatment and other specialized equipment. The plant also features five-axis CNC machining, a fully automated surface treatment line, priming and painting capabilities for parts and assemblies and nearly 110,000 sq ft of space for the manufacture of major airframe assemblies and subassemblies. The new plant cost about $25 million to build and carries the capacity to yield about $40 million in revenue per year at peak capacity. The company first plans to make small parts and subassemblies, then gradually advance to larger, more complex assemblies (https://www.ainonline.com/aviation-news/aerospace/2013-10-28/indias-mahindra-opens-new-plant-partners-aernnova).
- **RUAG Aerostructures**, a global supplier and integrator of aerostructure components, and **TAL Manufacturing Solutions** Ltd, a Tata Enterprise, have entered into a partnership for manufacturing and supply of aero structural components and sub-assemblies. The two companies have signed a multi-year contract with a potential value of over $150 million. The new work scope allows RUAG to strengthen and optimise the global supply chain to the advantage of Airbus. As part of the contract, TAL will manufacture and supply over 550 sheet metal components, machined parts and sub-assemblies to RUAG, for Airbus' fast moving, successful A320 programme. Going into two fuselage sections of the Airbus A320, these parts are processed from steel, aluminium and titanium and involve the use of some of the most sophisticated and futuristic equipment in aerospace manufacturing (https://www.thehindubusinessline.com/economy/logistics/ruag-aerostructures-tal-manufacturing-enter-into-150million-multiyear-deal/article6904761.ece).
- On Monday, 3rd December 2007, **Dynamatic** Technologies signed an MoU with **Spirit AeroSystems** (Europe) Limited, the European division of Spirit AeroSystems, Inc. – the world's largest supplier of commercial airplane assemblies and components. The MoU between Dynamatic and Spirit Europe covers a significant complex metallic precision assembly for Airbus Single Aisle (A320 family) aircraft. The assembly by Dynamatic marks a major step towards further development of the parties' strategic partnership. Spirit AeroSystems, a global supplier of structures for commercial aircraft, today said that it is teaming up with Infosys to set up an 'engineering centre' at the latter's Bangalore campus. The centre will focus on high-end engineering services including product development, design and analysis of airframe structures, engineering change management and stress

engineering support. The engineering centre will grow into a 'global virtual real-time operation' for Spirit AeroSystems. Speaking on the occasion, Bob Waner, senior vice-president and chief technology officer, Spirit AeroSystems, said, "This is a great opportunity for Spirit AeroSystems to strengthen its presence in India (https://www.dynamatics.com/news13.shtml, https://www.business-standard.com/article/companies/infosys-to-set-up-engg-unit-for-spirit-aerosystems-106021601116_1.html).

- **GKN Aerospace India** (GAI), a global first- tier supplier of complex wing and fuselage structures and engine components, has collaborated with **Aerospace and Aviation Sector Skill Council (AASSC) and P3 Academy (P3A)** to enhance the skills and knowledge of rural and underprivileged students in India. GKN Aerospace India (GAI) has been supporting **Skill India** Mission through their CSR initiatives through a skill-based course in Aerospace Structural Engineering to bridge the gap of Engineering students (https://www.nationalskillsnetwork.in/gkn-aerospace-india-gai-csr/).
- **GKN Fokker Elmo** and the **State of Maharashtra (India**) have signed an MOU for investment in a **second manufacturing facility for wiring interconnection** systems in India. The new site, a fully-owned GKN Aerospace business, is located in Pune in the state Maharashtra and is scheduled to come on line in the fourth quarter of 2018. Production will start in the first quarter of 2019, the work force is expected to grow to 800 in 2027. The site will focus on the assembly of wiring systems for commercial aircraft and will operate alongside the existing Joint Venture for wiring systems in Bangalore which is serving the defence market. The plans also include the installation of proprietary wiring design and manufacturing system, a unique tool that is rolled out globally throughout all manufacturing locations worldwide to ensure the same high quality everywhere in the world. Pune offers favourable conditions in the areas of business development, labour, education & training and infrastructure. It also has an excellent location relative to the company's major customers in India (https://www.aero-mag.com/gkn-aerospace-establishes-new-wiring-facility-india/).
- Following the successful induction of the K-9 Vajra-T 155 mm, 52 calibre gun in the Indian Army, built jointly by **L&T and Hanwha Techwin**, several defence and aerospace companies from **South Korea** are seeking joint ventures in the defence sector to participate in 'Make in India' initiative. **They also expressed their keenness to establish a presence in the defence corridors in Tamil Nadu and Uttar Pradesh, after establishing a contract relationship in a weapon system Indian forces are interested in**. Top company executive of **Korean Aircraft Industries (KAI)** maker of the trainee aircraft 'KT-1' offered its Utility Helicopter to the Indian Air Force. The company has earlier offered to work with the Hindustan Aeronautics Ltd (HAL) and is willing to share technology for building the trainers here in India, as in South Korea there's no law that would stop the transfer of technology (https://www.financialexpress.com/defence/top-defence-companies-from-south-korea-looking-for-ventures-in-india/1559934/).
- **ShinMaywa and Mahindra** Defence aim to set up MRO services in India. In addition, the partnership will carry out the manufacturing, assembling of structural parts & components for US-2 amphibian aircraft. Commenting on the tie-up, SP Shukla, Group President, Aerospace & Defence Sector, Mahindra Group and Chairman, Mahindra Defence, said, "This partnership between two companies familiar with the aviation business is positive especially for MRO and maintenance services in the Indian defence aerospace sector. We are committed to absorbing maintenance TOT for this large amphibious aircraft in India. Our partnership will enable us to leverage our strengths and consequently, this will contribute to growing Indian aerospace ecosystem." (https://www.mahindra.com/news-room/press-release/mahindra-defence-and-shinmaywa-industries-limited-join-hands-for-us-2-amphibious-aircraft).

- **Collins Aerospace** established their presence in India in 2008 with the opening of India Design Center in Hyderabad. This enabled them to support local and international governments, aerospace Original Equipment Manufacturers and defense contractors with engineering design services and systems that can help achieve a shorter time to market, at a lower program or project life-cycle cost, with innovative solutions of the highest quality. These factors present opportunities to partner, market directly and develop locally advanced communications, navigation, avionics and electronics products, solutions and services for military and commercial customers. The Hyderabad facility is dedicated to software development.
- **Boeing India Private Ltd** has partnered with **Lakshmi Machine Works** and Learning Links Foundation to impart **technical training** in aerospace tool design and manufacture.
- A joint venture between **Tata Advanced Systems and General Electric**, is setting up an aircraft engine component manufacturing-cum-research hub in Hyderabad,. This facility will manufacture components for Leading Edge Aviation Propulsion (LEAP) engines for jets and will cater to aircraft manufacturers like Airbus and Boeing and supply components for India and global markets of GE.
- Chennai-based **Rialto Enterprises Pvt Ltd,** and US-based **$50 million Carr Lane** Manufacturing have formed a 30:70 joint venture to make aerospace components (non-flying) for both domestic and export markets.
- **ANKIT** Fasteners leverages its vast experience and JV **with Lisi Aerospace** in fastener design and manufacture to help customers design smart fasteners that reduce costs and double productivity. It is an Airbus approved supplier in India
- **Magellan's** Joint Venture with **Triveni** (since 2013) provides aerostructure and aeroengine machining and assembly: machined metallic components and assemblies; advanced 5-axis machining; hard and soft metals - titanium, steel, aluminum alloys; assembly and test.
- **Henkel** invested $ 36 million to set up the first phase of India's largest manufacturing unit for adhesive, sealant and surface treatment products at Kurkumbh near Pune. This plant will reduce imports while bringing the best global technology to India. They have also recently inaugurated an acoustic lab and an MRO Center of Excellence.
- **Bostik**, a part of French speciality chemicals company Arkema, provides adhesive technologies for aerospace. In 2017, a new adhesives production facility in Gujarat was opened primarily to expand manufacturing capacities to serve the fast growing demand in India and export markets for industrial adhesives
- Mumbai office is the hub for **Huntsman's** activities in the Indian subcontinent and Middle East. They have invested in green field plant in India to manufacture Araldite® resins and Aradur® hardeners. The state-of-the-art plant built in Manali, Chennai, is a part of the expansion plans to better serve Indian and the overseas market. With a capacity of over 30,000 MTA, a fully equipped laboratory and our trained personnel, we are fully geared up to meet the growing expectations of our customers.
- **Hexcel** is announcing the opening of its new sales office, Hexcel Composites India LLP in Bangalore
- **Lockheed, Boeing and Airbus are very active in Indian startup space in Indian aerospace industry.** Founded by IIT Madras alumni, Terero Mobility is a spin-off from a Lockheed Martin-sponsored R&D project. Lockheed expects to provide Terero Mobility with a scope of work for design development, test and qualification of the Cargo Ground Buildup System (CGBS) for fixed and rotary wing aircraft, apart from system engineering support and mentoring. Lockheed intends to offer a scope of work to NoPo Nanotech for qualification of as-produced, purified and metallic sorted HiPCO carbon nanotubes to provide electromagnetic interference and lightning protection. Lockheed Martin expects to provide Sastra Robotics with a scope of work for qualification of robots produced by the company for avionics testing. These products can help in the testing of avionics display of tactical

fighter platforms including the F-21. Boeing's India Engineering & Technology Centre (BIETC) along with T-HUB launched Boeing HorizonX India Innovation Challenge in 2018. The initiative has selected three aerospace startups -- Merxius (develops an extended reality (XR) authorising software for non-coders), HuviAir (unmanned aircraft services and software solutions for surveying and workflow management) and ZestIOT (provides airport and airplane IOT technologies).

6. Research and Development

Research and Development (R&D) activities started in HAL way back in 1941, with development of the first indigenously designed primary trainer, viz. HT-2, which made its maiden flight in the year 1951. Subsequently HAL's Research & Development capabilities have grown from strength to strength and have been harnessed to achieve greater levels of self–reliance and generate new business. HAL Research and Design (R&D) Centres are engaged in design and development of Fixed Wing aircraft and Helicopters, aero-engines, aircraft systems & its accessories, avionics equipment and software, aircraft Upgrade, Life Extension and materials.

HAL's R&D Performance during the last two years is shown below:

Sl. No.	Particulars	2016-17	2017-18
1	R&D Expenditure (Rs. Crores)	1284	1612
2	R&D Expenditure as % of Sales	7.29%	8.82%
3.	IPR Filed Cumulative	1419	1542
4.	IPR Granted- Cumulative	54	110

Patent : 7 ; Design Registration: 18; Copyright: 153

HAL is good at product innovation (spends 2% of gross revenue every year in process innovation and improvement) and some of the examples are as follows:

a) Light Combat Helicopter (LCH): LCH is 5.8 ton class combat helicopter indigenously designed and developed by HAL. LCH has the distinction of being the first combat helicopter to land Siachen at a height of 4700 mtrs. LCH draws maximum commonality with the ALH Dhruv to make is a cost effective product to meet the combat requirements of the customers.

b) ALH with tail and main rotor blade folding for Naval role: Considering the requirements and constraints of naval role, HAL has made efforts to develop ALH with tail and main rotor blade folding and demonstrated the same in Aero India 2019. This effort enables HAL to offer a product to meet the requirement of customer at shortest period of time. ALH will also provide benefit to the customer to minimise cost of fleet management, training of pilots & support crew etc.

c) LCA MK1A: HAL is developing an improved version of LCA MK1 with additional features like Self Protection Jammer, Active Electronically Scanned Array (AESA) RADAR and Beyond Visual Range(BVR) Missileetc to offer a product which will be at par with the 4+ generation aircraft. This will help HAL to offer an indigenous fighter aircraft with better mission capability to customer.

d) Hawk i: HAL has incorporated the advance systems to enhance existing Hawk MK132 mission capability and training capability, which will facilitate better training of Customers' Pilots

e) Light Utility Helicopter (LUH):The LUH is a 3-ton class new generation helicopter indigenously designed and developed by HAL to meet the requirements of both military and civil operators. The helicopter with Glass Cockpit will be deployed for reconnaissance, surveillance roles and as a light transport helicopter.

f) HAL has also taken up Artificial Intelligence enabled Projects such as Voice Activated Command System, Automatic Target Recognition and Helicopter Maintenance Algorithm.

g) Other innovative futuristic projects under pipeline are Aero Engines, IMRH(Indian Multirole Helicopter, 12 Ton Class) etc

HAL has a Technology & Design Policy Committee (TDPC) to sanction innovative design projects. These projects are reviewed in Committee of Institutions Network (COIN), a committee with

heads of all R & D unis of HAL under one roof, before putting up to TDPC. An R&D Corpus has been created from internal funds to carryout Technology Development projects for future exploitation in our products. Also, Technology development groups have been formed to identify, develop and implement advanced technologies required for future airborne platforms/projects. Academia and IITs / IISc are involved in technology development – specific Chairs have been established for development of future technologies. Engineers are regularly deputed for higher studies at IITs, IISc and foreign universities in chosen areas. In addition, A Defence Innovation organisation(DIO) has been formed by HAL and BEL, as a non-profit company, to foster technology development and innovation products for the defence sector.

Design consultancy was availed from MBB for Advanced Light Helicopters. This has helped HAL Design Team to obtain technologies and knowledge in the various areas of helicopter Design and Development. Today, HAL is one among very few companies who can design, develop, manufacture and maintain the helicopters

So far, there is no indigenous manufacture of semiconductor gas sensors in India. Most of the work in our country is limited to basic studies on such sensors rather than developing marketable products. In order to promote indigenization of sensors technology. Department of Science and Technology (DST) has initiated the concept of “SENSOR HUB” in many centers in our country. In partnership with Council of Scientific and Industrial Research, DST has instituted a “SENSOR HUB” in CSIR-CGCRI as a multi institutional endeavor for indigenous development of gas and bio sensors. R&D in the area of piezoceramic actuators have been very active worldwide. Some of the national R&D efforts have fructified into setting up of micro and nano fabrication facilities at IISc (Bangalore), IIT (Bombay), ITI (Bangalore), SCL (Chandigarh), CMTI (Bangalore), CSIRCGCRI and CSIR-NAL. Indian commercial manufactures of PZT based materials and devices are Sparkler Ceramics Pvt. Ltd, (Maharashtra), Concord Electroceramic Industry, (Sahibabad (UP)).

5.3 Summary of Findings and Analysis: Weaknesses

- Though policy initiatives have been taken by the government for improving the financial condition of lower tier suppliers who are mostly micro & small enterprises, they are still facing issues in the domestic market itself in respect of stringent quality & delivery norms. So the migration in respect of lower tier suppliers to global standards can be expected only gradually.
- The challenges for Indian aerospace industry are already notified in our findings and HAL inputs as,

a. High Capital Investment
b. Longer Lead times
c. Longer Certification processes
d. Technology Limitations
e. Lack of matured Defence ecosystem
f. Taxation Structure of Civil Aviation and MRO Business
g. Lack of Coherent Policies

- ISRO develop their own vendors, they invest on their vendors and those vendors solely work for them. this is the key success of ISRO. They made their own value chain. Currently HAL has no tier 1 supply chain with whom they can share technology or subcontract assembly or subassembly. The vertical integration burden and responding to changing marketplace is taking toll on HAL’s design and innovation capability.
- HAL has high dependency on foreign OEMs for critical materials and LRUs. HAL, despite its success in designing aircraft, was not only dependent on foreign sources for special steel and

aluminium but also for all instrumentation, undercarriage, braking systems, communication systems and electronic systems. The engine of the LCA are sourced from abroad, indicating the lack of depth in indigenous capability (Behera, 2016). The LCA's technological shortcomings are further illustrated in the recently published list of 121 systems (pertaining to avionics, electronics, hydraulics, landing gear and propulsion) that the Aeronautical Development Agency (ADA) – an autonomous body functioning under DRDO – wants to indigenise through the participation of Indian vendors (https://www.drdo.gov.in/drdo/whatsnew/Indeginization.pdf). The 40% import content in defence procurement till date is a further indication of the technological gap that DRDO is confronted with in its developmental projects.

- HAL made a delayed entry in the civil market and has little experience in civil aircraft development, testing, certification and managing civil projects.
- HAL has little presence outside India in export market. In year 2018-19, HAL has registered sales of Rs 19705 crore, out of which Rs 770 crore sales is from civil segment and Rs 405 crore is from export business.
- HAL's 82% of raw Material, spares arts and components consumed is imported.
- Research spending on DRDO is only 6% of total defence budget. This is a meagre amount.
- Most of the supply chain has no knowledge or expertise of design and development. Though they have experience in machining or casting or forging complex parts and components but and exporting to foreign OEMs, all of these are built to print, which can be easily substituted.
- Aviation grade raw materials is a critical area of weakness for the industry. Nearly 95% of raw materials are imported currently (as per HAL workshop interactions). Though India is rich in Titanium reserves, the technology of extraction and processing is yet to fully mature. However, with the successful commissioning of the Titanium Sponge Plant in collaboration with ISRO, India has joined the elite club of seven countries capable of producing aerospace grade Titanium sponge. The Plant has the basic infrastructure for increasing the capacity to 1000 tpa in future. With Sponge to metal yield at 35%, the requirement of Ti-sponge on a conservative estimate would be 2,500 tpa for India. The plant capacity now will be just sufficient to serve the strategic industry like the indigenous Space & Defence programmes. The product however still proves costly due to lack of scale. Titanium metal and sponge production is highly energy intensive. The power requirement however gets reduced with increased plant capacity. At present, India has neither an economically viable bigger size Ti-sponge plant nor Titanium castings plant, or any heat treatment facility for Ti-rings. The titanium metal industry in India has not progressed at the desired pace mainly for the fact that the plants require huge investment and also the demand keeps on fluctuating due to government policy on Aircraft, Defence and Industry budget allocations. The high specific power requirement also acts as a deterrent to put up large plants. The cost of reducing agents like Magnesium makes the process expensive (source: https://tifac.org.in/images/tifac_images/2035/tv2035/TV%202035%20-%20Material%20-%20LR.pdf). Indian Aluminium industry spends a meagre 0.02 to 0.04% on R&D, which is extremely low by international standard. At present, the R&D efforts in the Iron and Steel industry in India are far from adequate (0.4% of revenue). Global average is 2%.
- The MSME sector is struggling to meet the GST burden as per one component supplier with machining capability said that the GST he has to pay is 28%, procuring one single tool tip for his cutting tools attract 18% GST. At the same time, though DPSU's release payment within stipulated period, the other business from private sector has problems with payment and with heavy taxation and interest rates, it becomes difficult to sustain.
- According to OEMs and customers, vendors always try to find an easy way to enter in the aerospace industry. They also show no accountability or promise to improve and all vendors are manly making same kind of product and in effect killing each other.

- “Capabilities we have but we are lacking in LRU development. LRU is a modular component of an airplane, ship or spacecraft (or any other manufactured device) that is designed to be replaced quickly at an operating location (1st line). For making an aircraft LRU development is necessary in any kind of manufacturing in aerospace industry. We are still importing LRUs. Focus should not be duplicating the capabilities which HAL already have or which is already in the country. Development is needed in making LRUs, avionics and Engines.
- HAL products are highly technology sensitive and closely regulated by the Governments. There is very little scope of improvisation and building talent who can transfer advanced knowledge after doing MTech/ PhD to the practice and in effect would create something new for the organisation. As everything is so regulated and rule-bound in HAL, a new joinee continues doing work that is in work order. In any manufacturing if it is a commercial product or tested and proven product then customer will pay but if it is a technology development, the future is insecure in that case financing from government is necessary, which takes a long time currently due to many government regulations. However, HAL has devised strategy similar to that of global OEMs to achieve higher level of outsourcing by developing Tier-II and gradually Tier-I suppliers over a period of time while retaining the core areas as prime integrators. HAL would outsource manufacture of sub-assembly and major assemblies along with detailed components to achieve higher levels of outsourcing in terms of Standard Man Hours (SMH). By outsourcing a substantial part of the manufacturing to the vendors and by way of the experience gained in the process, HAL is moving towards a system integrated process and its goal of becoming a lead integrator. The process involves spreading awareness of airworthy quality & safety requirements, initial hand-holding and over-the-shoulder production supervision to finally turn the supplier into a reliable partner of HAL's value chain. The pace of its progress is very slow and will depend upon willingness of private Indian industry as well as its capability to enter into this low-volume capital intensive industry.
- Lack of common testing facilities, air field, laboratories accessible to all players. One supplier had to send materials for testing to Spanish laboratory and he is waiting for one year with no response.
- Make in India has not worked in indigenisation of aerospace raw materials, paints, sealants, standard parts. Import is an added costs for the supply base. India is perceived as a low cost country only for labour. All other products we are high costs as raw material is not available to us and it is a low cost for them as those are developed in EU/South east Asian countries and locally available raw materials. We spend 15% more than them in raw materials. Then there is logistics costs for FG deliverables. Only criteria supply base is still surviving is due to cheap manhours. Since India is developing fast, over a period of time this will not be cheap anymore
- Except DRDO other companies are not getting any Innovation funding. So, if they get any order or tender, they have to develop first their capabilities by their own.
- Strategic partnership between nations for knowledge and technology transfer is not happening in aerospace and defence sector. Particularly co-development projects are not working.
- Quality, aesthetics are compromised for L1 in defence sector.
- “We don’t have standards (we follow MIL, NaS or GOst standards developed by some other countries) – nobody wants to use Indian standards as JSS for military or BIS for civil. CEMILAC and others say they will only look at MIL standards. MIL environmental testing standard MIL810 – Indian equivalent is JS555. Though we operate at sea, sub sea levels and also 6km at Siachen – both different environmental areas – specification for ground and Siachen are same (standards should cover entire geography). Same aircraft operates in both areas. Any product made in this country must follow these standards”.

- Most of the MSMEs we interacted scored very poorly in exchanging ideas, collaborating with other MSMEs or networking skills. Though there is a cluster in Bangalore but it appears that, it is not cooperative and this is detrimental to the progress of the industry.
- Skill development is a challenge in this industry.
- Though individual states are announcing policy to attract foreign and domestic OEMs, it is not coordinated. All the policies we studied are either copy or mere modification in the rates or subsidies. Lack of innovation in the state policies or focus will not yield enough partners. States are using generic subsectors (sometimes announcing bigger incentives for whole aircraft manufacturing) but not specifying on a particular critical industry as avionics or engine or materials or adhesives which can be related to existing competencies in the state or local academia. Otherwise it will remain in paper and not achieve fruition.
- Most sourcing of HAL is to small scale industries. If HAL wants to scale up and they want to have global footprint in terms of sales they want big players in their supplier list then only they can be system integrators. All subassemblies to big players and they will offer sustainability, reliability and cost competitiveness. Due to this, supply chain failed to deliver promised parts. L1 systems make bigger companies uncompetitive to small scale industries. HAL is missing out on design, innovation solutions, manufacturing flexibilities, support through 100% delivery and quality assurance.
- The key competitive challenges faced by HAL are:

1. Government policy of keeping DPSU out of the Strategic Partnership.
2. Governments direct purchasing / procurement of defence platforms from foreign OEMs.
3. High manpower cost to compete with the private industry
4. Restriction from Foreign OEMs for export

- India — a country of more than 1.3 billion people — has fewer than 200 civilian helicopters in operation. Though helicopter forms a larger share in military assets than the About 40 in the private category, 15 with the para-military and 25 with state governments make up the rest in a total fewer than 300 civil helicopters in the whole country. High Cost of Operations in the form of turbine fuel, customs duty for import of helicopters/spares and application of fixed wing air traffic rules to helicopters have stymied the growth of civil helicopter industry to a large extent. Another major problem is lack of infrastructure. While the scope of operations and utilisation for commercial helicopters is vast, the requisite infrastructure is almost non-existent both in the metros and remote areas. Helihub, heliport and helipad development requires investment in the range of $5bn.

Availability of Pilots and Training Facilities: With the expanding civil helicopter industry the demand for pilots is ever increasing. Presently 80 per cent of pilots are being provided through the armed forces (Retirees/Premature Retirees). There is a need to boost up the training facilities to get pilots.

Regulatory Bottlenecks: The biggest bottleneck is the applicability of fixed wing operation regulations to helicopter operations. Fortunately, based on the recommendations of the Parliamentary Committee on Aviation the requirement for looking into helicopter operations in a more holistic manner is being pursued but the progress is lethargic to say the least. There is a need for clearing regulatory bottlenecks faced by the industry on a fast track to enhance growth and smooth operations. While some action for having separate corridors for operation of helicopters in Delhi and Mumbai airspace is in progress the pace is again very slow. This is a major step that will help in increasing safety as well as efficiency and capacity for helicopter operations.

- The offset policy has inherent design weaknesses and is poorly implemented and monitored. Compared to the policy followed by many countries such as Canada, Israel, Malaysia, South Korea and Turkey, the Indian offset policy gives too much leeway to the foreign companies. Its biggest weakness is the freedom given to foreign companies to

choose offsets that they want to deliver. Obviously, they have so far chosen offsets which do not add to the capability enhancement of the local industry.
- The hike in threshold would mean that fewer arms import contracts would now be eligible for offsets. This would be a big setback to the local industry, particularly the manufacture of parts and components which have exploited the existing offset policy for boosting their export performance, and in the process set up capability which could have been further exploited for Make in India.

5.4 Summary of Findings and Analysis: Opportunities

- HAL operations are in a very Focused market and the Client Base is limited. Although the Client base has not changed over last five years, we look forward to increase the Client base through exports and in Civil Markets. HAL maintains on an Avg., 80% of total Air Assets of Indian Defence Forces:. 100% of Indian Army, 80% of Indian Navy and 75% of Indian Airforce. The size of the industry will certainly change in coming years which can propel the procurement and HAL has its products and Service offerings such as LCA Mk –I, LCH, LUH, ALH, HTT-40 etc., These products also have a global market thereby there will be increase in the client base as well.
- At $16 billion, India is the fastest growing and currently the ninth largest civil aviation market in the world (Source: export.gov.in). The year on year growth of domestic passenger traffic during the financial year 2018-19 has been estimated at around 14%. Total Domestic passenger traffic in the FY 2018-19 has been estimated as more than 140 Million passengers against 123 Million during the FY 2017-18. The international passenger traffic carried by scheduled domestic airlines (to and from India) has grown annually by around 9% during the same period. It is expected to become the third largest by 2022. The passenger traffic is expected to grow six-fold to around 1.1 billion. Its scheduled commercial airline fleet is likely to grow from 550 in March 2019 to around 2300 in March 2040 (Source: Vision 2040 for civil aviation industry in India, KPMG & MoCA). The growing demand has encouraged Indian carriers to place large orders as shown below. In December 2018, Indian carrier had a fleet of around 670 aircraft with pending deliveries of around 1024 aircrafts2. A buoyant market growth rate coupled with the expansion of infrastructure, is likely to help the Indian civil aviation industry grow at an accelerated space. With large domestic and global opportunity, there exists a real case for building 'Make in India' capabilities in this segment including manufacturing and associated maintenance, repair and overhaul (MRO).
- India's HAL is projected to be the third among the world's top four manufacturers of light military helicopters weighting less than 15000 pounds, over the next 15 years. More than 1,600 light military helicopters will be built over the next 15-years by manufacturers worldwide for a value of about $22.2 billion, according to a report by market intelligence firm Forecast International, of which Production of light military rotorcraft, weighing less than 15,000 pounds (8600 kilograms) has been on the upswing since 2014, rising from the 160 units produced that year to 208 in 2016 and further increasing to 217 in 2017. (https://www.defenseworld.net/news/21069/India___s_HAL_Among_World___s_Top_4_Light_Military_Helicopter_Manufacturers#.XWkxJC4zbIU)
- HAL and government of India have already indicated the plan to use Dornier 228 aircraft for civilian purposes and also, there is already demand from plane operators, both domestic and international, for the Dornier aircraft. Plus, India can provide such 18-seater aircraft at a lower cost than other manufacturers which is an advantage. Air India has indicated that it could initially acquire at least 10 such aircraft to operate regional routes. Pawan Hans, the state-owned helicopter company which plans to diversify into fixed-wing aircraft operations, is also said to be keen on acquiring the Dornier aircraft. Also, neighbouring countries like Nepal and Sri Lanka are also keen on using Dornier 228 for civil aviation purposes. Thus, we

should spend our money on making Dornier better equipped rather than waste money trying to compete.

- Being a major importer of weapons, India is naturally keen to export indigenously developed ones. To-date, Egypt, Sri Lanka, the UAE and Singapore have 'shown interest'. India should wait till the Mk 2 is in service and all its kinks are removed, before offering it. However, the trainer variant is not affected by the low payload/range performance of Tejas, and could be offered earlier. Tejas is likely to be further developed in the future, and to be upgraded with such developments as Direct Voice Control (through verbal signals to the sensors), an engine thrust vectoring nozzle (for greater agility in flight as well as for better runway performance), and hopefully a Variable Camber Wing (which will maintain high efficiency throughout its flight envelope), as well as a more advanced engine, and the like.
- HAL's extensive experience in maintenance of aged fleet would make it enter MRO markets which cannot afford to buy advanced jet fighters
- A big opportunity for Indian aerospace industry is the transition of many companies from one industry to another. Though there are many weaknesses in HAL and its supply chain management but the vendors who transitioned admitted that, when they started they did not have any capability. Initially OEMs used hand holding to build skill. This is a positive sign for any industry to develop – flow of skills from higher tier partners to lower tiers. This opened up many export opportunities for the supply base. In fact, many companies
- In particular, lots of opportunities exist for British firms. The UK may be leaving the EU, but that opens up opportunity for Indian firms to partner and enter into co-development alliances.
- NAL's success in testing revived SARAS opens up opportunity in regional jet market. Though there might be delays in international certification, DGCA and MoD can work together to start these aircrafts in regional routes.
- Another opportunity for India is the civil and commercial helicopter market. HAL is recognised worldwide as a leading helicopter manufacturer in defence aerospace market. Also HAL has acquired maintenance capability from foreign OEMs and have designed and developed new models. So there is a huge opportunity for HAL to enter civil helicopter market provided the regulatory bottlenecks are cleared.
- HAL is looking to make inroads into the lucrative South American market with its indigenously developed helicopter, `Dhruv'. HAL is in contact with other potential customers in the region and business prospects are being pursued in countries such as Bolivia, Peru, Colombia, Brazil etc. Several countries in the region have also approached Indian companies, especially MSMEs, in the defence and aerospace sectors to set up manufacturing bases in their countries and are offering tax incentives. MKU has the contract to armour M-17 helicopters for the Mexican Navy and Police. MKU had won a global tender in Ecuador as its body armour was chosen by the Ecuadorean Interior Ministry through extensive tests and field trials before being selected. It may be recalled that Ecuador was among the first countries to import India's indigenously developed seven ''Dhruv'' Advance Light Helicopters (ALH). Samtel Avionics Ltd has signed an MoU with Avionics Services, Brazil for supplying MFDs for multiple helicopter programmes as well as fixed wing aircraft. The company has also won a trainer programme in South America, and is in talks for transfer of technology on displays. (mea.gov.in). Thus our aerospace and defence sector can look into friendly markets for export of aerospace equipment.

5.5 Summary of Findings and Analysis: Threats

- Currently, the IAF has 31 fighter jet squadrons, against an authorised strength of 42. This gap is due to the slow induction of newer fighter aircraft after the existing planes retire from the fleet on completing their technical life, the December 2017 parliamentary committee report found. Over the next decade, 14 squadrons of MiG 21, 27 and 29 will retire from the

IAF fleet, leaving only 19 squadrons by 2027 and 16 by 2032. To arrest the drawdown, the Air Force will induct Sukhoi-20, Tejas Light Combat Aircraft and Rafale jets, the IAF told the parliamentary committee.

- Due to the taxation structure, the Indian suppliers are becoming globally uncompetitive. To fulfil the offset obligation, MoD has provided a range of avenues to foreign companies. One is to purchase from the local industry. The purchase can be for own use or for integration in India. For the latter option, it is up to the foreign company to take the help of its Indian supplier. The structure of the existing taxation policy is such that the foreign company does not find it cost-effective to carry out integration in India. Rather it prefers to import the product and re-export to India after integration. In the process, the Indian partner loses out in developing or harnessing a key capability of system integration, which is the basic objective of the offset policy.
- Poor R&D infrastructure and incentives will result in import dependence and it will be a vicious cycle as on one hand offset will not work, foreign OEMs will not be parting away with their core knowledge and help develop LSSIs in India but only access cheap labour. The condition is not going to improve in the near future as private sector and government are not willing to put money in research projects whose future may be uncertain and outcome delayed. The government is also equally responsible for not incentivising the industry. From the private sector's point of view, the biggest obstacle has so far been the nonoperationalisation of Make projects, which were supposed to spur design and developmental efforts by the private sector. The private sector also complains that the restrictive income tax provisions pertaining to expenditure on scientific research are also a major hindrance for their poor investment on in-house R&D. As per Section 35 of the Income Tax Act, industry's contribution to national research laboratories/universities or its own in-house R&D investment is allowed a 200 per cent weighted tax deduction. However, the tax benefit is limited to four heads of expenditure: plant and machinery; materials and consumables; utilities and services; and human resource. As noted by the Joint Committee of Industry and Government (JCIG), set up by the Department of Science and Technology (DST) to suggest policy measures to stimulate R&D investment by the private sector, these heads of expenditure do not include the entire R&D value chain, which includes R&D in the laboratory, pilot production, test beds, design and development, standardisation, field trials and pre-commercial trial production. The JCIG had drawn attention that other countries factor the entire value chain for the purpose of providing incentives to industry and had recommended similar measures. The recommendation is yet to find acceptance by the government.
- There is also a doubt where it would be able to create a high-end labour force, especially engineers and designers to meet the requirement of the high value aerospace manufacturing industry of India. Particularly the private sector (including MSMEs) which are expected to undertake complex designing/manufacturing under the Make and Buy and Make (India) projects. This problem is a threat to the industry survival. As of now, Strategic Manufacturing Skills Council (SMSC), CII is geared more towards imparting training to shop-floor level workforce, with maximum six months of training. Evidently, there is an absence of a plan to create a pool of engineers/designers which can only come from dedicated engineering/academic institutions with exposure to defence. The existing academic institutions are not only below the global standards but the research undertaken by them is hardly related to defence. To bridge the gap, the Prime Minister has promised to set up dedicated universities on the lines of ones set up by the Department of Atomic Energy (DAE) and ISRO. However, no such announcement is yet made. Thus there is a threat that India will remain a 3rd tier supplier to the global aerospace industry rather than an OEM which require design and engineering staff with real R&D capability.

- Poor human resource base is plaguing the DRDO. The scientific manpower has not enhanced compared to the projects resulting in delays in product development. DRDO's limited human resources base is further constrained by a number of other factors such as the high attrition of scientists, low educational profile of the scientific cadre and poor training, which together makes DRDO less dynamic for a qualified and motivated workforce to work in. This is direct result of poor budget allocation for DRDO in defence.
- In our sample for studying Indian aerospace sector, only 3 suppliers out of 21 received offset benefits. Most of them did not receive any technology transfer. HAL's meagre exports itself states the offset status for them. Thus offsets are not helping to build capabilities neither boosting exports. This is a big threat for the future of the aerospace industry in India. Indian exports of aircraft and parts constitute only 0.5% of total Indian exports in 2018-19 financial year

5.6 Recommendations

- **Enhancement of Capital Budget in defence** to introduce need based procurement involving the industry representatives, research establishment and armed forces. There should be two elements of the enhanced capital budget – one for enhancing indigenisation in critical areas through large scale "make" projects involving private and public sectors, another for enhancing armed force capability based on equipment upgrades, technology adoption, equipment buy [IDDM]. The enhancement may be carried out in an incremental manner over subsequent fiscal years. Any project of national interest technology/capability has to be developed in country. Such projects though covered under "Make" can be termed "Design and Make"in India. Needs huge investment from ministry. DPSUs can invest small amount. Engine, Radar, Avionics of national use to be developed by Government under capital budget. Every project has to be national interest, for example AMCA/5th generation fighter/ autonomous armed helicopters – identify production agencies (including private), customers, quality control and design agencies. One nodal agency is must. For aircraft, integration of modules be done by HAL, design be taken up by ADA or DRDO. For electronics BEL will be nodal agency. Midhani given responsibilities for all raw materials (develop including private companies using faiclities available). Any national project (niche technology) all the agencies have to be together –instead of duplicating capabilities. Private companies if start afresh incurs huge cost of runway, jigs fixtures, testing after assembly and cost of product increases. Whatever available with design agencies, DPSUs be utilised by all for the national "design and make" projects. LRUs, avionics –development of technology be taken over by private sector and whatever is available with PSUs be utilised by all.

- **Building self-reliant Tier-1 Indian supplier and a strong ecosystem:** Right from independence India's focus was on self sufficiency and self reliance in defence industry development. For this, HAL has been under full control of Indian government right from its inception. In today's world, we have seen even countries as conservative as Italy or France relaxed their control and provided autonomy to their indigenous defence sector. It is high time for the government to realise that HAL, the national champion must make a place in the global value chain of aerospace. This can be done by developing a capable Tier 1 or LRU supplier so that they will come forward, they will share risk, make good ecosystem, make the product of its own and independent product line. Government need to give HAL autonomy to develop this second line of industry as early as possible as it has given ISRO to develop its own vendor base. Long term contracts and co-development projects to be awarded to capable vendors. We have already seen that in aerostructure there are many capable suppliers available in India who can become Tier 1. Some capabilities need to be outsources. Government first need to decide which capabilities are going to be retained and

which are to be outsourced. There has to be few operational recommendations for effecting this goal:

- Find a commonality between civil and military so that vendor will get volume.
- Single certification for both civil and military.
- Consultation on common and similar components.
- Training of manpower in aerospace and defence aircraft production and assembly, LRU level technologies etc at HAL facilities to be absorbed by vendor base. This is done by Toyota in India, where they have their own technical training institute jointly run with one government ITI – curriculum, on the job training provided by Toyota. On completion of the programme, best talents are absorbed by Toyota and rest by dealer base.
- R&D support to vendor base through state or central government incentive schemes
- Making the testing facilities available to vendor base or facilitate/train in certification
- Train in process innovation, quality systems
- Modifying the concept of L1 based tendering (a requirement for DPSUs)
- More informal relationship with supply base (like Japanese companies) by giving up adversarial mindset to more collegial mindset
- Internal process streamlining (faster decision making, internal functions particularly finance accounts to be synchronised in project mindset of quick response and clearance)
- More lenient approach towards private industries considering their lack of access to facilities and infrastructure (use cost sharing contracts or performance based payments in long term contracts)
- Organise vendor meets where smaller tier to facilitate cross learning on manufacturing practices and capabilities

- **Rekindling Offset Policy:** India can make some changes to the current offset policy to develop access to advanced technology. For this they can take a lesson from countries like UAE, Malaysia. First, the multiplier can be removed and percentage of offset can be increased to 70 or 80%, that means for each dollar spent on aerospace purchases, the vendor must invest 80c in Indian domestic aerospace industry. Secondly, the same offset provision can be extended to all large government contract bidders as Tata, Mahindra, HAL etc. Third, the offset threshold need to reduced to include all types of purchases. Fourth, an objective measure needs to be introduced to assess the value of offset obligation – input credit (knowledge, equity,industry enablers) and output credit (export sales, profit and employment generated) or current concept of value addition with inclusion of product and services. Fifth, offset contracts must state additionality and causality clearly as specified in Malaysian contracts – "all new proposals or activities must reflect visible increment of value-add on top of the basic/mandatory needs of the main procurement contract through direct offsets and present offset recipient's capability/capacity through indirect offsets in order to be considered for offset credits. All offset programmes must result directly from the procurement contract". Sixth, selection of domestic player can be mentioned by the vendor but final say should rest with DDP. Seventh, DDP while negotiation must state clearly the required offset areas and clearly state the scores on each area (state of the art technology and R&D attracting maximum score). The vendor which agrees to maximum number of areas with the maximum score on offset gets the contract rather than only price or capability. Eighth, offset 'programmes proposed must be economically and operationally sustainable after the [offset] discharge.' While extending the offset clause to domestic industry, it has to be clearly mentioned how they are going to discharge the offset obligation. Here the

informal atmosphere will help to reduce the burden on the domestic industry. Finally, offset policy should be extended beyond defence, particularly in developing civil aerospace.

- Establish 'Defence Fundamental Research Fund'. Separate sufficient funds, other than the DRDO budget, should be earmarked to encourage fundamental research in the futuristic defence technology by various universities, Indian Institutes of Technology (IITs) and other research centres. The funds may be allotted under a head that could be named as 'Defence Fundamental Research Fund' and further sub-allocated for utilisation by the Army, Navy and Air Force; enabling them to focus on futuristic technologies.

- Expedite establishment of Defence Corridors. The establishment of two defence corridors, one each in Uttar Pradesh and Tamil Nadu, already announced by the Govt, should be carried out in mission mode with targeted timeline. The Govt needs to work out an implementable plan to promote these defence corridors, offer reasonable tax concessions, create enough demand for defence products, incentivise export of defence equipment and make further progress in improving business environment.

- **Formulate New Defence Procurement Procedure**. The DPP is required to be further refined and simplified for easy execution. A single window clearance is required for getting approvals (vendors who are certified globally or DGCA are not getting RCMA or CEMILAC approval). Common standards for civil and military procurement. An overly cautious approach, along with too much bureaucratic emphasis on procedural correctness, has made the entire procurement process complex, cumbersome and prone to prolonged delays. While transparency and probity need due consideration, yet the speed and flexibility of execution must be realised. This can happen when the culture becomes more informal as in French ministry of defence and industry. Private sector in India is paid by the Defence Accounts Department of MoD, while foreign companies are paid through irrevocable Letter of Credit system . This payment method should be extended to the private sector in India to reduce delays and bring in greater certainty. However, as there are no specific guidelines or standards laid down in the DPP with regard to the IP being transferred in TOT arrangements, most of the TOT arrangements are in the form of restrictive licenses with regard to the IP being transferred. In fact, management of IP rights, whether in procurement-cum-manufacturing contracts such as "Buy & Make", or public-funded R&D-cum-production contracts such as "Make" cases, or licensing of DRDO developed technologies for that matter, is still one of the relatively unaddressed areas in the DPP.

- Promulgate New Production Policy of Critical Technologies. A revised, improved production policy is likely to catalyse indigenous defence manufacturing and facilitate creation of a military industrial complex. The new defence production policy should be expeditiously promulgated. This policy should identify critical technologies as aero engine. In anticipation of significant business growth boosted by civil and military demand for new and overhauled engines, OEM partnerships with suppliers, in addition to coordination within the engine supply chain within the country, have become vital to the production of aero engines. As such, in order to ensure steady long-term production and meet stringent quality requirements, the aero engine industry players, each responsible for a different process, may come together to form an industrial cluster. Furthermore, this will attain subsidies to lessen the burden of capital investment and establish a streamlined production process to enhance both productivity and price competitiveness. Aircraft engines consist of components with complicated shapes. In particular, use of heat-resistant nickel-based

superalloy, require highly advanced manufacturing technologies for difficult-to-machine materials. Accordingly, the development of such technologies with low cost, short lead times, and high quality is the key to maintaining and enhancing the country's international competitiveness. To this end, such cluster will promote the introduction and development of cutting-edge technologies, the development and application of advanced production control systems and methods, and the thorough review and improvement of various processes. The number of missions supported by the cluster will raise the scale of production. To meet such development and production demands, the production capability of a single factory is no longer sufficient. As such, it is vital to utilize a manufacturing network formed with supply chain partners with high production capacity. The production of components is outsourced within the industrial cluster, while research is being carried out as academia-OEM-supplier joint projects, with financial support from state, centre and large OEMs under the incentives accorded to the defence corridor (may be in the form equity ownership/ research partnership). Furthermore, the introduction and operating control/management of a common quality management system covering the entire cluster, work orders based on the contract specifications of each partner, standards creation and management and procurement systems needed to be well developed and implemented through multiple iterations to create a win win scenario. This cluster, made possible with private-and-public sector partnerships and at a low cost, will be an industry-first initiative in offering such a service. Building on the experience gained through the formation of the cluster, Indian defence contractors continue to pursue the growth of the cluster, supply chain enhancement (MSME growth), the expansion of the civil and military aircraft engine business, develop advanced technology in materials and component manufacturing and the overall strengthening of domestic industrial infrastructure. In this manner, depending on the performance of the cluster/complex India can think of building sensor complex, avionics complex, actuator complex as part of national aerospace manufacturing capability.

- Devise a new Defence Innovation Authority: A fund for special loans to start-ups in the field of science and technology. The interest rate of loans may be almost zero. Generally speaking, 30 percent to 50 percent of the R&D funds of start-ups can be borrowed from the authority. This can be linked to startup India with special focus on defence and aerospace. As per Israli model if the project succeeds, the government will take back the loan or ask for equity in business; if it fails, the loan will not need to be repaid, thus encouraging people to venture. Government might not choose to invest as the money invested in successful startup will add to the economy. But the government is by no means in charge of everything. Start-ups must also look to the capital market. If they can't raise it, it means their projects are not good. That's not going to get government loan support. Generally, the government does not participate in the decision-making of specific projects. In the Defence Innovation Authority, there will be experts (from IIMs, IITs, banks, VCs, industry) who assess each innovation project in four aspects, namely, technology description, global market potential, market and technology team, and the impact of Indian economy.

- Advanced Materials Policy: Better exploit the dual-use potential of materials by SMEs and large companies. Promote R&D programmes for the development of high-tech and advanced materials that can address the need of both defence and civil communities. The Indian defence industry needs to strengthen the materials processing know-how and materials transformation capabilities. Accordingly, Indian materials industry has to work closely with different educational institutions and research organisations, preferably on a Public Private Partnership (PPP) mode. A synergistic network of universities, laboratories and industries in this front will be a powerful enabler to achieve excellence in this sector. All global primary producers such as ALCOA, HYDRO Norway, RUSAL and CHALCO follow the

PPP model. Regular interaction between all stakeholders like prime producers, downstream product manufacturers, regulators, traders, information providers & end-users. More applied R&D – with industry involvement in areas like new alloy development; Industry, R&D Centres and Academic Institutes to join hands. Reduction of scrap / waste generation – awareness creation on possible solutions already available. Some of the most common solutions include: Controlling of all process parameters (through improved Quality monitoring tools like Process FMEA-Control Plan) to improve the quality of in-process / finished material. Training and Awareness: Industry owners need to be made more aware of benefits of economy, environmental preservation & waste disposal; this can be initiated by the concerned ministry and nodal agencies dealing in a particular material – steel/aluminium/copper. Organising regular training programmes using films showcasing international best practices for individual industries or industry clusters, highlighting material's intrinsic properties for the end users & for personnel involved in material selection. The other area to revamp in the Indian R&D set-ups is the link with the main stream of production for developing a new material, or a new process window jointly with the operating departments. Unless Indian R&D improves its record of timely delivery of projects and develops aggressive plans to launch new products in line with the demands of preferred customers, the metal sector may further lag in development. The Industry must develop at least 3 to 4 World Class Laboratories, employ a number of Doctorates (foreign or Indian) to carry out Research in the areas of Scientific and Industrial importance, in close collaboration or contact with industry, generate IPRs. For India to achieve a leading position in best utilising the resources, the concerned authorities in private and public sectors must keep an eye and track the research being carried out in other countries in the forefront of research. However the success of such collaborative ventures would largely depend on preparing a framework covering financial, legal and administrative aspects.

- Grant of "special" status to the aeronautics industry under the Harmonised Master List of Infrastructure Sub-Sectors. This will entail financial incentives and tax benefits for the defence sector. Also this will ensure no unionism and 24x7 energy at a subsidised rate. Ship-building and ship-repair have already been included in the Master List as infrastructure industry. This is likely to attract a great deal of private investment in the sector as the cost of funding will be at a concessional rate and the players will have a plethora of options to raise money . Not only this, the status will help build related industries dependent of aeronautics (capital goods, heavy engineering, advanced materials, testing and certification, travel and tourism, telecommunications, logistics, civil construction, healthcare and many more industries are permeated by aeronautics)

- Although the government announced tax incentives for investment in sunrise or advanced technology sectors. It is hoped that section 35AD of Income-tax Act, 1961 is suitably amended. This might encourage some of the large manufacturing companies consider moving their plants from China to India. Granting 'Deemed Export' status in certain cases refers to those transactions in which the goods supplied do not leave the country and the payment for such supplies is received either in Indian rupees or in free foreign exchange. The main objective of this concept is to substitute imports. The benefits of holding a 'deemed export' status is (a) Advance licence for duty free import of input materials, (b) duty drawback of taxes paid on inputs and (c) Exemption from terminal excise duty where supplies are made against International Competitive Bidding; in other cases , refund of terminal excise duty. Under the Buy (Global) procurement category, an Indian company can compete with the foreign company. In the event the Indian company wins the competitive bid, it would be deemed to be import substitution (since the item would have otherwise been imported from the foreign company). In such cases, the items manufactured and

provided by the Indian company should be accorded 'deemed export' status. Other tax incentives and price preferences should be provided to private firms in order to offset the large costs incurred by the companies. As a notable example, South Korea, Singapore infused capital into its private defence industry through imposition of a tax for a period of 15 years and routed its proceeds as investments into the defence industry

- The establishment of skill development institutes and dedicated educational and technical institutions that will create skilled workforce to address a predicted shortfall of around 1.5 million workers with specialized skills who will be needed in the near future by the domestic defence and aerospace manufacturing industry. The various incentives offered can be co-funding joint training programs, double deductions on training expenses, scholarships for aviation degrees/certifications, vocational institutes and degree programs.

- Following on the successful model of LCA development, Indian government should think of building the civil helicopter industry using a public private partnership model (PPP). It has also been noted that by combining the expertise, assets and resources of the government with the 'additional contributions from the private sector', PPPs can offer diverse advantages, such as the reduction of capital investments, creation of new capabilities and early influence of new technologies, all of which can allow the targeted development of capabilities in civil helicopter industry. A typical, traditional contracting out gives the responsibility of project completion and delivery to the private sector party, whereas under a PPP regime the government retains full responsibility for the project's success. Traditional procurement also involves limited or no sharing of control or risk between the two parties—the private sector is exposed to the risk but not the government. Under a PPP regime, risks and rewards are shared by the two parties. Finally, the nature of ownership rights is also different between the two regimes. In the traditional system, ownership rights are sold to the private partner, whereas under the PPP mode, the government retains legal ownership of the asset under consideration, though specific limited rights may be given to the concessionaire (like lease- -operate-maintain type of model . Through PPP, government can take care of regulatory approvals, while private sector can develop resources, invest capital and in return there can be a mutual sharing of revenue/profit and losses/costs based on performance.

- **Setting up of a National Aerospace Council as steering body to guide industry-government collaboration in implementing the National Aerospace recommendations. This council constituting all stakeholders can be the high level apex body which will serve the dual purpose of capability building and indigenisation of India's aerospace and defence sector and identify critical projects, monitor and control development and resolve the multiple issues plaguing the sector. Before this, the most important part which is ignored so far is the visibility of the sector to the outer world. Aerospace manufacturing does not feature in national accounts survey under separate head. The vendor base capabilities are not available anywhere. Even we did not find any vendor details in Indian OEM websites (BEL, HAL etc), which is an integral part of global major OEMs. Government can have a dashboard or a mobile app which can show the status of capabilities and opportunities in aerospace industry value chain. The national council can have its own website and report all such features of Indian aerospace industry.**

6.0 Aircraft MRO

6.1 Global Industry

Drivers, Trends and Restraints:

- ***Increasing Fleet Size***: In 2018, the aviation industry posted a record post-tax profit of $38.4 billion. This was achieved as a result of increase in demand, positive impact on cash flow of industry restructuring, and slightly lower than expected fuel costs. This positive growth has fuelled the growth of civilian aircraft fleet sizes all over the world. The aviation market has reported rapid increase in traffic across the world. This has allowed the airliners to provide frequent flights and place orders for new aircraft. Airbus and Boeing together have a combined current order backlog of 18,000 aircraft. In 2015, the aviation industry saw the biggest orders for the purchase of a narrow-body jet, when Indigo placed a second order for 250 A320 aircraft, in order to cater to the increasing demands of connectivity and regular services. The delivery of these aircraft began in 2017 and is expected to be finished post-2021. Led by increasing penetration of commercial airliners in emerging markets, the number of aircrafts in service has been increasing rapidly. This is providing necessary impetus to the global aircraft maintenance, repair, and operation market. Naturally, the size of the aircraft MRO market is directly proportional to fleet size of operational aircraft all over the world. Hence, the rise in the number of operational aircraft increases the size of the aircraft MRO market.
- ***Increasing customer preference for LCC Airlines***: Low-cost carriers are expanding at a fast pace in the airlines industry. These airlines offer minimal passenger amenities, and they aim to squeeze in as many seats as possible, in order to maximize the revenue per trip. Many profitable airlines in the world, like that of Southwest Airlines, Ryan Air, and Indigo are low-cost carriers. Even regular passengers of full-cost airlines sometimes shift to low-cost airlines, because of reduced fares and little difference in amenities offered. This has been evident in the Indian aviation sector, where even high-income passengers were observed to shift to Indigo from full-service carriers, like Air India. In 2016, three out of four most profitable airlines in the United States (barring Alaska Airlines), were low-cost airlines. With such tough competition from low-cost players, full-fare carriers are trying to add value to the services they provide to the customers. Most parts of the European Union are under the robust stronghold of the MRO activities carried for the LCCs. There are numerous infrastructural and structural developments that have taken place in the region, spearheaded by numerous airline providers and OEMs in the past few years, in order to improve the MRO activities. Construction had taken place, such as the building of the hangar for Ryan air's EUR 1.5 million aircraft maintenance, as well as repair and overhaul facility at Kaunas, Lithuania. The latter facility was designed specifically to handle an average of 60 aircraft a year and is unique in Eastern Europe. In Europe's southern periphery, SR Technics started D checks on two Airbus A320s from Finnair at the MRO facility at Malta Laquan airport, which specializes only in narrow-body work. SR Technics had also set up shop in Malta largely on the strength of a USD 1.6 billion agreement with EasyJet to specifically perform heavy maintenance work for their low-cost airlines. In addition, under the 11-year contract, SR Technics has been doing heavy maintenance, turning Malta into a MRO destination specifically built for narrowbody MRO segment. Across the Atlantic, TechOps Division has also opened a line maintenance station in Sao Paulo, Brazil, in the context of increasing their market foothold. In addition, most of Central America and Mexico has witnessed rapid growth in MRO activities, mostly for narrow-body aircraft, which is a development that has been driven by the rise in low-cost carriers operating in Latin America and by the area's cost-related advantage over North America. Asia- Pacific, on the other hand, appears to have lost in demand for wide-body airframe MRO work, since the cost

difference enjoyed by the companies operating in the region, when compared to US-based competitors, has reduced to a significant extent. LCCs could do with a fresh boost to the cost advantage they have held over other legacy carriers through infrastructural development. However, LCCs' costs are rising at a significant pace. However, gradually, with the decline in deferred maintenance, along with an increase in the scale of economies for MRO activities, has created significant opportunities in the segment.

- ***Advancement in cockpit technology necessitating upgrades***: Cockpit technology has been advancing at a great pace during the past 5 years, which helps make available a great amount of information at the fingertips of the pilot than it was formerly in the conventional systems. With manufacturers like Garmin and Honeywell devising the newest in avionics, it would help to create great opportunities in the advancement of the glass cockpit systems, thus making it more attractive to replace the conventional cockpit systems. One of the most modern developments is the synthetic vision system, which is a tool that provides the pilots with a 3D representation of all the obstacles in the aircraft's path. It is, thereby, extremely helpful in times of lower vision, while flying in mountainous areas. It helps to greatly enhance the situational awareness of the crew. The evolution of the technology would enhance and further improve cockpit display systems to a significant level. This can further be possible, when the crew is effectively trained on these new systems and features, in order to optimize the benefits offered, thus driving the operators to switch toward retro-fit digital glass cockpits. This is acting as a driver for the aircraft MRO market.
- ***Service life extension of military aircraft fleet***: As discussed earlier, in Section 3, due to exorbitant price of advanced fighter aircrafts, most countries in the world would not be able to procure new aircrafts in the coming future. They will have to rely on module upgrades, retrofitting of advanced devices/systems to enhance capabilities of the existing fleet. Hence, this will drive demand for military MRO market. Typically, a large number of a given nation's aircraft fleet will be undergoing some MRO. In particular, demand for MRO services climbs during times of war as aircraft experience increased wear and tear. Moreover, the sophisticated nature of many military aircraft increases the need for MRO. For instance, the coating of stealth aircraft requires constant and expensive care for it to retain its stealth features. Other services include training, logistics management and consulting. Individual components are becoming more expensive as the materials used in their construction are becoming more lightweight and durable. The control and sensing systems in many newer components are much more complex than traditional parts, driving up the cost per component. However, the newer components tend to require fewer man-hours for repairs and overhauls. One of the primary challenges to the introduction of new technology in military aerial platforms is the prohibitive cost, driven by safety and certification requirements. Aircraft systems and components go through various stages of testing and evaluation processes prior to certification. Other factors such as allowable load factors and ground maneuvering conditions are also needed to be considered while designing or introducing new technology and components to meet the upgrade requirements. Additionally, military aircraft upgrade programs have to meet the rigorous legal and regulatory requirements. This is primarily because multiple companies from several countries get engaged for one single project, and legal framework for companies and countries vary to a large extent. Hence, the finalization of upgrade contracts gets delayed by several months or even years, and countries are compelled to sustain the aging aircraft in their arsenal inventory, which only adds on to their maintenance expenses. Amid economic concerns and budget cuts, militaries around the world are finding it difficult to upgrade fleets of large military aircraft such as the Boeing C-17 Globemaster III and Lockheed C-130 Hercules. This cannibalization is so widespread that maintenance personnel spend considerable time removing parts from one aircraft to fit into another.
- ***Technology Drivers for future***:

- What sets the new generation of aircraft apart from its predecessors are innovations in both **materials** and systems – innovations that pose both opportunities and challenges for the maintenance, repair and overhaul (MRO) sector, too. While most of the current crop of narrowbodies feature conventional aluminium wings and fuselages, the newest widebodies, the Airbus A350 and the Boeing 787, both feature majority composite constructions. Although previous-generation aircraft have successfully utilised composite material – around 17% of the 777 is carbon fibre, for example – this proportion is set only to increase. While the properties of metallic and composite structures are well understood, and many airlines and MROs will have expertise in the repair techniques required for both, it is the increasing prevalence and scale of use of composite that poses the challenge for maintenance and repair. Metallic structures tend to bend under the force of an impact – in collision with a ground handling vehicle, for example – but that's not the case with composite material. While a simple visual check would reveal a dent on an aluminium fuselage, the sub-surface damage on a composite airframe can only be detected through ultrasonic scanning. And this requires special equipment and skills. Repairs require investment not just in equipment, but also in people, training, skills and process improvements to be performed properly.
- A further opportunity for the maintenance sector, capitalising on a headache for airlines, is in supporting the need for airlines to regularly refit a variety of updated commercial aircraft interiors. Changing passenger demands – driven by the fast pace of development in consumer technology and a new generation of digitally savvy airline customers – has resulted in airlines operating fleets with increasingly different cabin layouts. Emirates, for example, has three different configurations on its fleet of Airbus A380s, while Singapore Airlines is currently performing a large-scale retrofit programme on 14 of its super-jumbos, to bring them up-to speed with customer demands. Based on the predicted growth of the global commercial fleet, Airbus estimates that over the **next 20 years**, the maintenance, repair and operations sector will be worth $**120 billion** annually, by **2036**. The knock-on effect of this means the aviation industry will require an additional **548,000 technicians** over that time if it's to meet that forecasted demand. Boeing predicts an even more pronounced requirement, believing that the sector will need an additional **648,000 technicians by 2037**.
- **UAVs allied to improved imaging technology**, **are also finding a role in the maintenance sector**. UK low-cost carrier EasyJet, among others, has trialled them to detect surface damage, such as from lightning strikes, on its fleet. Results showed that **using drones reduced the time taken to inspect each aircraft, and freed-up technicians for other tasks**. As such, in 2018 EasyJet began rolling out the system across its network. The company has also been testing **3D-scanning technology** and hopes to be able to add this capability to its drone fleet. As a further sign of change in the sector, and a willingness to embrace disruptive technologies and digitisation, German maintenance giant Lufthansa Technik announced in April 2018 that its Malta facility was testing a number of technological innovations including **mobile 3D scanners and drone inspections**.
- Airbus is introducing state-of-the-art technologies under the **HANGAR of the FUTURE** – with the latter embracing automated non-destructive scanning, the introduction of augmented and virtual reality, and the use of big data to drive predictive maintenance. As aircraft systems become more sophisticated, and satellite datalink coverage becomes more robust, aircraft are becoming able to communicate 400,000 separate touchpoints, or parameters, in real time. That data

is invaluable – because time and cost are of the essence. It's being captured faster than ever before, and the next step is to successfully generate value from it.

- Maintenance has become digital (big data handling efficient algorithms (Analytics) are necessary to support the real time local monitoring strategies on composite structures (Testoni et al., 2016) and used by Boeing and Airbus for structure crack propagation study). Additive Manufacturing (useful to avoid large warehouses and cut the logistic chain: a part can be manufactured in metals like Aluminium or Titanium provided that a suitable AM machine and powders are available) and Augmented Reality (support the operators with user-friendly manuals where virtual models and instructions are mixed with real world. In this case, a reduction of workload and time required to complete tasks, and an increase in reliability can be expected, consequence of the reduction of errors which are made using AR augmented maintenance manuals) (Ceuti et al., 2019)

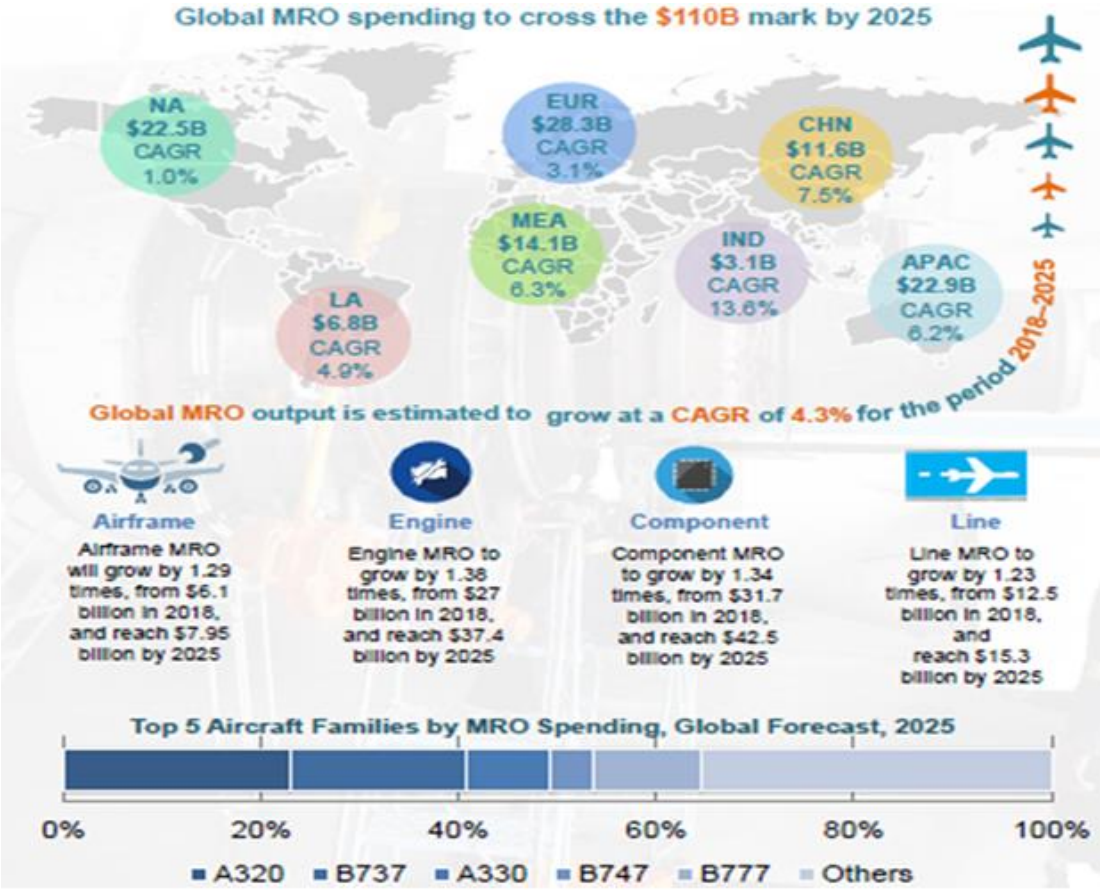

Figure 6.1: Global Civil/Commercial Aircraft MRO market (Source: Frost and Sullivan)

Market Size:

According to Oliver, Wymann's forecast, 54% of the aircraft to be retired over the next decade date back to the 1990s. Another 34% were built in the 1980s, and 12% were made in either the 1970s or post 2000. Those most likely to be retired are smaller-capacity narrow-body planes, regional jets, and turboprops. By 2028, jets built in the 1990s will drop from comprising two-thirds of the global fleet to 41%. By that year, aircraft built in 2010 or later—equipped with advanced sensors, data collection, analytics, and autonomous functions—will make up more than 36% of the fleet. The commercial air transport MRO market is going to grow to 2028, with total MRO spending expected to rise above **$110 billion in 2025** from **$77.5 billion in 2018** at an average 4.3% CAGR (Frost and Sullivan, Figure 6.1). Part of this growth will be driven by technology and another by scale

advantages of MRO firms. Mergers and acquisitions will hold true for the aftermarket, too, with AAR's agreement to buy two Canadian MRO facilities from Premier Aviation and China's HNA Aviation Group's purchase of Swiss-based SR Technics as prime examples. The trend in MRO is cutting the number of players while simultaneously increasing the scale of those left standing. Some of the fastest growth is projected for MRO operations owned by aircraft manufacturers and other major original equipment manufacturers (OEMs), such as engine maker General Electric. Boeing, for instance, has set a $50 billion goal for its aftermarket services as part of its effort to capture more life-cycle value out of its aircraft. Oliver Wymann's research indicates that OEMs servicing engines handle about 53% of the market, while airlines and their affiliated MRO operations control 64% of the airframe maintenance market. OEMs handle about 58% of the component MRO aftermarket. As airlines begin to 97avour small and midsize wide-bodies, such as Boeing's 777 and 787 and Airbus' A350, another maintenance challenge will present itself—a function of how doing better can sometimes cause unexpected problems. For instance, the newer aircraft like the 787 and A350 have longer airframe maintenance intervals, essentially extending the time between scheduled maintenance downtime. While this has a positive impact on airlines' bottom lines, it causes a small problem for them keeping up their interiors. Whereas conventional check intervals once provided carriers a time slot to refurbish interior components—such as seats, overhead bins, and lavatories—newer, technologically advanced aircraft with extended check intervals no longer afford timely opportunities for cabin repairs. This can cause image problems for airlines, given their renewed emphasis on customer satisfaction and attraction.

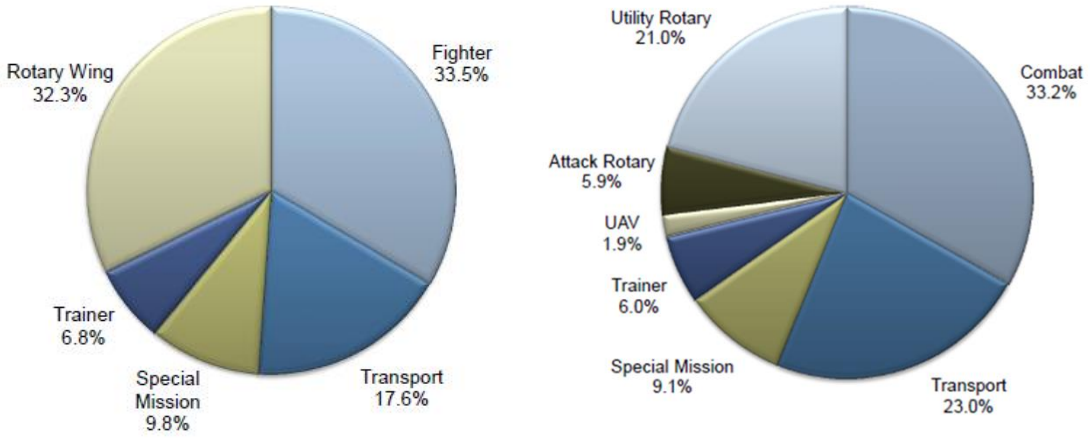

Figure 6.2: Market distribution of Military MRO services in 2016 and 2025 (Source: Frost and Sullivan)

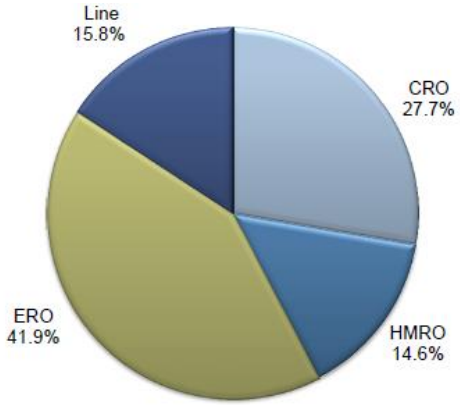

Figure 6.3: Total Global Military Aircraft MRO in 2016 - % by MRO activity, HMRO—Heavy Airframe MRO; Line—Flightline Based, Airframe MRO; CRO—Component Repair and Overhaul; ERO—Engine Repair and Overhaul (Source: Frost and Sullivan)

In military MRO, as figure 6.2 depicts, fighter jets will remain the prime MRO equipment in the coming 5 years until 2025. While in 2025, there will be a new area of spend as UAV MRO which will take out shares from the other segments of rotary wing (will now need two different sub-segments – attack and utility), trainer and special mission MROs. The engine maintenance remains the single largest portion of military MRO market as is found in civil/commercial MRO segment (figure 6.3). Countries with extensive military depots often have a significant portion of the engine maintenance and routine engine component repair performed by those depots. However, in many countries those tasks are migrating to contractors to simplify military manning fluctuations and location infrastructure. Engine component repair is a fragmented area. Light repair and replacement may be done in-country, but full repair and overhaul is performed by depots, original manufacturers and third-party specialty repair providers. Engine maintenance is migrating toward OEM partnerships with local companies or military depots. New aircraft may have local suppliers that form an aftermarket relationship which includes engine MRO. The line maintenance portion of MRO is largely an airframe MRO element. However, systems troubleshooting and parts replacement are attributable to component maintenance activity. Line maintenance is almost exclusively performed by military personnel, except on new aircraft during their introduction and initial capability period. Component maintenance during line maintenance activities varies by geography and component as to personnel involved. The airframe heavy maintenance may be performed by military personnel, civilian government workers, airline employees, or third-party personnel. Most countries wish to keep the heavy maintenance activities in their country. Component maintenance is the most highly fragmented activity and revenue may be attributed to several competitors on the same maintenance action. For example, an Egyptian C-130's hydraulic pump may be removed by Egyptian military personnel for testing by Egyptian civilian personnel, and then sent to Warner Robbins AFB for depot maintenance. They on inspection, send it to Hamilton Sundstrand's facility for a rebuild. Both airframe and component maintenance may have military partnerships with contractors. This can result in one contractor providing a selected group services while another contractor provides other services, and military personnel provide still other services. The total market size in **2018** for military aircraft MRO is **$45 billion** (source: IBISWorld, Frost and Sullivan). The market spending is directly proportional to defence spending, fleet age, new aircraft production/delivery and economic prosperity. This is reported to grow at a 2% CAGR. While this is not very significant, it reflects both new additions to some fleets and the performance of deferred maintenance on many older aircraft. Fighter aircraft MRO will experience a 2.3% CAGR. Many older aircraft are either being replaced or parked. Utility rotary aircraft MRO spending will see a 1.3% CAGR. Many countries with poorly maintained aircraft are restarting long-deferred maintenance. Attack rotary aircraft MRO spending is increasing at an 1.9% CAGR. Operators in the region are refreshing their small fleets of attack helicopters. UAV growth had been slow, but the growth of Chinese programs has sparked interest throughout the region. UAV MRO will grow at a 20.2% CAGR. APAC trainer MRO growth will be 0.0%. Acquisitions of new trainers will be significant, but retirements may outpace procurements. Special mission aircraft MRO is growing at a 0.2% CAGR. Overall fleet sizes are not growing, but replacements continue at a slow pace. Transport aircraft MRO is declining at a 0.1% CAGR. Asian fleet sizes are generally small and procurement is modest. Total size in **2024, will be $51.5 billion**.

6.2 Indian MRO Industry As Is

Civil/Commercial MRO:

Based on information given by MoCA, 99 Aircraft Maintenance Organisations (AMOs) are presently approved in India, out of which 12 are capable to undertake major maintenance of large aircraft. Most of these AMOs are not capable to cater to major maintenance/overhaul of components of aircraft and engines of all Indian operators, the operators take their aircraft to other countries for such work. Given our technology and skill base, the government is keen to develop India as an MRO

hub in Asia, attracting business from foreign airlines. Accordingly, the following steps have been taken by the Government so far:

- The tools and tool-kits used by the MRO have been exempted from Customs duty.
- The process for the clearance of the parts has been brought in line with that of the tool kits for a one time certification by DGCA approved Quality Managers in MRO's.
- Restriction of one year for utilization of duty free parts has been extended to three years.
- Notification revised to enable advance export of serviceable parts.
- Foreign aircraft brought to India for MRO work will be allowed to stay for the entire period of maintenance or up to 6 months, whichever is lesser, provided it undertakes no commercial flights during the stay period. The aircraft may, however, carry passengers in the flights at the beginning and end of the stay period in India. For stay beyond 6 months, DGCA's permission will be required.
- Reduced GST rate to 18% from 28% on paints and varnishes (including enamels and lacquers).
- Developed Nagpur Engine MRO for GE Engine repairs; set up GE-90 testing and overhaul facility; upgraded GE-90 test facility for Genx engine.
- Upgraded A-320 APU Test Cell at Kolkata; correlated with 131 9A APU test run.
- 100% FDI permitted via automatic route for MRO.
- Liberalised policy for accessing ECBs, Trade Credit, Borrowing and Lending in Foreign Currency and Rupees on competitive terms by MROs.
- Ease of issuance of visa and other travel permits for foreign MRO/OEM experts.
- Provision for adequate land for MRO in all extant and future airports.
- Further, the government's aims to make India a hub for aircraft financing and leasing activities by utilizing existing International Financial Service Centres and SEZs is quite innovative and appears to be attractive basis several tax concessions granted to IFSCs.

90-95% of engine and component maintenance activities for civil aeronautics sector take place outside India. The existing Indian airlines do not carry out engine or component maintenance domestically. Only line maintenance work is mostly carried out in Indian supply base. Some companies are found to be involved in malpractices carrying out major inspection checks without necessary tools and equipment, illegal cannibalisation of spare parts, use of locally fabricated tools that have not been subject to appropriate inspection for certification to carry out critical inspection of B200 and Agusta A109. Inadequate facilities and infrastructure, lack of procedures and trained manpower, non-adherence to standard procedures are the blatant lack of capabilities in Indian MRO bases. One company (https://www.businesstoday.in/top-story/air-works-releasing-planes-without-recording-rectifying-defects-dgca-audit/story/305452.html) was accused of indulging in various malpractices including releasing planes for flights "without recording and rectifying known defects" – on audit DGCA found that dedicated store inspectors had not been made responsible for the facilities. Companies did not have system of assessing maintenance man-hour requirement to establish that it has sufficient staff to plan, perform, supervise, inspect and quality monitor the organization in accordance with the approval at any given time and at each approved facility. Creation of MRO infrastructure requires a level of investment both initial and recurring which most MROs do not find economically viable to support. Though Air India is going to start Mihan facility for GE engine testing, resource crunch and the company's financial future would be a big question mark for the facility's future. While heavy maintenance needs will grow as India's fleet grows and ages encouraging big players to invest require some ground breaking measures. Government is already working on some of these. End of lease checks are carried out outside India at lessor's designated facilities – This is huge business and require innovation to be undertaken in India. Component overhaul along with heavy checks go hand in hand to ensure India's presence in global industry. Currently for component overhaul aircrafts are send to DGCA approved foreign MRO location. Out of 99 MROs, only 7 can do complete aircraft overhaul. Component MRO requires avionics, electronics, actuators MRO. Opportunity to tie up with Key players as Lufthansa Technik, KLM, Air France will

open the Indian MRO industry and build scale. GST is making Indian MRO inefficient (in addition customs duty for aircraft being serviced out of country). Imported components are attracting no duties while indigenously developed and produced parts attract 18% GST. Despite labour advantages, Indian MROs are financially unviable for sub-contracts, due to impact of GST, particularly on materials (which is almost 70% of the total value). NCAP-2016 (para 18(b)(f) states, 'Airport royalty and additional charges will not be levied on MRO service providers for a period of five years from date of approval of policy'. However, 'royalty' is charged by airports (including AAI) under different heading such as Ground Handling, Revenue Share, Demurrage, which ranges from 11%-20%. There exists a mismatch between the component certification qualification criteria, between EASA and DGCA. Pertinently, the same maintainers can be positioned overseas and certify the same component, without the license exam. However, he is unable to undertake maintenance of the same components, if he is positioned in India, till such time he qualifies the relevant module exam (s).

The civil MRO market size in 2018 is estimated by the MRO spending of airlines. Indian airline carriers (Airlines annual report) annually spend roughly Rs.15 crore per plane on average (this is irrespective of new and old, we just obtained the service cost and divided by the current fleet size). Indian civil aircraft fleet size is 670 (source: DGCA). Total spending in civil MRO is **Rs. 10050 crores**. As India is forecast to induct more new airplanes in its fleet in next 5 years, this figure is going to rise as civil aeroplanes need regular line and base maintenance and preventive maintenance in stipulated intervals.

Table 6.1: India's major MROs

MRO Name (Revenue, Rs)	**Location**	**Types of MRO**	**Services**	**Clients**
Indamer Pvt Ltd (64Cr)	Mumbai	Line Maintenance	Maintenance and Phase inspections	State Govt, corporate
Air Works (certified by FAA, EASA, Cemilac) 600Cr	Mumbai (small facilities in 8 other states)	Engine, Line Maintenance, Airframe and Defence MRO	Airframe, component and Engine level	Air India Express, Essar, Reliance
Max Aerospace and Aviation (10Cr)	Mumbai	Components	Electrical, Mechanical	Blue Dart, Spice Jet, Military
GMR AeroTechnic (10k Cr)	Hyderabad	Line and Component	Avionics, airframe, electrical and simulation	Airlines
HAL (19K Cr)	Bangalore	Airframe and Engine, Defence	Overhaul and repair	Air Force and Pawan Hans
Air India Engineering Services Ltd (750 Cr)	Nagpur	All	Line, Airframe, Engine	Airlines, defence

Taneja Aerospace (30 Crore)	Pune	Line	Tie up with Air Works Commercial MRO Services	Commercial
Sika Interplant (100 crore)	Bangalore	Line, component and equipment	JV with Aerotek for world-class manufacturing and maintenance, repair and overhaul (MRO) of Landing Gear, Hydraulic LRUs and Actuators for fixed and rotary wing aircraft.	Civil, Defence

Defence MRO:

Indian government's initiative to develop indigenous MRO industry in defence is phenomenal. The Maintenance, Repair and Overhaul ("MRO") activities in Defence sector will be treated as services and would not be subject to IL requirements unless it involves manufacturing of any components/sub-assemblies which are licensable. The product would remain the property of the same customer after MRO operation. HAL and IAF have developed capabilities to upgrade and maintain complex military aircraft engines, airframes in India. The Base Repair Depots of IAF is mainly responsible for Line and Component Maintenance (which is catered through the stores expenditure) while HAL is responsible for Air Frame and Engine Overhaul and maintenance (which is catered through the capital expenditure). HAL's transport division is certified by the Directorate General of Civil Aviation (DGCA) for the MRO of Dornier 228 and Avro 748 aircraft for civil operators. During the year life extension studies on upgraded MiG-29 aircraft landing gears was successfully carried out. Failure analysis and accident investigation is one of the core/niche activities of the laboratory, a major contribution in the last year was related to failures of aircraft structures and aero-engine components/systems. Of late there has been involvement of private players in military MRO activities mostly in line and component maintenance activities (Sika Aerospace for components, HAL-Safran MRO to be operational in 2020 for TM333 and Shakti engines, AirWorks India as authorized Rockwell Collins dealer, Taneja Aerospace). There are many IT companies as Wipro, CapGemini which can be developed for future MRO activities, digitization of MRO activities. Few MSME sector players (Aviyen Risk Management Services, Shree Engineers, Data Patterns) can be developed for MRO activities with support from OEMs. The Indian defence MRO segment size in 2018 is **Rs. 6000 crores** (source: HAL revenue report). Different MROs of India are listed in table 6.1.

Primary data:

We carried out a workshop with Airline operators, DGCA, MoCA and MRO Providers (defence and civil), quality control agencies. The sample included 4 airline operators, 13 MROs (including few operators who also carry out MRO), 4 suppliers to MRO and 6 (government representative, MoCA, industry chamber or MRO association, consultant, quality agency). Some key findings from the interactive discussion are highlighted below:

- There is **no ecosystem** in India for MRO.
- There is **no OEM and Joint Venture** support.
- There is **no capital**, **ROE because volumes of MRO are very less** so investment doesn't make sense.
- There is **no ToT (Technology/ Training)** opportunities.
- For Engine MRO, **Air India** is the pioneer in India. Air India Engineering Services Ltd. is leading MRO (Maintenance, Repair and Overhaul) service provider in the country providing both Line Maintenance and Major Maintenance for various type of aircraft in its fleet, third party Airlines as well as to the defence forces. It has **capabilities for both narrowbody (320) neo and ceo engines**. They have the capabilities for **A320 and B737** aircrafts. Others have only line replaceable capabilities. Except Air India all other airline's engines are going outside India for overhaul.

- There is **no pull factor for MRO service** providers in India as there is **no facility available, no incentives and infrastructure** is very poor for getting international certification. **There is also a barrier between civil and defence sector capabilities and certification. Transition to adjacent sector for MRO is very difficult for the existing players to generate volume or build ecosystem**.
- Offset clause does not apply to MRO sector for new aircraft purchase.
- In order to develop indigenous MRO sector, the Airlines sign a particular contract with a particular aircraft OEM vendor and they have to push them to setup a facility in India if they contract with them. First of all, **airlines are actually not the acquirer of the aircrafts** and the actual owners, the lessors, are not from India. Secondly, even if the offset clause is allowed for the airlines, they would have to **pay more taxes for doing MRO in India** than the tax they pay when they send it outside.
- There is **ambiguity in part classification** for aircrafts. Though GST for Aircraft Parts is 5%, when an airline is importing aircraft computer may be for single use, it is classified for personal use and the government charges 18% GST. Complete restructure of taxation system is important for airlines MRO.
- Most important is that there is **no link between Indian civil and defence Industry**. Civil aircraft industry does not know what kind of components and certification defence require. So even if it is not a component affecting the safety of aircraft, airlines cannot buy a product from defence Industry and fit it in their aircraft. They are forced to import it from outside. **There needs to be an awareness about what defence Industry is manufacturing and what kind of approval and certification they have** and also what kind of component they can offer for which civil aircraft industry need not to go outside India. Indigenised products which are certified, common in standard and got approval, need an awareness to the Airlines, Airlines are seeking a common forum where they have the details of the product which they can utilise. For example, for rotating components civil certification is more stringent than military certification. For civil certification errors should be 1 in billion and while for military errors should be 1 in a million. However, for spare parts and others (like seats, folding table) there are not much difference in civil and military certification. So common standard of consumable product and standards of safety and reliability is also important. **ALH Helicopter(HAL DHRUVA) used by both civil and military and their spare parts are certified by both civil and military, so these things needed more common certification and common standards.**
- **Reverse Engineering** is not certified in India.
- There is no **cost effective MRO** as there is no provision of availing all kinds of MRO facility in a single place (One shop stop).
- There is a direct link of manufacturing with MROs. The airlines need to treat MROs as the OEMs through facilitating better and faster technical support from OEMs. Understanding the constraints of MROs in times and costs need flexible approach from the airline. Besides MROs and airlines need spare suppliers which will ensure minimum spare availability at nominal cost. Airlines must encourage local vendors for basic things (like cabin items) not for safety items and up scaling MRO facility to the global standard is also important.

The ten most critical requirements identified by the customers from the MRO providers are:

1. Service desired to meet regulatory compliance
2. On time performance relating to engineering
3. Quality, airworthiness as per national certification
4. Reliability, availability and readiness of MRO provider
5. Safety Management System
6. Uses modern technology (eLearning, apps, Demos etc)
7. Alignment with customer's culture
8. Availability of qualified staff
9. Unscheduled maintenance work support
10. Low cost of service

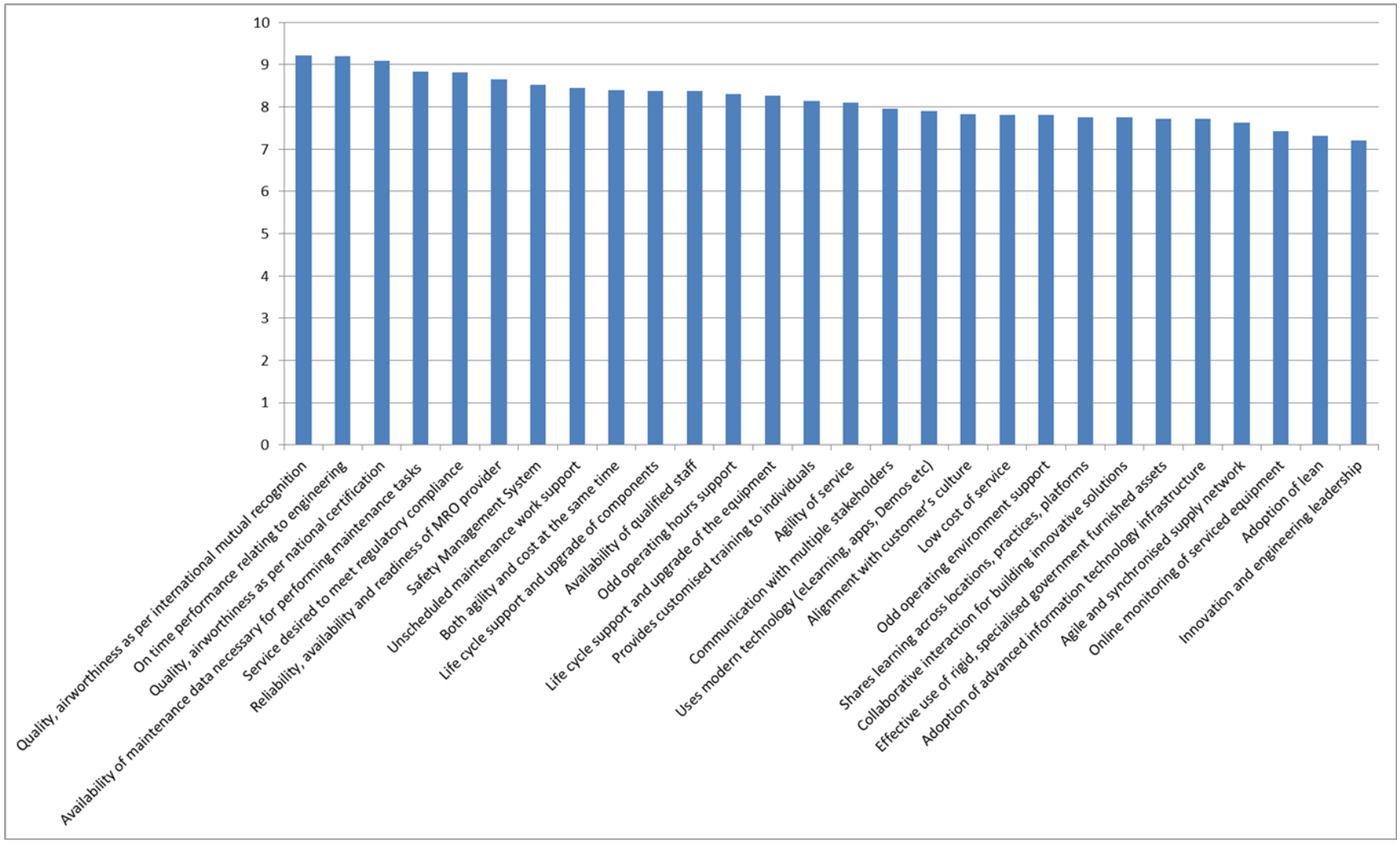

Figure 6.4: MRO Provider's Capability Score as perceived by the respondents

However, based on the score given by all respondents between 0-10, by the entire sample on the performance of the MRO supply base, the top performance of the MROs is perceived in the following 10 areas:

1. Quality, airworthiness as per international mutual recognition
2. On time performance relating to engineering
3. Quality, airworthiness as per national certification
4. Availability of maintenance data necessary for performing maintenance tasks
5. Service desired to meet regulatory compliance
6. Reliability, availability and readiness of MRO provider
7. Safety Management System
8. Unscheduled maintenance work support
9. Both agility and cost at the same time
10. Life cycle support and upgrade of components

The performance scores of the MRO capabilities are shown in figure 6.4. On asking the criteria for selection MRO providers, price was not found to be the most important factor. In fact quality and delivery were the two most important factors for selecting MRO providers (Figure 6.5). Not only is this, even in defining the MRO agreements, “service price” was not among the top 5 features to be considered. Although for many MRO providers cost and service price were the most importance features in contract and criteria for selection. Figure 6.6 states the condition of outsourcing of MRO activities in India. It is found that, though line and base maintenance are carried out domestically, of which line maintenance in most of the cases is performed by the customers themselves (as outsourcing fraction is low). MRO opportunity actually lies in engine and component maintenance where there is a huge gap between outsourcing fraction and % of the job done in India.

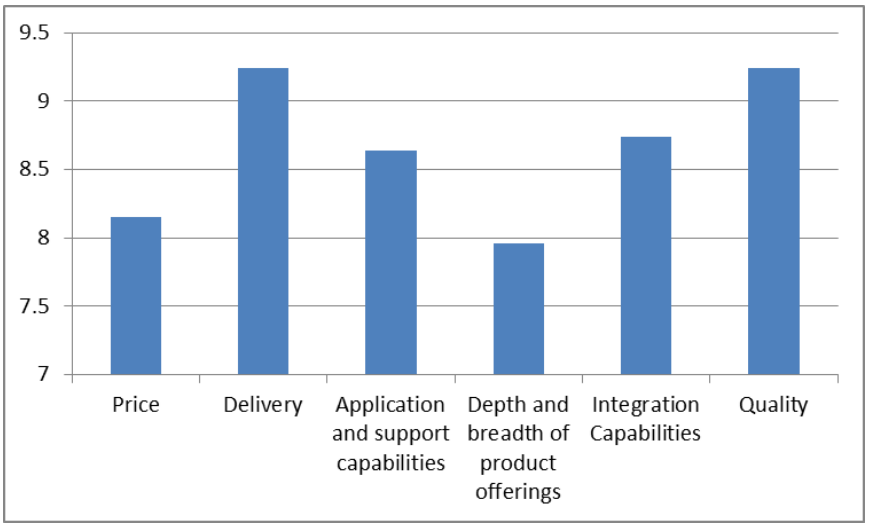

Figure 6.5: MRO provider selection criteria

The respondents were also asked to identify the drivers of present day MRO industry. This would help policy makers to identify the exact levers for accelerating MRO industry in India. Figure 6.7 shows the rating of these different drivers based on their impact level measured in a scale of 0-10. A score of 10 implies maximum impact. We can see from the figure that, on average, tax restructuring, strategic partnership with OEMs, passenger growth, financial stability of airlines score the most. Additionally, some respondents mentioned about tariffs, disincentive for import of services, government subsidy for establishing new MRO facility, regulation regarding licensing / certification and renewal to MROs, availability of premises adjoining major airports, ready availability of talent pool, proactive cooperation from AAI, BCAS and support to MRO establishment as key drivers.

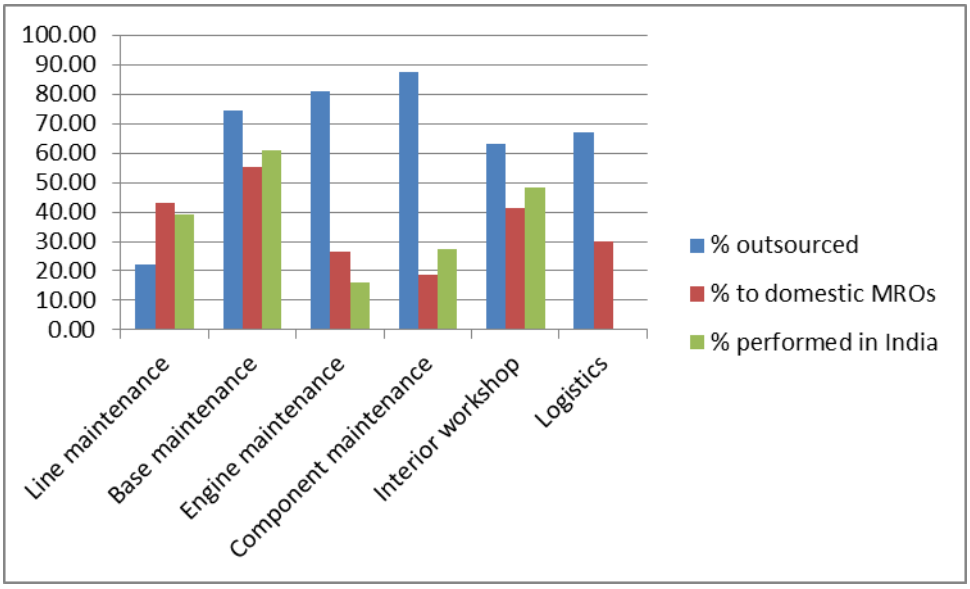

Figure 6.6: MRO Outsourcing

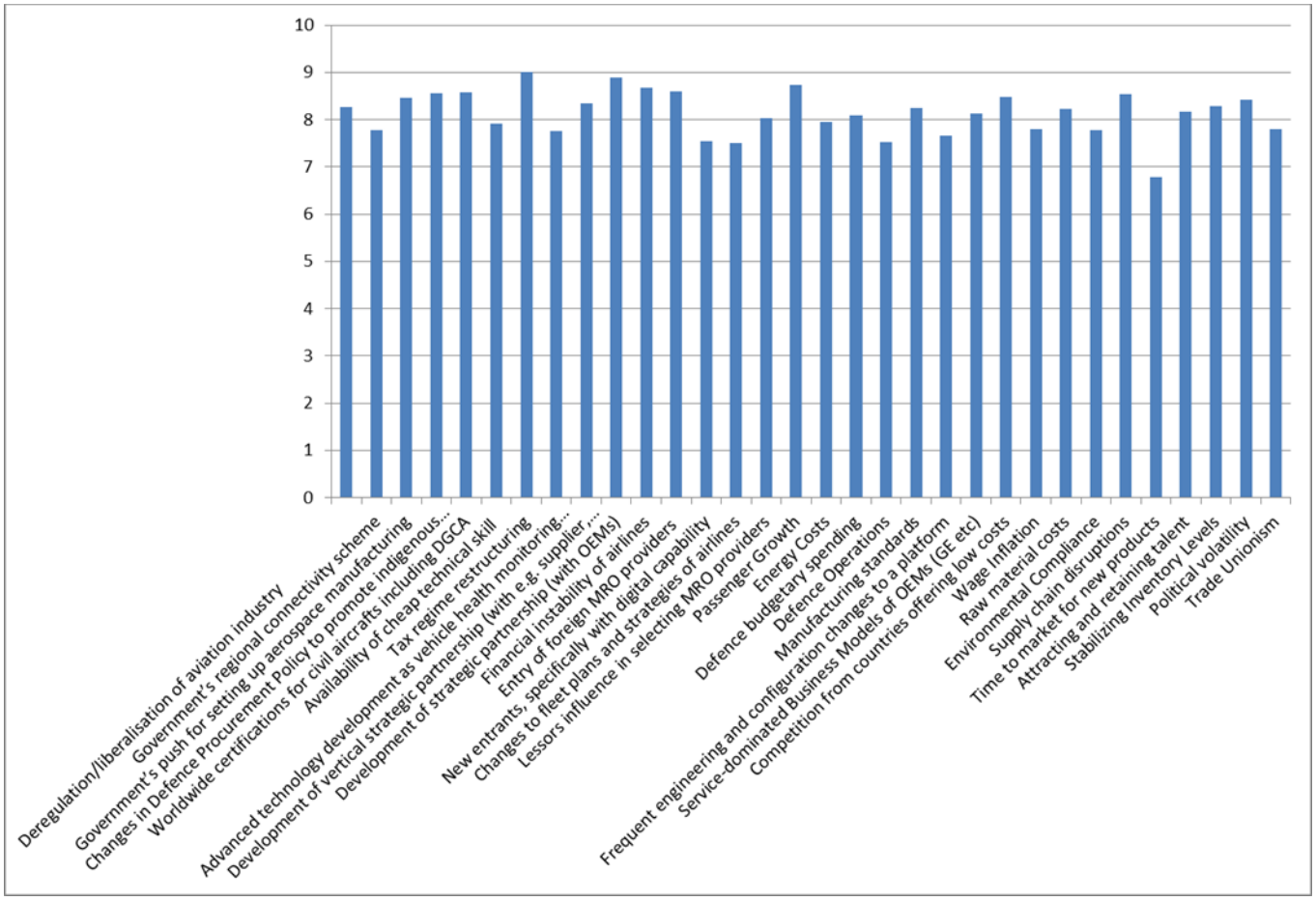

Figure 6.7: MRO industry drivers relative importance

Respondents were asked about the existing capabilities present in MRO providers which will be relevant in coming decade and which will probably be irrelevant with advancement of technologies. Some capabilities are also identified by respondents, which will be definitely needed in future (in 2024-2030) but the industry lacks them. Table 6.2 gives the details of those capabilities.

Table 6.2: MRO Capabilities (Existing and Future)

Capabilities existing today and relevant in 2024-2030	Capabilities not relevant in future or will be substituted	New capabilities need to be developed for future competitiveness
Business Intelligence	Customer Relationship Management (CRM)	Warehouse Management System
Use aircraft health monitoring and predictive maint.	Asset Management System	Transportation Management System
Establish technician training or partner with OEMs	ISO certifications	Leverage data analytics
Partner with OEMs to secure discounts on parts/materials	Maintaining accurate record of repair and spares	Intelligent contractual terms to negate all operational risks
Cybersecurity strengthening of communication network	Demand Planning & Forecasting	Product Lifecycle Management (PLM)
Investment in right forecasting technique for MRO demand	ERP	Policy to use alternative parts rather than purchasing costly OEM parts
Implementing job sharing	Effective use of supply chain risk management programme	Reverse Engineering
Online Purchasing/Selling	Product Data Management (PDM)	Additive Manufacturing
Mobile/Wireless Management	MRP/MRP II	
Cloud		
Increase overall use of cannibalisation		
Artificial Intelligence/Machine Learning		
Manufacturing Execution System (MES)		

6.3 Recommendations

First recommendations (denoted by the letter M) are already being worked out by the Economic Advisory Council to MoCA. The italicised portion is added by us.

M1. **Royalty Fee:** MoCA should issue a formal notification to all the airport operators (private as well as AAI):

– Emphasizing the policy reform and directing not to impose any royalty (or any other equivalent charges) on MROs

– A refund of the amount already charged by airports after the NCAP would be very cumbersome. So, the 5 year period envisaged in the NCAP should be applicable prospectively. However, MoCA can think of giving away some offset type of obligation to the MROs. *They can get the refund if they can develop some capabilities either jointly or independently with foreign providers/customers. These capabilities should be based on the capability gaps identified in earlier section. Alternately, they can be urged to train people in relevant skills and show the employability of the trainees in the industry.*

The goal of this step is to reduce the cost burden on Indian MROs to free up cash for investments into training and capital expenditure for long term growth. This will Improve the ability of Indian MROs to attract business from international carriers.

M2. **Repair and Return:** Clause 4 (e) of the FEMA notification needs to be amended and Industry should be permitted to import :

– A different serial number of part being exported

– Such serial number can be an exchanged / reconditioned / overhauled / repaired or new unit (the concerned company/vendor needs to furnish all documentary proofs showing that this is received in exchange of the exported damaged or non functional equipment/part)

– The part first and then export the unserviceable aircraft part within 03 months' time

All duties & taxes should be for the differential amount between the exchanged and the old unit sent for repair

Exports under warranty programs should be allowed to be executed as NFEI transaction

AD banks should be permitted to issue GR waiver for such transactions.

This improves overall efficiencies for airlines and MRO providers and brings them into line with international practice. This helps in ensuring availability of parts and airworthiness of aircraft at all

times. This improves effective utilization of warranty programs run by various OEMs. Under these programs, airline / operators pay a fee (period / flying hour/ cycle based) and OEM sends a replacement whenever the part covered under such scheme is not operating efficiently or requires a periodic maintenance. On receipt of replacement, airline / operator is expected to permanently ship the existing unit back to OEM

M3. **Import for repair of parts:** At present there is no such regulation for situation where an Indian MRO does repair for jobs originating from foreign customers. Parts being imported for repair in India and then re exported (same serial number or different under exchange / overhauled / reconditioned etc.), being temporary in nature, should be made completely customs duty and GST free. Regulation for allowing such exports as No foreign Exchange Involved (NFEI) export under FEMA and Customs should be brought in. Master circular for import of goods needs to be amended to capture guidance on such transactions and to promote 'Make in India' concept. MROs can establish stand alone Component MRO facilities which are cost competitive with other regional MROs. India can be developed a regional hub for component MRO improving import substitution for aviation industry and creates new technical and engineering jobs.

M4. **Warehousing:** MROs, who act as authorized services facilities for OEMs, should be permitted to import parts on Customs duty / GST free basis as these are temporary imports and the stock belonging to OEMs. MROs should enjoy custom duty exemption if parts are used on maintenance of aircraft by anybody in the industry. A provision to re export (under NFEI) the goods after the 3 years' time provided for utilization of aircraft parts cleared under notification no.50/2017 Customs dated 30th June 2017 Sl.no.536, read with condition 75, without any penalties, interest and applicable customs duty. Export of unserviceable parts back to OEM for replenishing the pool should be permitted. Common parts inventory will help in improving availability of critical parts, reduce lead time for availability and reduce inventory holding costs. This will help in creating significant pool / insurance stock for the kind of exponential growth we are looking at for the industry over the next decade

M5. **Clearances:** All customs process should be operational round the clock (365 days) including Bill of Entry (BOE) filling, BOE assessment (RMS and Non RMS both), Bond debit, Duty payment, Gate pass, OOC etc. Most of aviation clearances originating from US, UK, Germany, France land at night (Indian Standard Time). Pre alerts are received late in the night to file BOEs for advance clearance but due to customs system not being available 24*7, BOE filling can happen only on the next day and hence this delays clearances. Ministry of Finance should instruct all Custom Commissioners to follow a common process and declare aviation clearances as eligible for Manual Assessment. Timely clearances will help in reducing downtime for aircraft. Common and standardized processes will help in removing the discrepancies at various airports and provide predictability in clearances

M6. **Skill Development:** Fast Track Certification to CAR 147 organizations

– Dedicated desk / cell in DGCA to look after matters related to 147 organizations

– Time bound clearances for applications

DGCA Examinations

– Examination frequency should be increased and candidate should be able to appear for an exam whenever ready

– Online examination process can be outsourced to professional agencies; this will provide necessary infrastructure and scale to organize exams at shorter intervals

– *DGCA should make some exemptions in the examination for foreign certified candidates. Some different form of examinations (oral/interview/practical) can be conducted through an expert panel (using retired staff of DGCA or on the job).*

This will help in the form of larger number of certified engineers availability to the industry to cater to current and future demand. DGCA Examinations will improve the availability of certified candidates to be hired by MROs. Better schedule of examinations as per industry requirements. This will create a strong pool of resources to improve import substitution, create jobs and turn India into MRO hub for the region quality manpower is the most important factor in creating a good and sustainable ecosystem for the industry

M7. **Security Clearance from by BCAS:** There should be separate security clearance application procedure for MROs de linking it from Ground Handling Services. This will open up a new business segment for the MROs to access defence or common use airports and MRO business. Security Clearance process should be simplified, fast tracked and made a time bound process

– Directors of MRO companies are all duly security cleared

– Majority of MROs operate within airport premises which are well guarded by CISF and other para military forces

– MROs also comply with the guidelines of the respective airport operators

Only the main bases of the MRO should be audited for renewals and not the sub locations which have very small presence. Faster clearances will help MROs in offering faster turn around times to the customers. MROs will be able to meet the varying requirements of airlines and other customers in a time effective manner. This will help in improving the "Ease of Doing Business" for the MROs

M8. **GST:** GST has actually benefitted MRO in many ways, input credit for GST can be taken reducing the overall tax incidence. Previously, VAT, CVD etc. were not eligible for input credit. Net savings of 10% 12% to airlines on MRO services increases competitiveness of India MROs. Common rules, regulations and procedures to be followed across India greatly simplifies the tax procedures. Before GST MROs used to export duty free. NFEI transaction should be kept outside ambit of Bond/Undertaking or payment of GST requirement as these are not transaction involving any foreign exchange. GST on NFEI transactions should be permitted under a cash less mechanism for GST payout and input credit. This improves overall efficiencies for MROs and brings into line with international practice. This reduce the heavy working capital burden on Indian MROs and frees up cash for effective deployment in business.

M9. **IGST:** As per Notification no. 2/2017 Integrated Tax (Rate), Exemption is given for levy of IGST against Chapter 8803 and it shows "Parts of goods of heading 8801". However, 8801 is not relevant for MRO industry and it should be 8802. This will protect MRO industry from additional tax burden.

M10. **Customs**: Non RMS clearances and shipments on which a query has been raised should be put under a timebound resolution mechanism. This is required to ensure timely clearances for maintenance of aircraft. Engine, APU, Starter Generator etc. should be declared as aircraft parts as clearances of these happen as Aircraft parts in Delhi and Mumbai, but Bangalore doesn't consider these as aircraft parts.

M11. **Course**: Most of the course curricula taught to students presently is outdated with very little relevance for actual on the job requirements. Courses consist of a general theory course of about 2 years in basic engineering skills and a 6 months practical training with an MRO. Institutes have no control on what the candidate does during the training. Focus should be on providing quality practical training in the institutes itself so that the students are equipped with all the necessary engineering and technical skills when they complete the course. *Alternately, there should be collaboration between industry and the training institute. The industry also can be asked to adopt the training institute to build synergy.* Infrastructure available in the institutes needs to be suitably upgraded for this and the duration of the courses should also be increased.

M12. **Aerodrome entry permit**: AME's AEPs are restricted due to validity of their license, since renewal of license is an ongoing process which takes 2 - 3 weeks , the affected AME is not able to perform his duties which disturbs the day to day functioning of MROs. Process of renewal of licenses should ensure delivery of new license within 2-3 working days.

Few more areas need to be addressed to make India an MRO hub of future.
1. Aviation experts noted that the government will have to create a level playing field in terms of rationalising tax levies on MRO and aircraft leasing activities to fulfill its ambitions. For instance, the domestic MRO activities are taxed at 18% as compared to 5% in nearby countries Sri Lanka, Singapore and Thailand, forcing airlines to do service jobs on aircraft overseas. These services include periodic engine checks, propellers and airframes, besides the intensive and multiple checks at the end of lease tenor of aircraft (https://www.financialexpress.com/budget/budget-2019-aviation-sector-to-get-major-boost-as-govt-eyes-maintenance-hub-status/1633258/).

2. Government can re-categorise few items for dual use to reduce the additional costs incurred by domestic MRO industry. These items can be taken for indigenisation based on strategic criticality and commercial viability.

3. On an average India exports more than 100,000 aircraft components in a year outside for testing, repair, overhaul, exchange or modification. The average turnaround time for these components varies from 15 days to 21 days. Most of the Business & General Aviation operators prefer to go for an exchange option at much higher cost due to the time is taken to return their components and to avoid grounding of their aircraft. The number of SME MRO's in India doesn't exceed single digits as of today, whereas in matured aviation markets we can locate a handful of them in each city. The safety records of Indian Aviation are much higher compared to other ICAO countries. Of course, the credit goes to Directorate General of Civil Aviation (DGCA) for strict & cumbersome compliance matrices. This also comes as a roadblock for at least few to enter into the field. India should admit that getting an approval for a small MRO is not easy for an SME (Small & Medium Enterprise) due to the vast regulatory requirements laid out by the regulators. Regulators in India should work along with entrepreneurs to develop new entrants with open & vast outlook. This is not to dilute the safety standards or compliance levels rather facilitate the upcoming of new entrants. SME's should look at the possibility of Joint Ventures and Technology transfers initially for establishing themselves. A number of shops in USA & Europe are eagerly looking to partner with Indian enterprises to set their footsteps in India. This will also ensure building of ecosystem for the MRO industry.

4. Industrial planning policy of HR for Defence MRO: it took astoundingly large nos of training and R&D institutions to build HR required for these industries. Singapore government ensured breadth and depth of high engineering skills for high value additions supported by SBUs and capacity expansion of SIA along with obtaining MRO rights through offsets. Every successful technology recipient government and industry used this opportunity to develop civil and military industry to diffuse these technologies horizontally and vertically. Suitable HR and industry policies were formulated to build and develop institutions in Aerospace, Marine and Land to structurally integrate flow of these technologies vertically. This yielded two major benefits; ensured wide range of availability of hi-tech manpower and the complete landscape of civil industry got enriched with improved technology due to osmosis. The HRD ministry defined NOS for both quality and quantity standards based on strategic assessments. They went on to establish specialist universities, Design institutes and defence universities. The Chinese established Six Research Institutes, three Design Institutes and 19 Research and Design offices covering flight testing, aerodynamics and aircraft accessories by 1960's. We can define net centric-Land-Air-Marine standards for interoperability of equipment/component and systems and corresponding HR skills development plans. We are already defining the NOS(National Occupational Standards) under the NSDC. We may broaden these skills by

setting A&D institutions in the county. These skills can be gradually be passed on to the civilian use (Batra, 2019). Industry, R&D and academia need to come under one roof to find path-breaking solutions in MRO.

5. Common standards should be initiated for consumables, so that they can be procured in bulk for defence and civilian requirements. Government should prepare a list of dual use items which can be governed by single standards. These can be easily manufactured in domestic vendor facilities thus ensuring their development. Indigenised product which are certified, common in standard and got approval, civil airlines should be notified. Airlines are seeking a common forum where they have the details of the product which they can utilise from adjacent defence sector.

6. Most respondents felt the need for advanced manufacturing techniques as additive manufacturing, artificial intelligence for advancement of Indian MRO sector. At the same time Indian MRO sector should adopt reverse engineering of OEM components. Government should bring out policy to develop these capabilities.

7. Policy should be made to incentivise OEMs through royalties or other means to supply components at cheaper price or allowing use of parts made by other providers/local vendors. OEMs can certify those parts at a fee or develop the vendor to gain lifecycle royalty.

8. MROs and component/spares warehouses need to be declared as free trade zones with zero rate of GST and a ten-year holiday on corporate tax, capital gains tax and dividend distribution tax. This will particularly help in encouraging new players to enter the market and grow the industry. The concessions include providing exemption from basic customs duty on parts and testing equipment's for maintenance, repair and overhaul of aircrafts and parts thereof. State governments can build separate policies for encouraging development of MRO parks in tandem with logistics parks to ensure fast movement through connected networks.

7.0 UAV

7.1 Global Industry

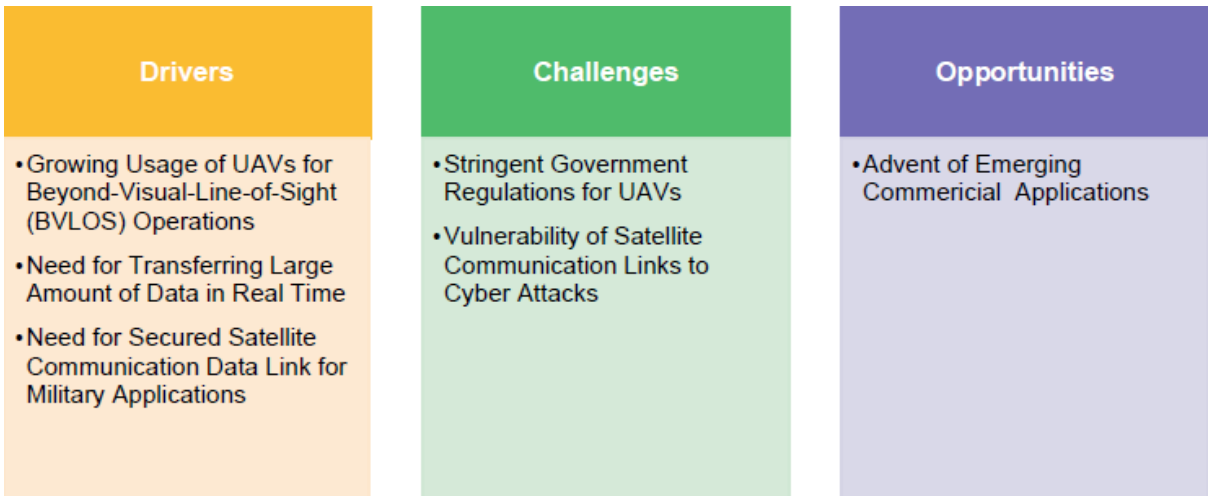

Figure 7.1: Global UAV Market Dynamics (Source: BIS Research)

Drivers: Market drivers are those factors and reasons which contribute to the growth of the market. Following are the drivers responsible for the growth of the global satellite-based UAV market:

- Growing Usage of UAVs for Beyond-Visual-Line-Of-Sight (BVLOS) Operations

  Initially, UAVs had the ability to fly only in VLOS (Visual-Line-of-Sight). The usage of UAVs in BVLOS range applications have started gaining traction. The growth in the demand for UAVs based on satellite communication is mainly driven by their rising applications across commercial and military end users for remote locations. The commercial applications of UAVs further extend to mapping and surveillance activities, in order to build navigation systems, monitor oil and gas pipe line, inspect wind turbine, and among others. Apart from commercial applications, UAVs also cater to defense and security needs of the nation. Increase in terrorism and other unlawful activities has led to the growing need for UAVs. UAVs are being used for purposes such as surveillance, reconnaissance, bombing terrorist bunkers, and marking targets in remote locations. The usage of UAVs in military and defense locations minimizes the risk to human life. The main challenge for UAVs is regarding traditional communication systems which provide connectivity between the UAVs and operators for the limited range or visual line of range. Using satellite communication, the UAVs are able to operate in BVLOS range due to which they have been rapidly adopted mainly for defense and security domain.

- Need for Transferring Large Amount of Data in Real Time

  The communication between UAVs and ground stations is the major concern as UAVs transmit the captured information, such as images and video files, to ground station and that has to delivered in real time that are essential for mission critical operations. The need for enabling real-time intelligence, surveillance, and reconnaissance (ISR) information about the remote areas has become an essential need for military and commercial operations, as it gives important information about the enemy's whereabouts, warning defense forces in advance. The information transmitted is present in the form of images and video files that require broadband connectivity between the UAV located in remote and ground station. Due to the wide applicability of UAVs in military and commercial applications, such as oil and gas pipeline monitoring, agriculture field monitoring, military and intelligence monitoring,

and others, the UAV systems captures high definition images and videos, and send this data to the ground station in real time, so that actionable intelligence can be generated. In order to transmit large amounts of data and transmit to the ground or base station, UAV systems need large bandwidth of data link connectivity which act as a challenge for UAV system. Capturing the data and sending it in real time to the base stations, UAV systems now-a-days uses satellite communication channel which solves challenge of transmitting the large amount of data in real time.

- Need for Secured Satellite Communication Data Link for Military Applications

  Since military UAVs use satellite communications due to the aforementioned uses, the communication links need to be secured. The exploitation of these links can lead to sensitive information being intercepted and possible loss of lives. In some cases, there is also a possibility of UAV being taken over by the hacker. Therefore, a number of companies are working to make satellite communications for military more secure. For instance, in mid-2015, advanced extremely high frequency (AEHF) satellites started operating. These were manufactured by Lockheed Martin and were designed to replace the popular Milstar constellation. These new satellites were jam resistant, and had five times faster data rates. These satellites provided an unmatched level of security to the defense forces. BAE Systems and EADS Astrium are some of the other companies working in this area. Thus, companies for providing secure satellite communication are in great demand, and satellite communication is a lucrative market that can reap rich dividends.

Challenges: UAV faces numerous challenges which could impede the growth of the market in the coming years which are discussed below:
Stringent Government Regulations – One of the major challenges for the adoption of UAV systems among the commercial application is safety concern. UAV providers need to comply with various rules and regulations obligated by regulatory bodies, such as the Federal Aviation Administration (FAA). The Federal Aviation Administration (FAA) has imposed rules restricting the usage of drones in civil airspace up to specific heights and has allowed their operation only in the daylight condition. Apart from the U.S., several other nations, such as the U.K., India, Sweden, and France, have also imposed strict regulations on the commercial usage of UAVs. These regulations are mostly focused toward ensuring safety and security of the public. Operating UAVs in VLOS range restricts the use of UAVs for various civil applications that require UAVs to operate in BVLOS. However, now the governments across different nations are working for the development of drone traffic management system to allow beyond visual line of sight operations, and the regulations for drone operations are expected to ease in the future.

Opportunities: With the increase in capability of drones to be used in BVLOS operations, there are numerous opportunities for the growth of the UAV market for several application areas such as mapping, surveillance, product delivery, Wi-Fi connectivity, natural disaster management, oil and gas pipeline monitoring, land management, mining and farming, firefighting, and others. The increased utilization of drones for oil and gas sector can be one of the major opportunities for the UAV market. With the help of UAV, oil and gas companies can inspect and monitor the pipeline's leakages and damages. Also aerial and satellite imaging have proven to be significantly useful applications in agriculture. This technology can further help the farmers to collect and analyze valuable data regarding an agricultural farm. Farmers can continuously monitor the quality of the soil and the crops produced for better productivity. Apart from precision agriculture, other valuable applications of the UAVs include surveying the construction sites, telephone tower inspection, insurance claim assessment, and environmental monitoring. Thus, the advent of emerging applications is expected to act as an opportunity for this market in the coming years.

Industry Analysis: The design and technological evolution has been influencing the development of UAVs over the years, therefore the UAVs have a complex design, at present. In 1900, Nikola Tesla presented the idea of wireless control of combat balloon, which was almost similar to the ones used by Austrians. The Kettering Bug was a biplane, which flew a pre-set course with the help of a gyroscope and an altimeter installed onboard. Technology further improved with Reginald Denny inventing a remote controlled aircraft and Northrop developing P-61 Black Widow, which could collect weather data. In 2000, researchers achieved their hard-sought goal of making a rotary wing UAV that didn't require the skills of a helicopter pilot. For example, Dragonflyer X6 helicopter and RQ-8 Fire Scout do not require a licensed helicopter pilot to fly the aircraft. UAVs continued to develop, and at present mini and micro-sized UAVs, which can go in hard to reach places and can be used for spy missions, have been commercialized. Engineers and scientists have developed UAVs with Vertical Take-off and Landing (VTOL) capacities and are completely electric. Satellite communication channels are being used to operate drones Beyond Visual Line of Sight (BVLOS), and this enables UAVs to scout remote areas and conduct cross country flights. In May 2018, Leonardo demonstrated its satellite-based solution to operate Piaggio Aerospace's P.1HH HammerHead drone. The drone's ground station is linked with Athena - Fidus satellite - to operate the UAV and its onboard sensors and systems thus enabling operation beyond ground-based radio coverage. Moreover, Hughes Defense, a leading U.S. satellite communication provider, entered into a contract with General Atomics in March 2017, to provide satellite communication to U.K.'s Protector UAS using the Skynet satellite. The company is interested in providing similar services to other countries as well. Cobham, a British manufacturing company and one of the largest defense companies in the U.K., released "Aviator 200 UAV" in February 2016. It is a satellite datalink system which specifically caters to small UAVs conducting BVLOS communications. Figure 7.2 tracks the evolution of drone industry in the world.

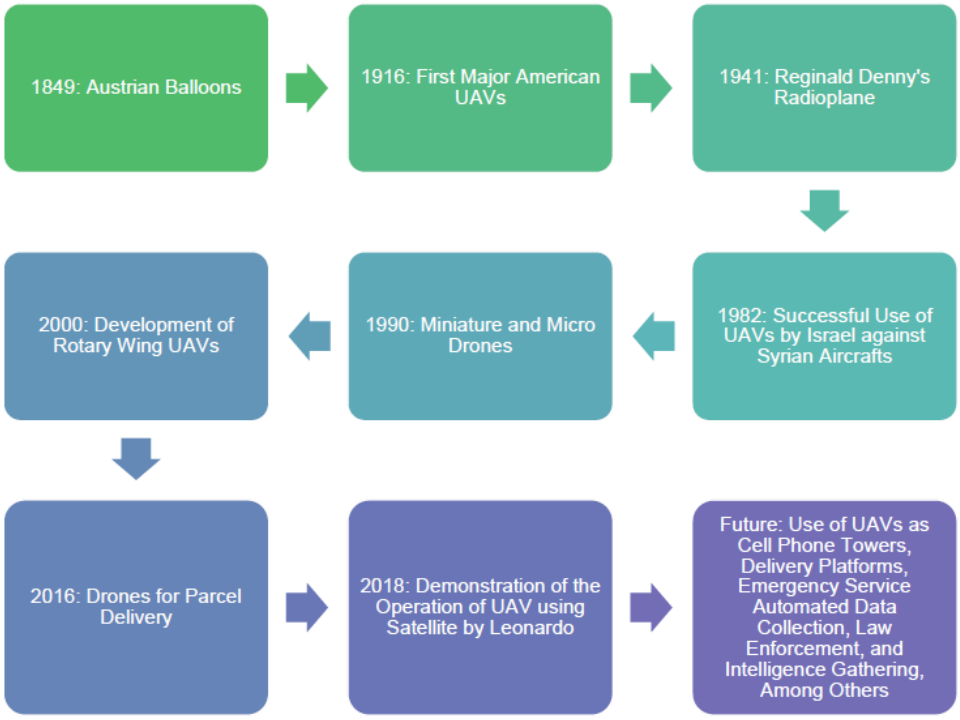

Figure 7.2: Evolution of UAVs (Source: BIS)

Supply Chain:

Research and development is a major step in the overall development of the product. Various phases in research and development include system design, software development and testing, prototype development and testing, and sustained engineering. In this phase, ground work is done to generate value across the rest of the phases by giving a concrete shape to the overall product. Almost all the major players in the UAV market such as DJI, Northrop Grumman, Parrot, Aerovironment, Lockheed Martin, and Precision Hawk, are investing in research and development activities to stay ahead of their competitors.

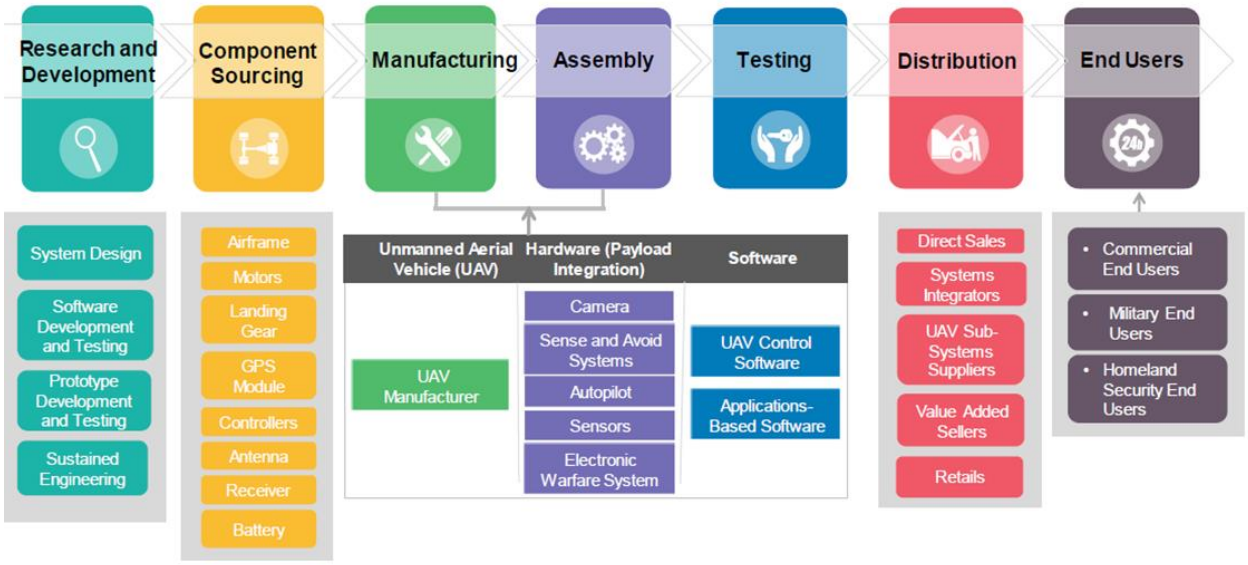

Figure 7.3: UAV Supply Chain (Source: BIS Research)

Component Sourcing: Key components, such as batteries, gimbals, payloads, sensors, and motors, are sourced by the original UAV manufacturers to develop the final product. Some of the prominent companies sourcing these components are:

Battery: Holy Stone, Cheerwing, Noiposi, Tenergy, ENGPOW, Powerextra, and Sky Viper, among others

Gimbals: TopIVision Ltd, Vision Aerial, Intuitive Aerial AB, Cloud Cap Technology, and Aerialtronics, among others

Sensors: Lumenera Corporation, FLIR Systems, Inc., Unmanned Systems Source, and Threod Systems, among others

Motors: Robot Aviation, Aerial Technology International, Flightech Systems, and Avartek, among others

Manufacturing: In the manufacturing phase, overall end product is manufactured in parts, which are then put together for integrating specific consumer requirements by original equipment manufacturers (OEMs). The various components, such as batteries, gimbals, payloads, sensors, motors, are manufactured or sourced from different suppliers in order to proceed to the assembly stage.

- Battery manufacturer and provider: Unmanned Systems Source (U.S.), Ballard Power Systems (Canada), and Eaglepicher technologies (U.S.), among others.
- Gimbal manufacturer and provider: UAV Propulsion Tech (Sweden), DJI (China), and Merio (France), among others.
- Sensors manufacturer and provider: Unmanned Systems Source (U.S.), and Azo sensors (U.K.), among others.

Assembly: In this phase, components developed by the component manufacturers are put together and integrated with software and systems, such as sense and avoid systems, autopilot, UAV control software, and application-based software. Different components that are sourced and manufactured include both software and hardware. These components are assembled to create the finished product i.e., UAV.

Testing: The final product is extensively tested, and any faults detected with system is rectified. Any manufacturing defects are also carefully checked for. Flight tests are conducted to test the UAVs overall performance. This is a crucial step and decides the quality of the manufactured product.

Distribution: It is the link between manufacturers and end users. UAV OEMs have one or more distributors and resellers to sell the products in different geographic locations. Some of e-commerce

retailers, such as Amazon, Unmanned Systems Source, and Robotshop, also provide UAVs to end users. Users can directly purchase UAVs from companies as well.

End Users: End users of UAVs are homeland security and defense commercial users and government agencies. Homeland security needs drones for securing places of interest, such as stadiums or open air events, by constantly monitoring them. UAVs are handy tools for defense forces to check infiltration on the borders and to keep away smugglers from smuggling illegal substances. Construction companies, oil and gas companies, and other companies that use UAVs for construction site inspection, crop monitoring, and so on are grouped under commercial companies.

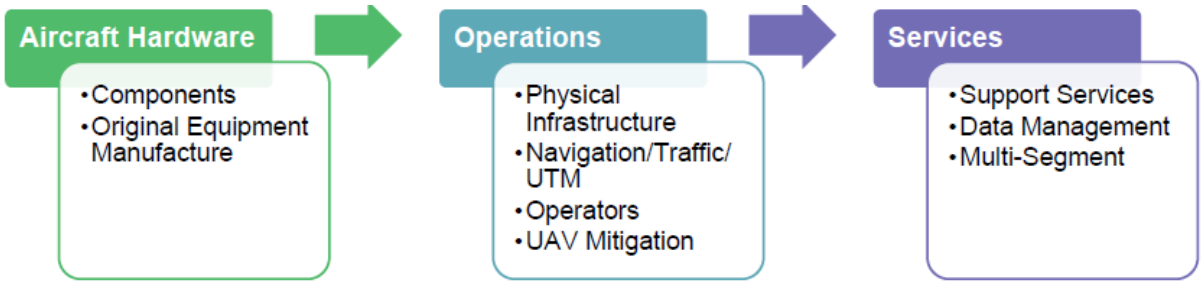

Figure 7.4: UAV Industry Value Chain

The UAV industry provides opportunities for multiple other forms of industry and activities as shown in Figue 7.4 in UAV value chain. Components and OEMs can be grouped under aircraft hardware. Components include batteries, gimbals, payloads, sensors, and motors, among others, which are used on the UAS platform. OEMs deal with manufacturing and integration of these components, which cater to consumer and commercial UAS. The operations section includes physical infrastructure, navigation/traffic/UTM, operators, and UAV mitigation. Companies catering to landing pads, UAS stations, vertiports, and chargers, among others are categorized as physical structure providing companies. Other companies that develop systems to navigate airspace are known as navigation companies. They generally use artificial intelligence software, GPS devices, do route planning and provide unmanned traffic management (UTM) services. Some other companies provide professional services, such as aerial photography and mapping as well as inspections of critical infrastructure, and are put under the operator category. Threat prevention and mitigation using UAS guns, nets, shields, and lasers, among others are important aspects in the industry, and companies dealing with these topics are known to provide UAV mitigation services.

Support services, data management, and multi segment are included under the services section. Companies dealing with supporting services such as UAS laws, insurance, consulting, maintenance and training services are known as support service companies. Data management companies use software and analytics to digitize the information collected by UAVs and organizations with multiple value-chain offerings are known as multi-segment companies.

Emerging Trends: UAVs have mostly been developed and used by military forces around the world for variety of missions such as strike operations, search and rescue missions, providing protection to ground troops, and reconnaissance and surveillance. In the commercial sector, they have been used for crop monitoring, aerial mapping, surveillance and inspection, parcel delivery and so on. In the coming days, UAV technology will improve by leaps and bounds, riding on advancement in sensors, processors, artificial intelligence, and machine learning.

- Advanced sensors and processors: These devices are used for advanced sensing, vision, autonomy, and communications. The four common advanced sensors are thermal, multispectral, hyperspectral, and LiDAR. Recently, sensors and processors have become power efficient, with design flexibility and ease to use. These devices can enable drones to be connected to the Internet of Things (IoT) platform. Currently, scientists and engineers are working to optimize these devices to work efficiently in space-constrained

UAVs. With improved sensor quality, increased point density, decreasing sensor size, and increasing data processing power, advancements in sensors and processors are compulsive trend to observe.

- Artificial intelligence and machine learning: Drones generate a large amount of information. At times, the information generated is not manageable for humans, and hence artificial intelligence is required to make efficient use of such large data sets. Artificial intelligence (AI), combined with machine learning and deep learning, is automating the process of data acquisition and analytics to a very high degree. Machine learning (ML) algorithms can improve and learn over time when exposed to new data. The utilization of complex AI algorithm continues to be increasingly feasible, as there is a rapid and immense increase in processing power, availability of digital data, and reduction in the costs of storage. If AI maintains this rapid pace, drones are expected to become highly automated devices that can add an immense amount of value to the industry they are serving.
- Remote drone identification: As the usage of drones increases tremendously over time, misuse of UAVs is also increasing, as is evident from incidents such as Heathrow, Gatwick and Dubai airport closures, attack on Venezuelan President, and Boston Marathon terrorist attack. Hence, countries around the world have realized the need to remotely identify the drone and its operator/owner and learn about its mission if possible. Technologies such as visual light encoding, Bluetooth, blockchain and LTE/4G enable authorities to access a drone's unique ID issued during its registration which enable them to track the operator and owner of the drone. This unique ID is like an electronic license plate for drones, which reveals all the necessary information to the authorities.

Regulations: Regulatory bodies have framed certain rules and regulations to monitor UAV operations in their respective nation's airspace. No-fly zones have been demarcated where UAVs are restricted from flying. Further, a detailed set of rules exist for various kinds of UAV operations, such as commercial, research, and recreational. The following table shows some of the rules and restrictions set by regulatory bodies around the world. Recently in April of 2019, Wing Aviation LLC, which is a subsidiary of Alphabet Inc., became the first drone operator to receive government approval to function as an airline. This approval is a forward-looking step in terms of acceptance by any government towards drone operations aimed at delivering products to customers. Although, permissions to operate drones over urban areas as well as crowded areas were not granted for such operations but the approval allows Wing to make any delivery on behalf of its customers on a chargeable basis. This further opens up possibilities for many more such operations by different companies to seek the same approval and expand their footprints in the growing drones market (https://www.hindustantimes.com/tech/google-s-wingaviation-gets-faa-approval-for-dronedeliveries-in-us/storya2aM63GPTZ8bfeuDWTxRPK.Html). while the FAA regulations categories drones by size and shape, the EASA regulations go for more risk-based categories. The government of Ghana has showcased interest in drones to deliver medical supplies and blood vessels to hospitals nationwide, especially in remote areas. The Ministry of Health has signed a Letter of Intent with USA based Zipline International Inc. to offer a drone-enabled supply chain solution in Ghana that will ensure deliveries of medical products and supplies to hospitals and other health facilities. The service seeks to leverage the drone technology to improve the supply chain of critical medical supplies and save lives (http://www.ghanahealthservice.org/ghs-item-details).

Countries around the world have been consistently trying to overcome the barrier for becoming drone operators and at the same time keep an eye on the nature of operations that are being conducted by the UAVs. Table 7,2 is a snapshot of near future drone regulations around the world.

Table 7.1: Drone regulations by Applications around the world

Country	Regulatory Body	Recreational/ Non-Commercial	Commercial/ Research	No-Fly Zones/ Restrictions
Australia	Civil Aviation Safety Authority	UAVs used for recreational purposes have been tagged as "Model Aircraft" and must carry out Line of Sight (LOS) operations only. UAV shouldn't be more than 30 m closer to any vehicle, person, boat and the like. UAV can't be flown during night and in poor visibility conditions.	The pilot of these UAVs must have UAV controller's certificate and the business operating the UAV should possess Unmanned Operator's Certificate (UOC)	UAV is not supposed to fly within 5.5 km of airfields, beaches, stadiums, parks and other populated areas. The drone should always fly below 400 ft.
Canada	Transport Canada	Special Flight Operations Certificate (SFOC) is required for operation of UAVs in Canada's airspace. Operators also need to notify Transport Canada with necessary information about the flight. BVLOS operations are not yet standardized but are accepted on a case by case basis.	UAV is restricted from flying within 9 km from airport, heliport and the like. It shouldn't be flown above 90 m from the ground and should be atleast 76 m away from people, animals, and buildings, among others.	
France	Directorate General of Civil Aviation (DGAC)	UAVs weighing less than 25kg are grouped as "category A" and don't require prior authorisation. UAVS weighing under 2kgs can operate upto a height of 50 m and a distance of 200 m. Autonomous UAVs can't weigh more than 1 kg.	Annual declaration of fitness required to fly UAVs weighing more than 25kg (category B). For BVLOS operations a pilot's license, 20 hours of drone training and 100 hours of flying experience is necessary. Cargo delivery drones can't carry cargo weighing more than 500 g.	UAVs are not supposed to fly within 4km of any populated and sensitive areas such as airports, nuclear power plants, stadiums, concert events and so on. Vertical limit for UAVs is 150m above the ground.
Germany	Federal Ministry of Transport and Digital Infrastructure	Any UAV weighing more than 0.5 kg should have an individual license plate which helps to identify the operator. BVLOS operations and flights above 100 m require official permission.	Authorisation from regional states authority is required for BVLOS operations or for UAVs weighing more than 25 kg. Commercial drone operators require to pass a test and obtain a license which proves their aeronautical skills and knowledge of aviation laws.	A radius of 1.5 km from any airport, military installations and scene of accidents and other such sensitive areas and airspace is prohibited for UAVs.

Hong Kong	Civil Aviation Department (CAD)	No application to CAD is required for flying UAV under 7kg for recreational purposes and these UAVs are categorised as model aircrafts. Maximum flying height is 300 ft and can be operated during day time only.	Only VLOS operations are allowed at a maximum flying height of 300 ft. Permission is required to operate UAVs for commercial purpose. Permission is obtainable only if the pilot passes competency tests.	Drone should always be 5km away from airports. UAVs should fly 50 m away from any person, vehicle, vessel or structure and during take-off and landing, the limit is reduced to 30m of any person other than the operator.
United Kingdom	Civil Aviation Authority (CAA)	UAVs under 20 kg need not register with CAA unless they are being used for commercial purposes. However, UAVs weighing more than 7 kg need permission to fly in class A, C,D, E or at heights above 400 ft.	An operator's certificate issued by the CAA is required to operate all commercial UAV operations. UAVs over 20 kg must be register with the CAA and the ones over 150 kg must obtain an air worthiness certificate.	Operations are restricted within 50 m of any person, parks, stadiums, controlled or restricted airspace, and military bases, among others. Further, any UAV should be 150 m away from any gathering of more than 1,000 people or any such congested areas. Drones can operate uptill a maximum height of 400 ft above the ground.
United States	Federal Aviation Administration	Drones weighing between 0.5 pounds and 55 pounds must do a web-based registration before commencing operations.	FAA exemption under Section 333 of the FAA Modernization and Reform Act of 2012 must be obtained by the operator.	UAVs must notify the airport and air traffic control (ATC) prior to flying within 5 miles of medium to large sized airports. Drones are not supposed to fly more than 400 ft above the ground.

Table 7.2: Upcoming Drone regulations

Country/Region	Rules
The U.S.	**Remote Identification:** It is a system to identify the drone operator/owner using a unique ID issued to the drone at the time of registration. It will reduce the complexity of operations such as BVLOS and operators are expected not to have to apply for lengthy waiver process.
Canada	Canada has nearly removed Special Flight Operations Certificate (SFOC) process which is a boon for drone operators. Operators are expected to need only an airworthiness design certificate and operator certificate which can the amount of time required to start a drone operation.
European Union Member States	European Union Aviation Safety Agency (EASA) is trying to adopt unified drone regulations for of the entire European Union (EU). Governments and industry stakeholders are partnering to identify most common opportunities and issues with the usage of drones. Issues, such as data security, self-regulations, BVLOS operations, and operator certification, among others, are to be discussed and rules are expected to be framed, accordingly.
Asia Pacific	Ministry of Land, Infrastructure, and Transport (MLIT) of Japan plans to pass laws that can promote BVLOS operations if the aircraft has a history of safe operation. Furthermore, radio communication allowance is expected to enable videos shot by drones to be transmitted over longer distances.

Competition: In global UAV market, companies with high competitive strength are Lockheed Martin corporation, The Boeing Company, and Northrop Grumman Corporation. Among these, Lockheed Martin Corporation currently fosters the highest competitive strength in the global UAV market. These companies offer a large product portfolio with the company's products providing long range and increased endurance. These companies also provide satellite communication which enables UAVs to carry out BVLOS operations. Companies in this section have a good global presence which helps them to increase their sales. Companies with medium competitive strength include Saab Group, Textron, Inc., Elbit Systems, AeroVironment, Inc., and Thales Group. Their products offer reduced features when compared to products of the companies with high competitive strength. Their global presence is also less than that of the high competitive strength companies. However, products from these companies have reasonable range, endurance, and operating altitude, among other qualities. SZ DJI Technology Company Limited, Parrot Drones S.A.S, 3D Robotics, PrecisionHawk, and Aeryon Labs, Inc. are the key players in the commercial segment.

Market Size: In terms of value, the global UAV market with SATCOM capabilities accounted for **$25.59 billion** in **2018** and is projected to reach **$70.28 billion by 2029** at a **CAGR of 8.45%** during the period 2019-2029. The number of UAV units in 2018 was approximately 2,656 units, which is projected to reach 27,204 units by 2029. UAV companies manufacture different types of UAVs with different features and applications. On the basis of their class, UAVs can be classified into small and large UAVs. UAVs weighing less than 500 Kg are considered small UAVs, while UAVs weighing more than 500 Kg are considered large UAVs. The large UAV market having SATCOM capabilities reported revenue generation of $24.51 billion in 2018 and is expected to grow at a CAGR of 8.27% during the forecast period 2019-2029 to reach $66.19 billion by 2029. The small UAVs segment is expected to grow at the highest CAGR during the forecast period 2019-2029, as these UAVs are small in size and have less chances of getting detected in the radar systems when used for military operations. In 2018,there were 542 units of small UAVs having SATCOM capabilities, and this number is expected to reach 19,971 units by 2029 at a high CAGR of 40.14% during the forecast period. The small UAVs with SATCOM capabilities was valued at $1.08 billion in 2018 and is expected to reach $4.09 billion by 2029 at a CAGR of 12.12% during the forecast period. Large UAVs are expected to have the largest market share during the forecast period, due to their higher adoption by military and security agencies, globally.

Small UAVs range from the size of an insect to medium sized portable drones whose any one dimension does not exceed 2m in length. These UAVs fly at low altitudes, within a range of 50km and have maximum gross take-off weight of less than 150kg. They are usually equipped with electro-optical (EO) or infrared (IR) sensors and are used for a variety of purposes **from filming events to spy missions and for intelligence, surveillance, and reconnaissance** (ISR) operations. **Small UAVs are making a strong headway in the commercial market,** as these drones have turned out to be useful in applications such as **aerial photography, precision agriculture, inspection of critical infrastructure such as oil and gas pipelines, and assistance in fire-fighting, among others**. The key manufacturers in the commercial/consumer segment are **SZ DJI Technology Company Ltd. and Parrot Drones S.A.S** that manufacture a variety of drones, ranging from toy drones to drones for photography and other civil applications. Although there are several rules and regulations which regulate the usage of drones, **certain end users have been granted permissions and relaxations to fly their drones in the national airspace**. These include **filming** drones which can be flown over closed sets and **Amazon's** parcel delivery drones which are used to deliver packages. Manufacturers such as **AeroVironment, Inc. and Northrop Grumman** Corporation have been catering to military applications which provide support to ground troops and supply intelligence on enemies to commanders. **Fixed wing UAVs** have a rigid wing which generates lift due to forward motion of the UAV. These UAVs have **high endurance**, **can carry heavy payloads**, and **cater to military and civil applications**. Defense forces around the world use fixed wing UAVs for **border patrol** to check

infiltration by terrorists or unauthorized individuals. **Homeland security** uses these drones to secure events where people gather in large numbers and for **surveillance** of places of interest (such as historical monuments and government buildings). These UAVs are also used for **search and rescue** operations and for dropping food packages in remote areas affected by calamities. Fixed wing UAVs have contributed to mapping and mining industries as well. **Israel Aerospace Industries Ltd., Elbit Systems Ltd., and Textron Systems** are the key manufacturers in this segment. Fixed wing UAVs are very useful for applications where a large piece of land needs to be covered. Since fixed wing UAVs have longer range and endurance than rotary wing UAVs, entire flight operation can be covered in a single flight. These UAVs can fly at **high altitudes** when compared to rotary wing UAVs, allowing them to provide a bigger picture of the area in interest. Fixed wing UAVs have a **simple structure** which makes them **easier to maintain** and also handle bad **weather** better than their rotary counterparts. Its ability to fly at higher altitudes and for longer time can be used to develop the UAV for **combat roles**. **Northrop Grumman Corporation, The Boeing Company, and Israel Aerospace Industries** Ltd. are some of the key players developing small fixed wing UAVs. **Rotary wing UAVs** consists of rotor blades which revolve around a fixed mast. The rotor blade and the mast together are known as a rotor. Since rotor blades are themselves in motion, **forward motion of UAV is not required to generate lift.** Rotary wing UAVs usually use more than one rotor depending upon the application they perform or payload they carry and thus come in a variety of configurations such as tricopter (3 rotors), quadcopters (4 rotors), and so on. Rotary wing UAVs are a great tool for **aerial photography** as they provide great control over positioning and framing. They have proved to be handy **for lifting payloads such as parcels** as they have **VTOL** and **hovering** capacity. Companies such as **CybAero AB and Saab Group** have developed rotary wing UAVs that are being used for **search and rescue** missions and for providing assistance to first responders. Some of the key manufacturers of rotary wing UAVs include **SZ DJI Technology Company Ltd, Parrot Drones S.A.S, CybAero AB, and Saab Group.** Rotary wing UAVs are **easy to use** when compared to fixed wing UAVs. They can operate in **confined areas** which helps it to reach **areas which are difficult to access by fixed wing UAVs**. Fixed wing UAVs lack VTOL and hovering capacity which is provided by rotary wing UAVs. This feature gives a **better camera control** when cameras are installed on rotary wing UAVs.

Large-sized UAVs weigh more than 150 Kg. This type of UAVs are classified into tactical, strategic, and special purpose UAVs on the basis on the nature of operations they can carry out. Large UAVs are mostly operated in the **BVLOS range** and mainly used by defense and security agencies. Large UAVs are primarily used for regional observations, surveillance, border security, target neutralization, and intelligence gathering. Due to stringent regulatory framework, the application of large UAVs is very limited in commercial applications. In future, commercial applications such drone-delivery, oil and gas pipeline monitoring, and others can expect the usage of large UAVs, as they have capability of flying in high altitude and large payload capacity. **Strategic UAVs** are mainly used for intelligence, surveillance, and reconnaissance (ISR) operations. In any war scenario, gathering valuable and actionable ISR information is considered one of the contributing factors to success in military missions. These UAVs transmit this actionable ISR information to the base station which help military personnel to get a clear picture of the current war scenario and, in turn, helps in deciding the future strategy. These type of UAVs are equipped with special type of electronic sensors for collecting the information. **Tactical UAVs** carry military weapons and are used for target neutralization in the war zone. The basic aim of using these type of UAVs is to save human life in combat situations. Tactical UAVs have capability to carry heavy advanced military weapons and have high endurance and range. These type of UAVs does not have on-board pilot and are managed and controlled by operators located at remote terminal. **Special purpose** UAVs are used during unrest situations and are developed depending on the mission requirements. The UAV manufacturers and defense agencies are developing the special purpose UAVs according to their requirements. For instance, Iran developed a special purpose UAV with a vertical take-off and landing (VTOL) feature, and also equipped with optical tracking device Dideban-1 in 2015. As a result of this, the UAV did

not require runway for takeoff and landing, and also with the help of optical tracking device, the quality of images and videos does not decrease in low light condition. Moreover, Indian Army developed an armed UAV which is used at line of control between India and Pakistan for monitoring and surveillance. Apart from this, this UAV is upgraded to carry weapon system which can drop grenades and IEDs on infiltrating terrorists.

Visual line of sight (VLOS) operations are those UAV operations where the operator maintains a direct unaided visual contact with the UAV. These operations are relatively simple, as UAVs need not have complex technologies such as detect and avoid, advanced sensors, and so on, which helps the UAV to safely navigate through the airspace. Reliable communication technologies, such as radio communication, exist which can transmit data back to the operator without the loss of communication link. Rules and regulations for VLOS operations are clearly stated by most regulatory authorities around the world and operators do not face any confusion or challenge carrying out these operations. These drones are extensively used by aerial photographers for taking good quality pictures and for filming a particular event. They are also good tools for inspection of assets which are hazardous to people or are difficult to reach, such as towers or tall structures. Defense forces often use these drones for keeping a constant watch on any particular area of interest, thus giving them valuable intelligence. VLOS UAVs are a great asset for homeland security as well, which use them to monitor dangerous and remote locations without putting its officers at risk. Fire fighters have been using these drones for keeping a watch on the spread of fire apart from helping them in taking crucial decisions. In April 2019, SZ DJI Technology Company Ltd. collaborated with Los Angeles fire department to advance drone technology in public safety applications. However, these drones cannot be used for operations in large areas. For instance, the fire department can't use them to monitor forest fire where large swaths of land are involved. These drones have limited range, endurance, and battery life, which limits their use. SZ DJI Technology Company Ltd. and Parrot Drones S.A are some of the major manufacturers of such drones. At present, satellite communication is not being provided for VLOS operations as it is expensive. This can turn out to be another niche area for companies if they reduce the cost for satellite communication and provide it for VLOS operations. Example of large UAVs are Heron (Israel Aerospace Industries Ltd.), European MALE (Airbus S.A.S), and Hermes family (Elbit Systems Ltd.). Examples of small UAVs include Mavic family (SZ DJI Technology Company Ltd.), Bebop (Parrot Drones S.A.), and Bird-Eye (Israel Aerospace Industries Ltd.).

Beyond Visual Line of Sight (BVLOS) operations are those where the UAV flies beyond the visual range of the operator. Manufacturers need to make UAVs truly airworthy by developing advanced sensors and systems which can enable these drones to clearly navigate in the airspace in specific pathways without collision. Rule and regulations put forward by regulatory body are dynamic and a challenge for manufacturers and operators around the world. Once these issues are overcome, BVLOS operations can help commercial market to expand more than the already existing military market. Manufacturers such as General Atomics Aeronautical Systems, Inc., Israel Aerospace Industries Ltd., Lockheed Martin Corporation, and Northrop Grumman Corporation have developed small and large UAVs which are capable of carrying out BVLOS operations which provide ISR and strike capabilities to defense forces. Research and development is currently underway to introduce unmanned combat vehicles which can reduce loss of lives by replacing manned fighter aircrafts. Military UAVs generally use satellite communication as it is a secure form of communication, and the UAV can maintain radio silence in enemy territory. In December 2018, German Airforce extended their contract for operation of Heron 1 drone in battle zones of Afghanistan and Mali. In the commercial sector, BVLOS operations can usher in safer, easier, and cheaper alternatives to helicopter and other such manned operations. The commercial sector is where multi-billion-dollar business potential for drone lies, and there are some commercial applications which are feasible

only with the help of BVLOS capable UAVs. For instance, measuring crop health on a large farm over a period of time requires UAVs to conduct BVLOS operations and remain in air for considerable time. These operations, if done with helicopters, would be unfeasible for the farmer. However, in the U.S., no one is allowed to fly BVLOS operations, which has locked the potential of these commercial applications. Besides this, BVLOS drones help in search and rescue missions, delivery of food package and medical supplies to remote areas in time of crisis, delivery of parcels, and much more. Companies such as Amazon want to use drones with BVLOS capabilities for parcel delivery. In June 2018, Airbus entered into a collaboration with Wilhelmsen Ships Services to provide shore to ship parcel delivery services.

7.2 Indian UAV Industry As Is

DRDO developed a MALE UAV for Indian Army, Indian Navy and the Indian Air Force. The nation is focusing on developing in-house capabilities to develop UAVs in the future. For instance, in February 2018, DRDO successfully tested the flight of Rustom 2. Furthermore, the government of India spent heavily on defense and security to develop and buy advanced technological weapons. For instance in 2019, Israel Aerospace Industries (IAI) signed an agreement with the Indian government to provide 50 Heron UAVs to India. BIS research estimates the value of the India UAV market from 2018 to 2029. India generated $1.20 billion in 2018 and is expected to witness a growth rate of 10.53% to reach $4.62 billion by 2029. India currently has a total of approximately 30000-40000 UAVs, most of which fall under nano and micro categories (KPMG-MoD study). With 22.5 per cent of the world's UAV imports, India tops the list of drone-importing nations (SIPRI). The UAVs presently held by Indian military are all of fixed wing type and research and development carried out by DRDO on UAVs are primarily on fixed wing UAVs. The current UAV population in India, armed forces is around hundred (source: HAL), most of which have been procured from Israel. Some of the details of the UAVs procured or in process of procurement by Indian armed forces are:

- The indigenous Nishant UAV for the Indian Army which requires a launching system with catapult technology. This does not have self-propelling ability and recovers with the help of a parachute. There is a decision in fact to phase out the Nishant.
- There are three types of UAVs from Israel Aerospace Industries (IAI), that are used by Armed Forces: The Heron: A Medium Altitude Long Endurance (MALE) UAV, has a flight time of upto 52 hours, but actual time of flight depends on the payload and flight profile. This has advanced features for artillery observation and surveillance and can be used for intelligence tasks.
- The Harpy carries a warhead to destroy radar systems after loitering. This can also carry out suppression of enemy air defences, including surface to air missile sites and anti-aircraft instillations. It has maximum speed of 185 km/hr and 500 km range of flight.
- The Searcher UAV has a speed of 200km/hour and can fly up to 18 hours. Both the Indian Navy and Air Force deploy there for extended reconnaissance
- TAPAS, earlier called Rustom-II, another MALE UAV is being developed by DRDO as a weaponised platform. IAF has placed a Minimum Order Quantity (MOQ) (on) TAPAS BH-201 (earlier called Rustom-II) which is likely to be developed by August 2020. Once the mass production of TAPAS BH-201 starts, it will be inducted in the IAF in next 3-4 years.
- IAF is exploring the possibility of procuring UAVs through Buy & Make (Indian-IDDM) routes. It is expected that in another four years, new RPAs will be inducted to meet the operational requirement of IAF.
- Indigenous Unmanned Combat Aerial Vehicle (UCAV) programme, "Ghatak", with DRDO is at D&D; stage and is being developed by ADA. Further, IAF is seeking UAVs with multirole capabilities and is exploring various options

Established Players: There are many established players in the industry. The Kanpur-based Lohia Group is acquiring an Israeli company, Light and Strong, which supplies high-end composites to IAI and Elbit. After the acquisition, a parallel composites manufacturing facility will be set up on a part of the 100-acre Lohia industrial complex in Kanpur. Construction of this "world-class facility" is likely to begin early 2019.

Recently, the Adani group launched a JV with Israel's Elbit in Hyderabad for the manufacture of airframes for the Hermes drone for the international market. The 50,000 square feet facility is also be the first outside Israel to manufacture Hermes 900 Medium Altitude Long Endurance (MALE) This facility where the Hermes 900 (MALE) and the Hermes 450-the most advanced UAV systems in the world will be manufactured, is in line with Indian government's strategic plan. Interestingly also, the Indian Army has selected the SpyLite mini UAV offered by Cyient Solutions & Systems - a joint venture between local company Cyient and Israel's BlueBird Aero Systems - for a high-altitude surveillance requirement. On 4 September 2018, the company announced that "the SpyLite was the only candidate to have met the army's need to perform real-time surveillance and target acquisition tasks during trials performed from 18,000ft above sea level, including in extreme weather conditions". State-owned defence electronics company Bharat Electronics Ltd. (BEL) plans to add a suite of advanced electronic surveillance devices that can be fitted on UAVs or naval systems.

Table 7.3: Few Noteworthy UAV Startups of India

Startup Name	Year Founded	Funding Raised	Funding Stage	Investors	Location	Description	Achievements
Aarav Unmanned System	2013	Undisclosed	Seed	500 Startups, Gorw X and others	Bangalore	UAV manufacturer specialising in 3D mapping and image processing and precision agriculture	Recently got DGCA certified NPNT compliance for small drones
Skylark Drones	2014	Undisclosed	Undisclosed	N/A	Bangalore	Enterprise drone solutions to improve productivity, reach and safety in mining, infra and utilities	Recently got approval from DGCA for micro drones NPNT compliance
Ideaforge	2007	$10.5M	Series A	WRV Capital and IndusAge Partners	Mumbai	Designs and develops drones for security and surveillance	India's largest UAV startup
Throttle Aerospace	2014	N/A	N/A	N/A	Bangalore	original equipment manufacturer for UAV and its accessories	Recently got approval from DGCA for micro drones NPNT compliance
CRON Systems	2015	Undisclosed	Seed Funding	YourNest Angel Fund, Techstars and Techstars	New Delhi	Aborder defence startup, developing scalable IoT based intrusion detection systems	Defence and BSF
Detect Technologies	2014	$3.3M	Series A	SAIF Partners, Bharat Fund and others	Chennai	Develops a completely automated remote control system	Industrial Applications
Drones Tech Lab	2016	Undisclosed	Undisclosed	Balmer Lawrie Startup India, IIMC, UBI	Kolkata	Surveillance drone and drone camera manufacturer cum distributor	DRDO, Indian Army.

Startups: Much of India's civil UAV manufacturing is by startup route. Also most of these startups are focused on producing rotary UAVs. **IdeaForge** is a leading player in this field. It developed India's first autonomous micro UAV. During recent Kerala floods with support from Indian military, they carried out surveillance and mapping operation for directing relief efforts. The Q Series and Netra Pro drones were used for this purpose. They also provide varied services as analytics, imaging software and operations training etc. The Haryana-based startup **CRON Systems** can secure borders with its IoT powered intrusion detection system. Founded in 2015, it caters to Border Security Force (BSF) and the Indian Army. Its initial product line, the KV series, is powered by infrared and laser. It provides notifications upon border infiltration in all terrains and weather. The company claims its systems have already been implemented at the Indo-Pak border. Currently, CRON Systems' research lab is working on automated drones and smart fencing. **Detect Technologies**, along with a 40-member team of hardcore techies, is building an innovative solution for heavy industries, especially the oil and natural gas industry. An AI and ML based industrial drone (with proprietary algorithms) is developed to inspect and assess large volume assets like boilers and stacks. They also have the ability to generate a report on the same day. They had signed a deal with Reliance Industries. In June 2019, Zomato said in a press statement that it had successfully tested its drone delivery technology. A hybrid drone was used for the experiment which was able to cover 5 km in about 10 minutes while

carrying a payload of 5 kg. Its peak speed was 80 kmph. Last December the firm had acquired a Lucknow-based startup, **TechEagle**, to work on delivery through hybrid multi-rotor drones. In January 2018, the Indian Railways had said in a press statement that it would deploy drone-mounted cameras to monitor activities such as rescue operations, track inspection, traffic regulation and infrastructure projects. It said it would start with the West Central Railways (WCR) headquarters in Jabalpur, Madhya Pradesh, which is the first division to procure drone-mounted cameras. And in October 2017, Amazon filed a patent application in India for multi-scale fiducials, which would allow Amazon's delivery drones to identify objects from varying distances to both avoid collisions and navigate better. In India's UAV history, for the first time, in 2019, DGCA gave approval to three startups for producing and selling small and micro drones in India following their NPNT compliance (Table 7.3).

Ecosystem and Expertise Available for Research and Advanced Development of the sector: A vast market exists for VTOL UAVs in India. Already startups are gaining necessary research and design capability. So India's steps towards joining the global value chain is in right track compared to aerospace capability development as India now has started with design and development before jumping into production and then design. In July 2019, a team of engineers and software experts **HAL** and **NewSpace** Research and Technologies, a Bengaluru based start-up looking at next-generation aviation technologies, is working furiously to fly the first Indian swarm drone prototypes in two years. The drones have a name - ALFA-S or Air-Launched Flexible Asset (Swarm). A lot of the technology being developed in-house presently is not available in the market. The United States, China, Russia and a few European countries are in the process of developing the first elements of their swarm-drone strike packages. "**Tests in this domain are going on all across the world and no nation will share the knowledge of swarming technology with someone else**," says one of the project designers of the ALFA-S system (https://www.ndtv.com/india-news/swarms-of-indian-drones-alfa-s-being-designed-to-take-out-targets-like-balakot-2068343). Indian vendor base through their experience with Indian defence and aerospace manufacturing have developed capabilities in supporting UAV manufacturing supply chain activities. For example, Trident Infosol designs and builds systems for UAVs, Zephyr Aerospace has developed capability in UAV aerostructure through involvement in Rustom1, Sree Sai AeroTech Innovations develop autopilot and autonomous systems for UAVs, SAAS specialises in UAV avionics, Pushpak products have acquired technology through ISRO and defence association to manufacture precision parts for UAVs, NRT for high altitude drones design and development, Kinetix for UAV electronics systems, Elcomponics develops civil drones with experience from component manufacturing for aerospace. Thus there are lot of players who have transitioned from adjacent sector to not only manufacture but also design and develop UAVs or parts/systems/subsystems. In the ecosystem, though there are many small companies, they cannot support large scale adoption and production of UAVs. For this, the aerospace OEMs and laboratories present in the country would have to take the lead. HAL has experience in design, development and manufacturing, DRDO Labs has experience in control laws, flight computers, data links, sensors and payloads, NAL has experience in system identification, development of flight dynamic models and control laws, companies in private sector can develop software and hardware and manufacture components and subsystems. Academic institutions IITs, NITs, IIScs can help build theoretical framework and develop advanced algorithm. Here the incubated startups can also support. We already observed huge investment in startups in advanced areas of UAV research. Armed forces can provide operational inputs based on experience with UAVs of foreign origin. Freelance pilots are available from armed forces. DRDO has developed 1kW anti-UAV laser system and plans to develop more powerful lasers.

Policy: Regulators have laid down guidelines for commercial drone operations, which involve the drone operator to be certified by dedicated flight training organisations. A generic curriculum has also been mandated. Apart from this, there will be demand for operators with use-case-specific expertise. A lot of jobs will also be created as drones need to be manufactured, serviced, repaired

and operated. And then there is a growing demand for skills that need to build algorithms to spot patterns in photographs, intelligent routing and collision avoidance systems. The other area is precision agriculture and pesticide spraying, using drones. To become a drone pilot, training and assessment is required, as per guidelines released by the Directorate General of Civil Aviation (DGCA), which came into effect from December 1, 2018. In addition, prospective pilots must be above 16 years of age and to pass a test on their practical and theoretical ability to pilot a drone. Also, a person who intends to become a drone pilot should ideally start by practising on simulators. Soon, drone flying will become a sought-after skill in India. New technologies do lead to newer jobs. After the launch of the DigitalSky Platform under Civil Aviation Regulations ("CAR") 1.0 with effect from December 1, 2018, a basic framework for regulations has been established.

- No permission, no take off (NPNT) – Before any flight, a NPNT clearance needs to be obtained
- UAVs will be classified into five segments based on their weight inclusive of payload.
- All UAVs (other than nano) will have to be registered and provided with a Unique Identification Number (UIN) before they can be operated.
- There will be a set of rules referred to as Civil Aviation Requirements (CAR) that all UAVs will have to adhere to depending on their classification.
- All UAVs can only be flown by trained pilots, training requirements for whom have been detailed.
- Each flight is expected to be tagged and recorded with the data made available to the regulator on demand.
- Drones can be operated only during the day, and within line of sight
- Air space has been partitioned into Red Zone (flying not permitted), Yellow Zone (controlled airspace), and Green Zone (automatic permission).
- Drones fall under the restricted items category and can't be carried in hand baggage in aircraft

MoCA has prepared a draft policy note on CAR 2.0 to promote commercial drone industry growth in India with recommendations on expanding the UAS operating airspace, permitting autonomous operations, creating a segregated drone corridor, new principles of airworthiness, UAS traffic management, advanced pilot training methods, droneports, DSPs, Payload /cargo, 100% FDI in UAS based commercial civil aviation services.

Table 7.4: Roles and responsibilities of govt. stakeholders for civil RPAs (source: DGCA)

No.	Stakeholder	Responsibility
1.	Directorate General of Civil Aviation	• Import clearance • Issuance of UIN • Issuance & renewal of UAOP • Suspension / Cancellation of UIN & UAOP in case of violations of regulations.
2.	Directorate General of Foreign Trade	• Import license
3.	Ministry of Home Affairs	• Security clearance
4.	Ministry of Defence	• Permission for aerial survey/imageries/ videography/ still photography over the restricted/prohibited areas on case-to-case basis
5.	Indian Air Force	• Air Defence Clearance • Monitoring of RPA movements in the country
6.	Wireless Planning and Coordination Wing, DoT	• Equipment Type Approval (ETA) or License for drone
7.	Bureau of Civil Aviation Security	• Approval of Security Programme
8.	Airport Authority of India	• Flight Plan Approval • Monitoring of RPA movements in the country
9.	Local Police Office	• Enforcement of violators as per applicable IPCs

Experts had several concerns with the policy formulation, which are notified by Narang (2018). The regulation was complex as shown in the Table 7.4. The digital sky platform to digitize approvals is not a single window approval system as the applicant has to submit equipment type approval from wireless planning and coordination wing of ministry of telecommunication for operating in de-licensed frequency band, security clearance from MHA and security programme by BCAS, MoCA. The need for the filing of flight plan manually and a minimum period of 24 hours before the actual flight could hinder optimal UAV operations in civil space. India does not produce critical parts like batteries, chips, propellers and semi-conductors. Indian UAV manufacturers need support from the policy for building capability in this area as there is sufficient expertise in the value chain already. Currently the policy for drones does not have provision for promoting manufacturing by Indian companies as it allows operations of domestically purchased (and not produced as per para 5.2 of CAR) and leased RPAs. As ToT is virtually impossible in this area, India drone manufacturing industry would face the same fate as aerospace manufacturing industry of build to print type of capabilities. India should grab the opportunity provided by Indian startups (as discussed above) and the eco-system spending so much effort in advanced R&D. The Drone policy should have a separate chapter on manufacturing infrastructure and ecosystems. Imported UAVs, though banned now, but must be brought under the defence items category and corresponding security guidelines could be applied to them. As Indian UAV market is small, the RPA manufacturers would need time to develop customised capabilities. All government departments while procuring drones should allow this time to Indian companies to develop, optimise, modify or upgrade their products to meet standards or capabilities being offered by global players. At the moment, the drone regulations should set up drone standards system for safe operations of RPAs. These standards should be reviewed at regular intervals to include advanced capabilities (as detect and avoid) as and when they evolve. The UAV operations are limited to VLOS range and day time alone, while Canada initiated BVLOS trials in June 2018, China allowed testing of 1000 UAV swarm in 2017. The CAR 2.0 must include provisions for research and development, testing and manufacturing of futuristic technologies in India. There is no provision for flying experimental or innovative drones outside closed spaces for facilitating R&D. There is no separate mention for research related drone operations. Hiring and training of swarm operators or designers, anti-drone pilot skill development are not mentioned anywhere. The regulations should always make spaces for adaptation and regular reviews with stakeholders. For military UAVs, development of RUAVs or swarms would need new certification standards globally. The current STANAG standards are more stringent. There has to be indigenous certification standards for new range of UAVs in Military. In India, dual use items are classified under special chemicals, organisms, materials equipment and technologies (SCOMET) items and regulated by DGFT. Currently all UAVs are listed under SCOMET and export of every unit needs dedicated permission from DGFT and MoD which consumes 30-45 days. Declaring end user details is also a must. In case of commercial market, majority market works on distribution channels wherein distributors maintain inventory in their own geography and defining end user is impossible. The overall lead time expectation for a unit is less than 30 days. India is signatory to Wassenaar Agreement and it defines a criterion for excluding certain dual use items that can be exempted from export control. UAVs form a part of this. If SCOMET is aligned to this definition, export performance would improve substantially.

Findings from the UAV workshop: We also carried out a workshop with government (DGCA, MoCA, DGAQA), industry bodies, UAV manufacturers (startups, established firms – DPSU, private sector), users (armed force). Regarding policy matters, we placed a set of questions/suggestions and asked them to put a score out of 0-10 to show agreement (10) and disagreement (0). Based on their position in the scale, we can figure out the need for the policy makers from the industry (manufacturer and others).

Policy Related Feedback: We found moderate to strong agreement (score of >6) from all participants in the following aspects of the policy:

- Stringent regulations might result in new companies in exiting the UAV industry
- All UAVs using airspace need to be regulated
- Industry self-regulation/co-regulation with audit and enforcement powers involving all stakeholders would alleviate the regulation challenges
- Setting up common industry standards for UAV industry will help alleviate the problems with self regulation or import quality control
- Setting up a centre of excellence for UAV operations, manufacturing and regulation help develop technology and build competitiveness?
- Protection against unjustified, disproportionate and unsafe surveillance can only be given by formal Governmental control.
- Legal inputs are essential while designing control of UAV surveillance and preventing the biggest risk of privacy invasion
- Laws are needed to spell out the obligations of drone operators, with limitations on the type of technology and, in particular, the camera lenses that can be installed on civilian drones.
- Government must take steps to educate the public about drones
- Government should focus on quality control to test the digital security mechanisms of each UAV to prevent hacking or unethical activities
- The insurance industry may play a constructive role, by declining to quote a price where an operator's practices are uninsurably unsafe
- Stringent monitoring of UAV operations will improve safety performance
- Proper guidelines for UAV repair and maintenance is essential for enhancing safety

However, we found general disagreement (moderate – a score between 2-5), on the issue of "Potential operators and regulators need to seek advice from the Armed Forces for the operation, maintenance and regulation of UAVs."

In the following two issues, we found the opinion split between manufacturers and others. Manufacturers do not agree with the following two issues, while others were in strong agreement.

- Import regulations for all types of UAVs including those for private use will help enhancing safety and security.
- HD photo image transmission (particularly for human beings) should be restricted and controlled.

The industry related opinions are depicted in Table 7.5 (the numbers denote the frequency of responses in each respondent category). It was found to be divided among the three groups of respondents in certain issues. While manufacturers felt, the industry "Awareness of Regulations and policies while importing" (3rd row) is Low, others felt it to be Moderate. While manufacturers are undecided between Very High and High "Knowledge Sharing" (New entrants exploiting the knowledge from established players/ academia to deliver new offerings) within Indian UAV industry, Government felt it to be High and others felt it Moderate. While manufacturers felt "Entry of new companies" (entering the market and experimenting with the technology) is High, Government was undecided between Moderate and High, while others rated it as Very High. While manufacturers felt, "Failure of Companies to grow" (exit market due to failure to provide differentiated offerings) in UAV market is moderate, Government officials felt it to be High, while others responses were equally divided between Moderate and Very High. While manufacturers felt the impact of UAV industry will result in High level of "Increased attention of indirectly linked stakeholders as insurance, consulting etc", government officials' responses were more towards Moderate while others' responses were divided between low and very high. While manufacturers and others felt "Options for other industries (software, camera etc.) to grow alternative business models" to be Very High in Indian UAV industry, government felt it to be moderate. While "Introduction of new features in the products" is moderate as per manufacturer response, government and others are

undecided between moderate to very high levels. “Introduction of new UAV related services as maintenance, customized offerings etc” is Very high as per manufacturers, High as per government officials and Moderate as per others. Thus the UAV Industry has lot of potential with technology yet to mature and players continuously evolving in terms of their capabilities (new entrants legitimacy level is moderate). This proves a lot of opportunity in this industry to grow as import dependency is very high.

Table 7.5: Indian UAV Industry Status

Score (Low [0-2.5], Moderate (2.5-5], High (5-7.5], Very High (7.5-10]												
Industry Type	Manufacturer/Assembler				Government Officials				Others			
	LOW	Moderate	High	Very High	LOW	Moderate	High	Very High	LOW	Moderate	High	Very High
Legitimacy of the new entrepreneurial firms	0	5	1	3	3	5	2	1	1	4	0	2
Awareness of safety, ethics, airworthiness regulations while manufacturing	2	4	2	1	1	6	2	2	1	3	0	3
Awareness of Regulations and policies while importing	4	2	1	2	1	7	1	1	2	3	0	2
Awareness and compliance to quality and safety requirements	2	5	1	1	2	4	3	2	1	3	0	3
Product Technology Maturity Level	1	5	0	3	1	6	1	2	1	3	1	2
Dependency on imports	0	0	2	7	1	1	1	8	1	1	0	5
Knowledge Sharing (New entrants exploiting the knowledge from established players/ academia to deliver new offerings)	1	2	3	3	1	3	5	2	1	3	1	2
Entry of new companies (entering the market and experimenting with the technology)	0	2	5	2	1	4	4	2	0	2	2	3
Failure of Companies to grow (exit market due to failure to provide differentiated offerings)	0	5	3	0	1	3	4	1	0	3	1	3
Market Infrastructure (market segments appear, and there are differentiated product categories for each market segment)	3	4	2	0	2	6	3	0	1	5	1	0
Increased attention of indirectly linked stakeholders as insurance, consulting etc	2	2	3	2	2	5	3	1	2	1	1	2
Options for other industries (software, camera etc.) to grow alternative business models	0	2	3	4	0	5	3	3	1	0	2	3
Introduction of new features in the products	2	3	2	2	0	4	4	2	1	2	2	2
Introduction of new UAV related services as maintenance, customized offerings etc	2	2	2	3	2	3	4	1	2	3	1	1

We asked respondents to score the current manufacturing capability of the industry, which will require boosting capabilities. Table 7.6 lists the current capabilities in terms of a scoring matrix out of 0-10. The scores are decided based on the maximum number of responses against each capability. The scores are rated as 0 – No capability, 1- Basic Technical Implications Identified, 2- Implementation in Manufacturing/Assembly Concepts Identified (feasibility study done), 3- Proof of Concept Developed, 4-Capability to produce/use the technology in laboratory environment, 5-Capability to produce prototype components or use the processes in production related environment, 6-capability to produce or use the processes in prototype subsystems in production related environment, 7-ready to produce or use the processes in components, systems or subsystems in production representative environment, 8- ready to begin low rate production or start using the processes, 9-capability in place to begin full rate production and start using the process, 10-full commercial production with all processes optimised.

Table 7.6: UAV Manufacturing Capability Level in India

Propulsion Devices for advanced application (balancing weight, power tradeoffs)	5
Batteries for advanced applications	2
Actuators and sensors for advanced applications (as health monitoring)	3
Communication Systems for multiple UAVs	5
Algorithm for autonomous UAVs (AI, ML)	6
Making standardised parts for a range of air vehicles	6
Integrated Product Process Development	5
Shared Manufacturing Process of military and commercial vehicle	5
Three-dimensional digital product models, modeling and simulation of manufacturing, assembly and virtual prototyping (AM, AR)	5
Fabrication of unitized structures	5
Development of performance standards for analysis methods	4
Element and subcomponent design and testing	5
Cost Data Modelling and Analysis	5
Development of Quality Control Methods	4
Process Validation	5
Conduct research to develop a fundamental understanding of metals processes applicable to UAV structures	6
MEMS and mesoscale technologies for integrated sensor-actuation control devices	1
Real time Accurate data collection on trajectories	6

At present there is no capability available in India to manufacture batteries, sensors and actuators. In fact, no area has reached the stage of production in factory. Currently, India's UAV manufacturing is at nascent stage.

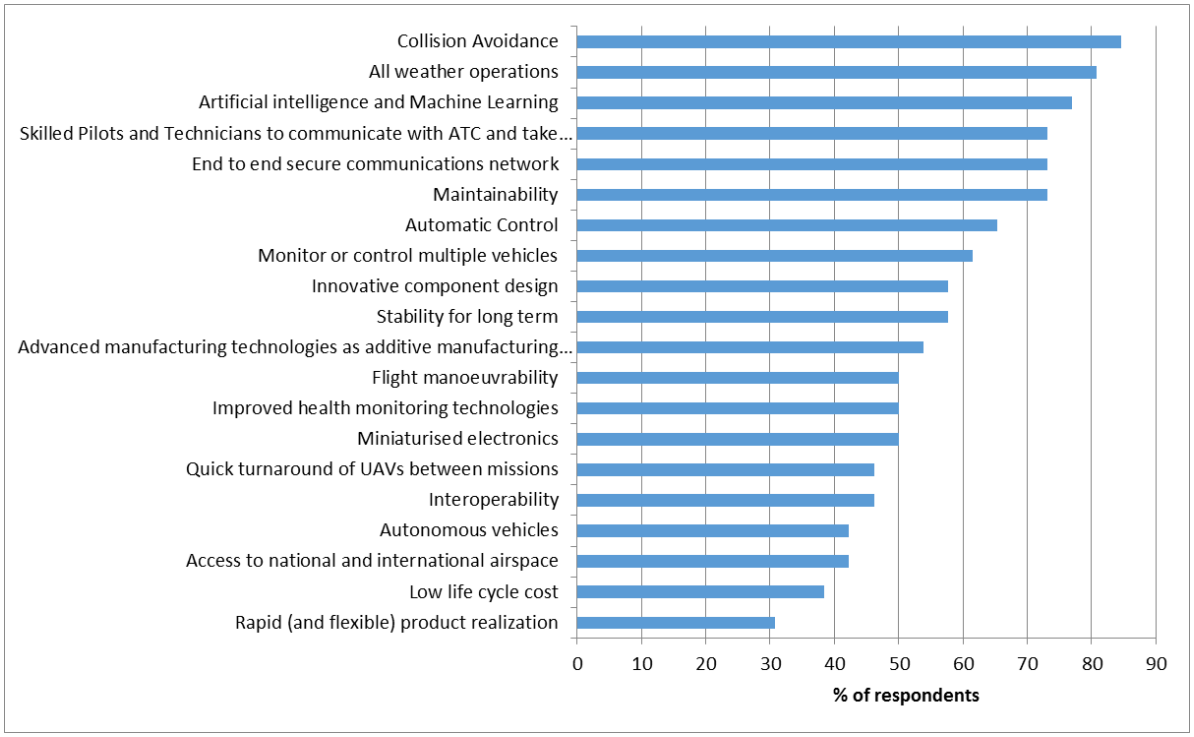

Figure 7.5: Future UAV Capability Requirements

Figure 7.5 shows that, future UAVs in India must have collision avoidance characteristics, all weather operation capability, advanced application of AI and ML, skilled pilots, secure communication and maintainability. Apart from this, respondents also added some more areas, where capability development will be needed to be researched - Industrial Maintenance Technologies, Development of unmanned traffic management (UTM) services, Detect the areas or drones flying illegally in Indian skies which are threat to Indian security as well as loss in Indian revenues, Transporting human, Real Time Tracking and Anti Drone capability.

7.3 Recommendations

1. Single Window Clearance: Single window application for issue of UIN and UAOP involving all stakeholders
2. Setting up common industry standards for UAV industry will help alleviate the problems with self regulation or import quality control. Setting up standards for airworthiness of UAVs and agency nomination to certify them.
3. Voice and data recorder to be made mandatory in larger UAVs for effective post accident analysis
4. Industry self-regulation/co-regulation with audit and enforcement powers involving all stakeholders would alleviate the regulation challenges
5. Setting up a centre of excellence for UAV operations, manufacturing and regulation would help develop technology and build competitiveness. UAV community should be set up to review development, share best practices and resolve issues. UAV courses in universities need to be introduced for building talent base. Alternately special educational setup needs to be built for pilots, designers for future industry needs.
6. Steps to protection against unjustified, disproportionate and unsafe surveillance can only be given by formal Governmental control.
7. Legal inputs while designing control of UAV surveillance and preventing the biggest risk of privacy invasion. Laws are needed to spell out the obligations of drone operators, with limitations on the type of technology and, in particular, the camera lenses that can be installed on civilian drones.
8. There should be awareness programmes (dos/donts, offences/crimes, legal aspects) by Government to educate the public about drones before opening the sky for civil/commercial drones.
9. Government should focus on quality control to test the digital security mechanisms of each UAV to prevent hacking or unethical activities
10. The insurance industry should be encouraged to play a constructive role, by declining to quote a price where an operator's practices are uninsurably unsafe
11. Proper guidelines in drone policy for UAV repair and maintenance to enhancie safety
12. Level playing field to be given to all Indian manufacturer by simplifying the process of issuing industrial licenses for civil RPA manufacturing.
13. Tax structure for imported spares should be favourable and can follow the recommendations made in MRO section.
14. Additional time after RFP to be given to Indian companies to develop products before field trials
15. RPA testing site to be earmarked and industry should not wait for permission to use the airfield or the site.
16. UAV advanced capabilities as swarm, AI, ML, anti drone, detect and avoid, BVLOS, night operations, unmanned taxies, human transport, integration of manned and unmanned platforms require continuous research - policies must have special provision and exemptions for promoting such research and it has to be stated in the policy document. There is no clear understanding regarding which institution will take prototyping accident responsibility. There should be policy intervention for trials of UAVs.

17. We have challenges on Electric propulsion system, new radar, motors and battery packs (most important). We have opportunities on Indigenous components, BLDC Motors and Battery Packs. We need quality assurance agency, skilled labour, proper training and colleges with curriculum on UAV (Not only Basic but also in-depth).
18. Currently in India, micro to small manufacturing is going on but multirole is not happening. Research is going on in artificial intelligence and vision based landing. For military, research is going on mainly in payload, search and rescue drone. Tangible investment in local manufacturing is needed from cross Industry (such as, material Industry, Microprocessor Industry) should contribute in UAV Industry. Through this we will not be dependent on imports and we can start our indigenous manufacturing. We need a centre of excellence for technology based infrastructure which will help both civil and military industry.
19. We are importing Electro optical sensors because we don't have awareness of our indigenous manufacturing sector. So a portal is needed where all product information of our manufacturing sector that will be shared with UAV manufacturers. We have to develop ecosystem for future capability enhancement.
20. Dedicated repair system is not available for RPAs. Currently major operators repair at their own level. Transfer of technology to the distributor is needed and tutorial is also important. For military, most important is transfer of technology and proper MRO Setup. Flight logs, Schedule Management, Component life time information, Awareness for not only manufacturer but also for customers- these are most important in near future.

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Appendix – 1

	UK
Government Role	The UK Government's **laissez-faire approach** to market rigor crucially included a high degree of openness to foreign participation in the defense market in all senses, including ownership of "British" firms. This openness extended to even allowing foreign firms owned or effectively controlled by foreign governments to purchase British firms, as in the cases of Finmeccanica's purchase of AgustaWestland and Thales' acquisition of Racal. Britain chooses to treat foreign firms with a significant UK presence or substantial partnership in the same way as wholly-owned or traditionally British firms. **Transparency in deals:** A sampling of its efforts includes Strategic Defense and Security Reviews, that set a rolling equipment acquisition plan, identifying for industry projected funding, equipment purchases, and force structure. Similarly, the British Government transparently determines the lower threshold it sets for the profits it accords defense contractors, adjusting the rates annually and, in particular cases, based on risk, performance incentives, and the cost of capital.
Factors	**U.S. firms, for instance, develop a larger "on-the-ground" presence in Britain than in other European markets**, in part seeking to use the UK as a regional hub. Overall Britain has been, "one of the most open defense markets in Europe and has shown a willingness to acquire important defense products and services from overseas suppliers while allowing extensive foreign ownership of the UK defense-industrial base. British government's relatively laissez-faire attitude toward its defense industry is a **rules-based, contractual, adversarial approach to interactions between governments and private concerns** that requires officials and corporate executives to keep relationships at "arms-length."
Demand	Britain also focused on **exports** for building the defence industry. In this respect, Britain, historically a leading exporter of military products, also remained focused on foreign markets to support its industry as well as to lower the total per-unit cost of its own defense purchases through economies of scale supported by export markets
Related Industries/ Countries	UK decided to selectively build spectrum of capabilities in collaboration with other countries either as a NATO operation or a U.S. led coalition. This was signaled by the signing of a France-UK bilateral Defense and Security Co-operation Treaty in 2010. In terms of acquisition, it meant that Britain participated in a wide range of **collaborative development and acquisition** programs with an array of partners through varying structures, including the A400M cargo transport aircraft, the Eurofighter/Typhoon, Eurojet engines, the Boxer armored vehicle, air tanker leasing, and the F-35 Lightening II fighter. At the same time UK also focused on **fortifying a national champion BAE Systems**, which points to a larger long-term pressure across all defense markets. This is the undeniable, underlying temptation within states to maintain certain core defense-industry capabilities if at all economically feasible. Though commercially owned, UK retained a "**golden share**" along with varying prerogatives designed to safeguard the country's ability to maintain particular military capabilities in its defense-industrial base. UK **privatized its defense research institution (QinetiQ), might have resulted in a decreased overall British pace of innovation**. The conclusion is that Britain shares with other countries the market-driven realities of market consolidation, collaboration, and export reliance. Britain is nonetheless still driven back toward the persistent logic of retaining an enduring, indigenous defence industry in part through a national champion.

	USA
Government Role	As was the case with the UK, Sweden, Italy, and France, the U.S. defence industry has gone through an **intense period of consolidation** in the face of declining defense budgets. The United States was not in the position of needing to privatize major industrial concerns, but the U.S. government has also sought the **rigor and discipline of intensified openness to market forces,** now **relying for many maintenance, operations, and support services on private-sector contractors**. Though the American armed forces operate many research centers, arsenals and depots, their relative significance has been smaller in the overall complex, and what remains has come under intense pressure from industry and analysts pushing for privatization.
Factors	In structuring defense acquisitions, the United States has pursued novel approaches in attempts to adjust to face new realities. **The quest for budgetary and market efficiencies has been relentless, whatever the contradictions and obstacles faced in a sector where market failure is a constant challenge.** This increasing trend toward monopoly producers, in effect national champions, has profound implications for the United States' preferred approach to defense-industrial relations. The ability to maintain at least the "adversarial" quality in the trio of the "**rules-based, contractual, and adversarial" approaches toward theDefence Industrial Base** could become increasingly challenged in the context of decreased competition. Absent real defense firm competition, the margin for government or firm error – in terms of expense, security, and the resilience of the remaining players – decreases steeply. The United States may very well face two options, both involving activist government involvement. On the one hand, a different government-industry relationship requires the government to coordinate more closely with defense firms. On the other hand It could take the best of the British and Swedish experiences of seeking to expand competition, efficiency, and industry resilience by working to create a genuinely fluid, more open defense market among its allies and close partners.
Demand	More important, for the first time there appears to be an increased recognition in the United States that **defense exports are not only about alliance building and partner capacity, but also a needed avenue toward managing the extremely high costs of developing sophisticated weapon systems.**
Related Industries/ Countries	Even though U.S. policy has been to preserve competition to the extent possible, the United States has slouched unintentionally toward **one national champion in each defence subsector.** The **United States has one producer of aircraft carriers (Huntington Ingalls), one producer of submarines (General Dynamics Electric Boat), one producer of tanks (General Dynamics Land Systems), one producer of armored personnel vehicles (BAE Systems), one producer of bombers (Northrop Grumman), and, as F-15 Eagle and F-18 Super Hornet orders stand to dwindle, is on track to have one producer of fighter aircraft (Lockheed Martin).**

	France
Government Role	**French government plays an extensive role in planning, structuring, building and governing firms.** France's defence industry encompasses a mix of state and private ownership. France is endowed with multiple institutions and organizations that facilitate non-market coordination by defense industries. In particular, Directorate General for Armament, **DGA, shapes aircraft policy by giving armaments producers greater input into policymaking processes. French government maintains control over defense firms not only through ownership stakes, but also based on legislation that gives Paris the power to block foreign acquisitions of companies in the sector.**
Factors	French decision makers are constrained to bilaterally negotiated agreements with firms and **do not operate in an environment where dual-sourcing strategies and much competition are possible. T**he **government and defense firms are in effect a one enterprise**, despite ownership structures. In part this is because France has a **tradition of professional schools that train both government and private-sector personnel**, who are expected to remain in contact and to cycle to and from jobs in both sectors. **DGA recruits its armaments engineers from France's leading engineering school**, the École Polytechnique, from which the leading defense-firm engineers also graduate. **French firms rely on detailed and retired DGA personnel to staff key jobs,** even more so than U.S. firms recruit former officers and Defense Department civil servants to serve in supporting but not necessarily leadership roles.This cohort of personnel passes back and forth between government and industry, creating **ample informal channels for coordination, communication, and consensus**
Demand	France's **autonomous approach to defense product development** means that it has always relied on exports to lessen per unit costs. This emphasis has only increased in recent years. Export orders are key to sustaining such systems as the Rafale as well as an integral to preserving France's Defence Industry as a whole.
Related Industries/ Countries	The French **defense-industrial ecosystem is able to communicate and execute more seamlessly than the adversarial ones in the United States and Britain,** but it also has more scope to resist change due to opacity and is more likely to be concerned with the displacement of workers and assets in periods of adjustment. The shift in France's DGA approach has been, to give greater autonomy to industrialists in managing joint programmes, improving the support given by state actors to this process, while inventing original solutions for financing both the development and the buying of defense products. France consolidated firms, but also kept **more than one national champion** in line with Italy (Leonardo and Fincantieri), despite a industry base that was similar in size to Britain's. In France's case, the major companies eventually distilled to Thales (electronics), Dassault (aerospace), and Airbus Group (aerospace).

	Italy
Government Role	Italian defense industry is **structured as a pyramid, featuring at the top four big corporations** (Finmeccanica, Fincantieri, Avio, and Iveco). Italy is firmly a "middle power" that recognizes that it cannot defend itself independent of an alliance network. As a result of – and despite the challenges just outlined – the country has chosen to step up its international role, particularly in coordination with the United States. **Italy holds approximately a third of the holding company that controls leading defense firm Leonardo (formerly Finmeccanica). Italy has tight controls governing its leading defense firms.** In the case of foreign investment, the Italian government pressures outside firms to take Leonardo or another Italian firm as a partner, as was the case when Carlyle Group acquired Avio, a supplier of rocket, naval, and aircraft engines, as well as gas turbines and parts. **Italy compelled Carlyle to accept Leonardo as a "leading industrial partner, with a 30 percent share" to keep key Italian management in place.** This approach extends to acquisition policy in which, unlike the British or Swedish cases, **Italy requires robust offsets and expresses** a clear preference for foreign firms to partner with Italian ones.
Factors	the Italian "procurement system is generally **one of the least transparent and rule-based" among a diverse selection of NATO and similar countries.** Italy has attempted to change this lack of transparency in 2015 through a White Paper on International Security and Defense. The White Paper attempts to define Italy's DIB by dividing capabilities Italy seeks to maintain into sovereign and collaborative or European technologies. Italy's political orientation toward overseas military operations with the United States and partners served tangible defense-industrial goals of building credibility as a defence supplier. Building on infrastructure at Cameri, which hosts a logistics hub for Panavia Tornados and now Eurofighters, Italy secured a final assembly and **check out/maintenance repair overhaul and upgrade (FACO/MRO&U) facility as part of its participation in the F-35 program**. With the exception of a U.S.-operated facility for testing and measuring the stealthiness of aircraft, Italy's facility with Italian staff will serve as MRO hub for F35 user countries in EU.
Demand	Leonardo's revenues showed a greater diversification of the firm's geographic engagement, particularly with regard to the United States and Rest of the World
Related Industries/ Countries	Long-term state ownership and direct policy engagement has **provided Leonardo "continuity and strategic perspective," been a "stabilizing factor,"** as well as permitted the firm to take a longer view toward financing investments. Italy already had a history of participating in big-ticket development and acquisition of military hardware with European partners, as in the cases of the **Panavia Tornado (Italy, the UK, and Germany) the Eurofighter (Italy, the UK, Germany, and Spain)**. It also participated in joint ventures with Thales. Interesting as these examples are, Italy's most rigorous, market-oriented approach was clearly evident in the case of the F-35 project. For the **F-35, Italy positioned Leonardo subsidiary Alenia Aermacchi, to serve as a strategic second source of F-35 wings.** Overall, **90 Italian companies are involved and the contracts awarded to the Italian industries have an overall value of $715 million.** Domestically, the Italian government consolidated multiple firms into Leonardo. The result was that **Leonardo became Italy's second-largest manufacturing firm and directly employs 70,000 workers as well as subcontracting with a plethora of small- and medium-size firms.** From at least 2009, Leonardo accounted for approximately 70 percent of the Italian defense research and technology as well as procurement budgets.The collection of capabilities in Leonardo also resulted in its being, **"Italy's leading high-technology business."All in all, the firm has the full the attributes of a national champion.** Leonardo became the Italian national champion in aerospace and defense, yet the cluster of firms that comprised the organization has not yet become a truly integrated group, with a common objective and strategy. As Leonardo seeks "to revamp the company's traditionally decentralized structure by making each of the individual companies into divisions," hoping "to eliminate overlap and better allocate investment between helicopters, aerospace, defense electronics and space based on potential return," it will struggle to maintain a coherent, competitive focus.185 Transforming while simultaneously competing is a steep challenge.

	Sweden
Government Role	The trademarks of Sweden's defense-industrial system were close cooperation between industry and government, incremental innovation, and the financial stability provided by bank capital. This is no more evident than in the case of Saab, effectively controlled by the extended Wallenberg family, which as recently as 2016 worked in close collaboration with the Swedish Government, as part of a "**broader corporatist pattern of economic governance**" Sweden differed from Britain by having a strong procurement agency, the Swedish Defense Material Organization (FMV). FMV controlled funding for the innovation that Sweden chose to pursue, standing up the innovation cluster surrounding Saab's aviation business at Linköping, in part by **arranging for the local university to focus on training a cadre of engineers to staff Saab and support defense-related research.** Though protective about local industry, informal channel of communication and transparency is maintained through Wallenberg family's connect with the Government. The Swedish MoD's Defense Acquisition Strategy reiterated a policy of pursuing collaborative development when it was not possible to upgrade existing equipment or acquire material "off-the-shelf". Despite that policy and although Swedish industry acknowledges the need for joint development and collaborative projects outside of equity investments, examples are rare. **Saab is now pursuing the jointly developed and produced TX trainer with Boeing.**
Factors	**Historically Offsets are used to develop or maintain military and security competence, and not to provide employment or random industrial development**. Instead, up until the 1990s Sweden's corporatist behavior insisted on being able to reproduce military technology domestically, but not insisting in all cases on autonomously innovating military technology as in France's case. This policy of **locally sourcing production** ensured that Sweden's defense industry was assured of producing a **wide and deep array of defense products domestically throughout the Cold War**. Sweden's defence industry was effectively **closed to outside investment.** FMV also **funded ambitious process-innovation projects aimed at enabling Saab to compete effectively as a systems integrator despite Sweden's high labor costs and limited domestic economies of scale**. The entire Swedish defense-product innovation and development system was geared toward taking proven technologies and pursuing gradual, incremental improvements. Swedish firms' **R&D rose to approximately 20 percent of turnover**.
Demand	Sweden took a changed approach post Cold War to exports. Although Sweden had long exported defense products, **before the 1990s it had restricted them to politically safe customers** – fellow Nordic counties and neutrals such as Switzerland and Austria. In the 2000s, **Sweden's defense exports grew to the extent that it was sometimes the world's top per-capita exporter.**
Related Industries/ Countries	Sweden no longer attempts to maintain autonomy in all areas of military production, but **designs, develops and produces only those systems and capabilities they cannot acquire elsewhere**.Sweden **began privatizing its 11 state-owned defense enterprises in 1997**. It did **not retain "golden shares,**" **nor did it retain government ownership of any firm, as Britain did for Nuclear Industry.** FMV, however, played a far more active role in managing the **opening of the Swedish Industry to foreign direct investment**. It first identified which capabilities would initially be opened and then actively negotiated many of the mergers of Swedish firms with multinational corporations in the hope the foreign ownership might preserve some local capabilities beyond certain core technologies. As various analysts have put it, the "Government collaborated with the Wallenberg business group to consolidate Sweden's most valuable defense businesses," **Saab's aerospace, radar, and sensor businesses to fortify a national champion**

Appendix – 2

	Tamil Nadu	Gujarat	Odisha	Mahrashtra	UP
Objective	Cluster Development and setting up defence/aerospace parks with forging, casting, fabrication, composite, design engineering and assembly facilities and maintenance	Dholera SIR in Ahmedabad district is an indicative location only to set up aerospace component manufacturing hub with focus on design, engineering, assembly, MRO, casting forging, defence technology	the enterprises to come up in the industrially backward districts namely Kandhamal, Gajapati, and Mayurbhanj along with KBK (Kalahandi-Bolangir-Koraput) districts will be extended additional incentives.	Cluster development approach to boost SME participation, State will offer 15Crore in Central Government's MSE-CDP scheme, Attract investment worth $2b in next 5 years, special support to units set up with PSUs, Vidarbha Marathwara zone	Defence Park at Kanpur and other districts such as Varanasi, Agra, GB Nagar.
Focus area	Component, MRO, R&D	Component	R&D, testing, manufacturing	MRO, R&D, MSME, Anchor unit	components, sub-components, sub-assemblies for aerospace parts, Testing centre, Hardware/Embedded Technology Centre, Technology innovation centre, Housing & Common facility centre
Incentives	Aerospace and Defence cluster through PPP route, Equity support for defence parks, facilitating interaction with DOFA for fulfilling contractual obligations, support for marketing and building partnership through organising industry meets and events, assist in setting up labs in existing institutes or bringing R&D cooperation with international and national companies, help in certification •Anchor unit subsidy •subsidy for skill development •subsidy for certification•Land concession •Capital subsidy for unit and park setup •Fractional Reimbursement of taxes (SGST) •Electricity and stamp duty exemption •Special package for offset obligation•Equity partnership in large scale projects as aircraft manufacturing by private sectors •Labour Law Flexibility •Single window clearance for all aerospace and defence projects	Graded interest subsidy for External Commercial Borrowings (ECB) and Domestic Borrowings •Reimbursement of taxes (SGST) •Electricity Duty and Power Tariff Incentive •Capital Investment Cash Subsidy to MSMEs on eligible fixed capital investment •Incentive for setting up R&D centres; Customized incentive packages for Mega and Large A&D Units •Reimbursement of training cost of employees	•Extend subsidy up to 50 percent of the cost of land, Building, Plant and Machinery to the special purpose vehicle (SPV) for setting up the first state-of-the-art Aerospace and Defence Park in the State. •The policy will also provide capital grants of 50 percent of the infrastructure cost limited to 10 crore for subsequent aerospace and defence parks. •It will also extend a capital subsidy of Rs. 100 crore for the first three OEMs (Original Equipment Manufacturer) for setting up manufacturing facilities in the state with an investment of at least Rs. 1000 crore and generating 1000 domiciled employment. •In addition, for the first three OEMs units in the state, interest subsidy will be allowed up to Rs 10 crore per annum and Rs 5 crore per annum, based on investment in plant and machinery for an amount of more than Rs 500 crore and between Rs 100 to Rs 500 crore, respectively. •The state government will also give an interest subsidy to new A&D manufacturer for timely payment at the rate of 5 percent per annum on term loan avails from public financial institutions for a period of five years, to a total limit of Rs 10 lakh for micro, 20 lakh for small, 40 lakh for medium, and. Rs 1crore for non-MSME units.	•Reimbursement ofstamp duty, •Anchor unit capital subsidy, •Special R&D subsidy •Land concession •Setting up industrial township for defence parks•Promotion of common facilities through equity participation of MIDC subject to FDI realization•Private sector companies to adopt one vocational training institute and develop sector specific curriculum and skill sets - government will give facilities•Earmarked lands for defence parks•Marketing assistance •Relaxation in working hours•Defence assembly with no effluent will not need PCB certificate •listed under essential service and continuous process industry to ensure maintenance and power supply	•Interest subsidy in the form of reimbursement of interest of up to 50% of annual interest on the loan taken to buy land •Interest subsidy in the form of reimbursement of interest of up to 60% of annual interest for 7 years on the loan taken for building infrastructure in the D&A parks for a certain capital, •same for technology centre •Patent Fee Reimbursement •Quality certification – Govt of Uttar Pradesh will provide financial assistance to MSME units in D&A sector for obtaining quality certification such as AS-9100 series, NADCP, etc. • Trade Mark registration application fees would be fully reimbursed, • On the job training cost reimbursement • Strengthening existing Skill training base • Govt of Uttar Pradesh will encourage Universities (in India and abroad) with excellence in D&A training and research to tie up with universities in the State to enhance pedagogy and R&D culture. • Training centres at D&A Park • cost reimbursement for marketing and participation in international summits • subsidy on R&D centre • capital interest, stamp duty exemption, • SGST reimbursement, • electricity duty exemption• EPFincentive• Tech transfer, wastemanagement, transport charge subsidy • Labor permits • single window • quality power• industrial safety and security with police posting in industrial zones
Facilities/Infrastructure	Government will setup roads, training institutes, facilitating setup of defence corridor combining clusters around Salem, Coimbatore,Chennai, Trichi and Hosur	Ease of sourcing key raw materials, nearness to airports, ports, logistics nodes, nearness to aeronautical institutes		280 industrial estates, 24x7 water electricity, dry ports truck and railsidings for easy freight movement, defence cluster near Nashik, Nagpur as aero hub, large number of training institutes, presence of other industries and plenty skills	Strategically located along the Golden quadrilateral, the State is well connected to major national and international airports. Uttar Pradesh has largest railway network in India spanning over 8,949kms. The upcoming Western Dedicated Freight Corridor (WDFC) that stretches from Dadri in Ghaziabad to Jawaharlal Nehru Port at Mumbai, is set to boost the economic activities in the state by reducing the transportation time to ports.