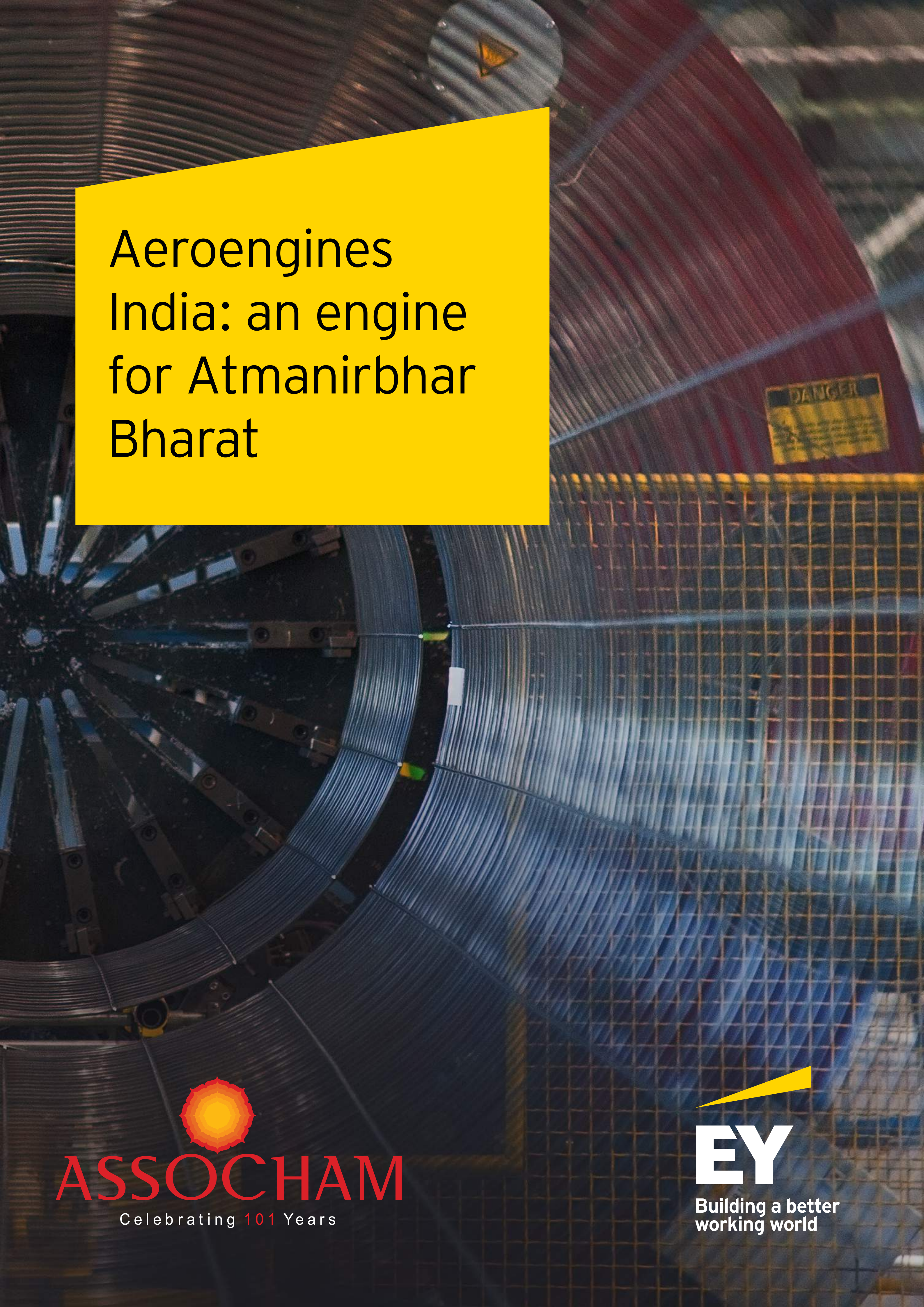
Aeroengines India: an engine for Atmanirbhar Bharat



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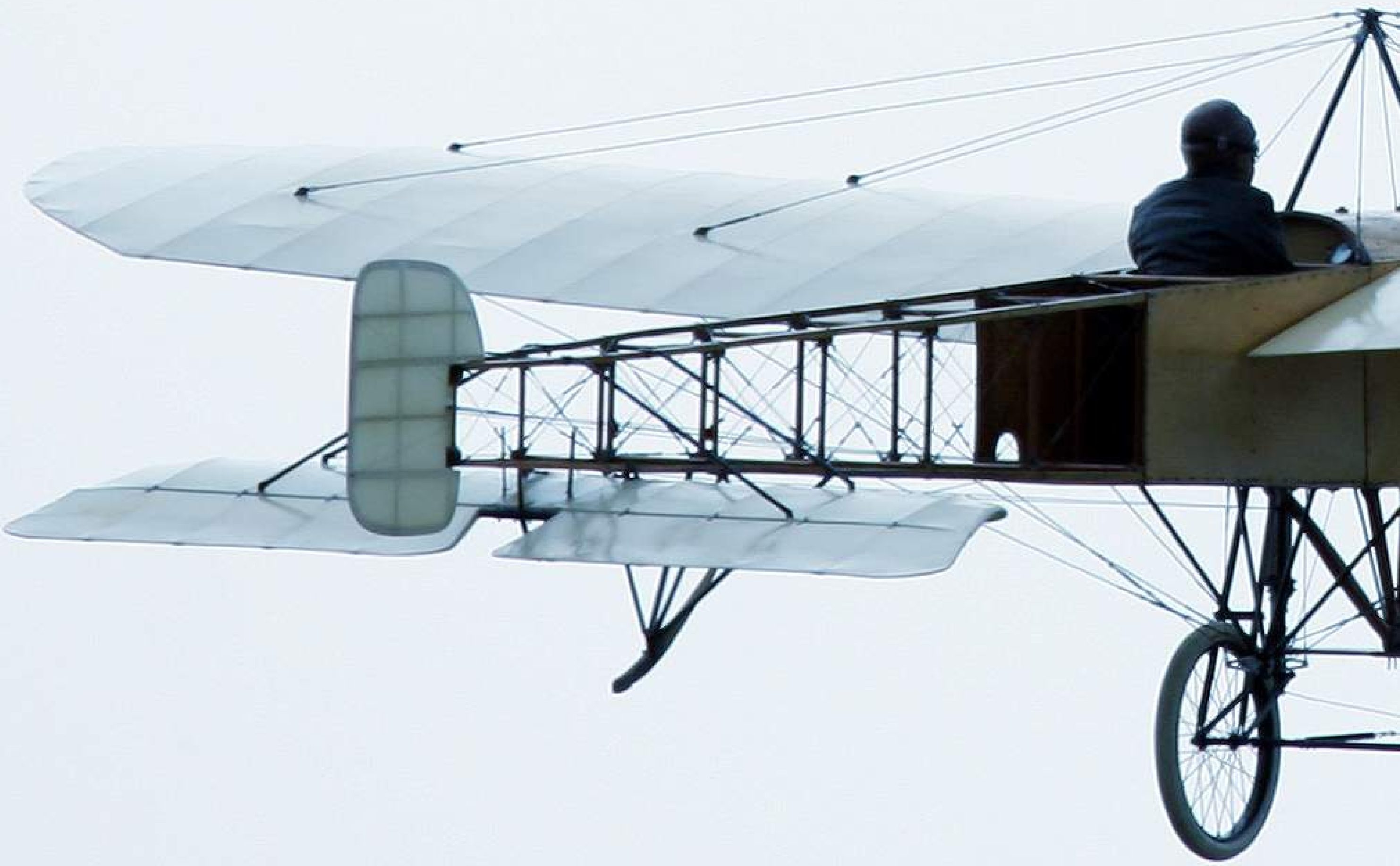

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Introduction

Aeroengines form an integral part of any air platform, be it a fighter aircraft, transport aircraft, or helicopter. Each of these different platforms will have different operating characteristics, thereby creating different qualitative requirements for the engines that are fitted onto them. There are different types of aeroengines, these include turbojets, turbofans, turboprops, ramjets and turboshaft engines.

As India is moving on with its path of modernization of its Armed Forces, the one prominent gap that remains and has been acting as a major obstacle is the inability to design and develop wholly indigenous modern Aero-engines which account for about one-third of the cost of the system. India's defence aeroengine market could be split broadly into four different segments, this includes fighter/combat aircraft, transport aircrafts, rotorcraft, and unmanned aerial vehicles. If we take the timeframe of around 10-15 years, one can map out upcoming procurement and with the assumption of aeroengines encompassing 25-30% of the total cost of a single platform, one could assume that the market potential for aero-engine and related activities.

Supply chain of aeroengines

The aeroengine supply chain can be split up into the following broad classifications

Original Equipment Manufacturers

are primes who design, develop, certify and produce, build and support the power plants over their life cycle. Examples of companies in this category are Rolls Royce, Pratt and Whitney, GE Aviation and Safran

Engine Sub-System (Module Providers)

These are Tier-I companies that provide entire modules to the OEM. Examples of modules could be sections of the engine, such as a high-pressure compressor section, low pressure turbine section, the combustion chamber, gear box etc. The Tier-I companies typically are risk-sharing partners in a specific program. For example, in Pratt and Whitney's PW6000 program, Kawasaki Heavy Industries is a risk sharing partner where it supplies the combustion chamber module/ section for the PW6000 program. MHI is estimated to have a 7.5% risk-sharing stake in the program.

Engine Component Suppliers

These are typically Tier-II and Tier III suppliers at the components level which go in building the module/section of an engine. Examples are compressor and turbine details, valves, seals, gearbox, FADEC system, etc. Companies in this category include players such as Hamilton Sundstrand, Honeywell, GKN Aerospace, Mitsubishi Heavy Industries, Kawasaki Heavy Industries, and others.

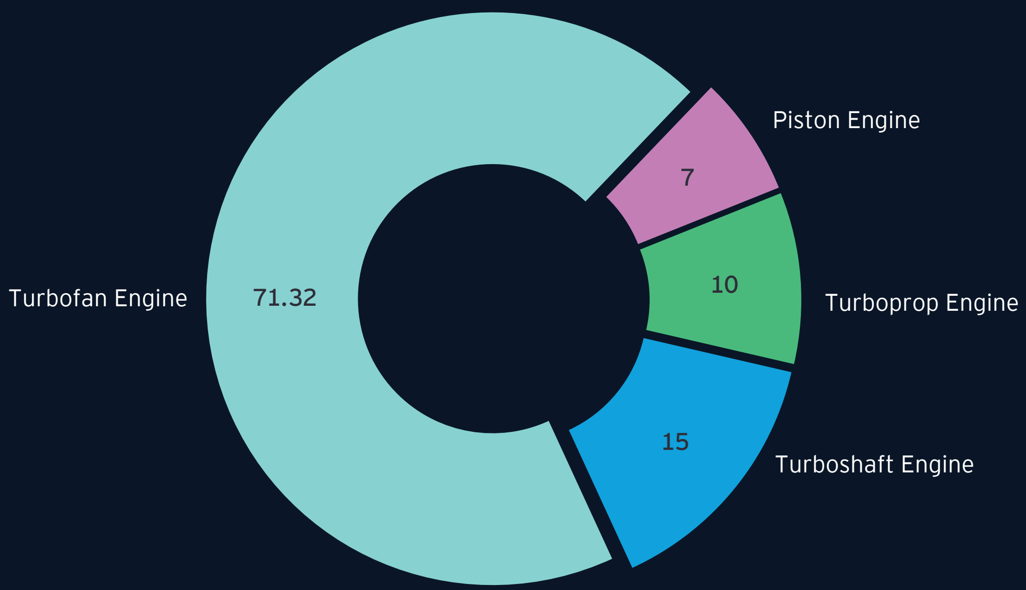
Material Suppliers

These are the raw material suppliers that supply castings, forgings, bar, sheet, tubes of the required grade and standard parts, fasteners, sealants et al. Examples are Aubert Duval, Carlton Drop Forge, ALCOA, TECT Aerospace, etc.

Market analysis

Currently, the turbofan segment holds a major share in the aircraft engines market and may continue to do so during the forecast period. Turbofan engines are most widely used in the commercial and military segments. New aircraft programs, like COMAC C919 and Boeing 777X, which are yet to enter service, are powered by newer generation turbofan engine. In 2018, Boeing and Airbus recorded 806 and 800 aircraft deliveries, respectively. With growing aircraft orders in the commercial aircraft segment, which is majorly dominated by the turbofan engine segment, the turbofan engine segment may register the highest CAGR during 2020-2025.

Global Aircraft Engine Market share, by Type



https://www.fortunebusinessinsights.com/industry-reports/aircraft-engine-market-101766

India has largely been dependent on import for aeroengines for its airborne platforms whether of indigenous design - LCA, Kiran, HPT 32, HF- 24, Dhruv, Rudra, LCH and LUH or aircraft built under license – Jaguar, Dornier 228, Chetak and Cheetah helicopters, Sukhoi 30MKI. For a majority of platforms manufactured under license, the power plants are made from raw materials by HAL Engine Divisions at Bangalore and Koraput. Examples of Engines made under license from raw materials are the Artouste IIIB, Adour Mk 811, Garrett TPE 331-5, Orpheus 701 and 703, Dart, R-25, and the AL31-FP.

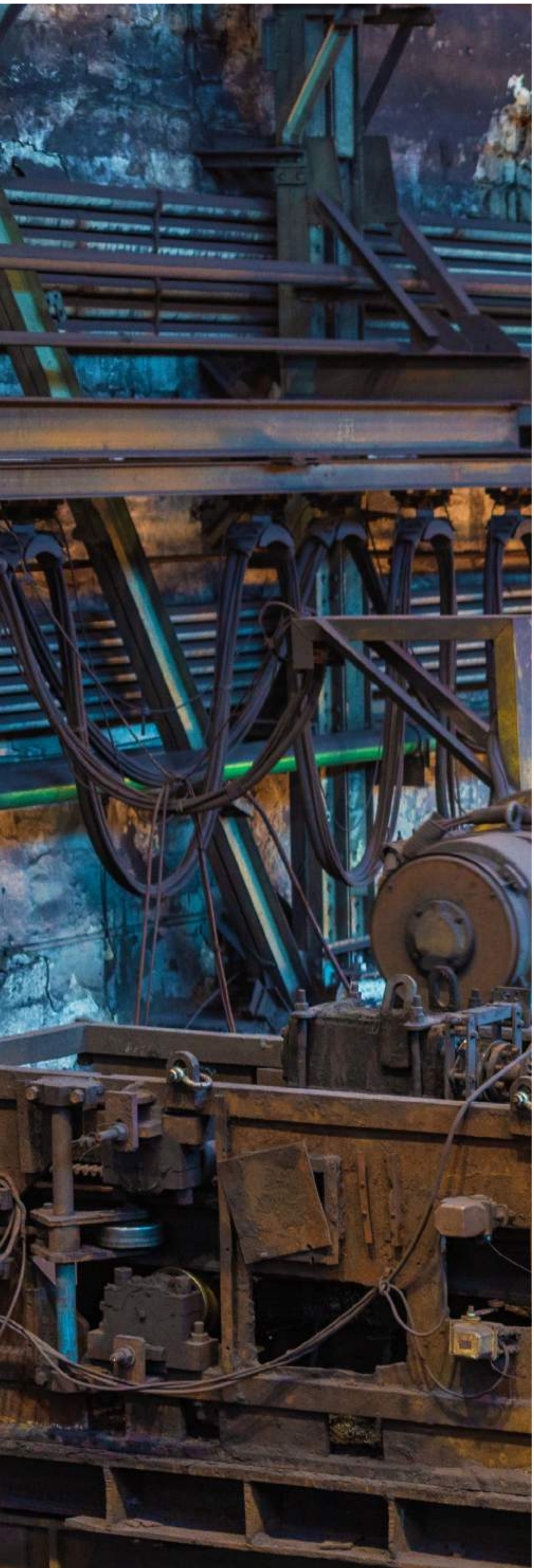
To understand India's dependence on aeroengine imports, whether they be direct imports or those engines that have been manufactured under license from an OEM; the table-2 below seeks to highlight the major platforms in the Indian Armed Forces existing inventory while mapping each platform to its corresponding engine type.

Operator	Type of Aircraft	Approx numbers	Type of Engine	Engine
Fighter Aircraft				
IAF	Jaguar	116	Turbofan	Adour Mk811 / Mk804E
IAF	Bison	81	Turbojet	R-25U
IAF	MiG 21	74	Turbojet	R-25U
IAF	SU 30 MKI	248+12*	Turbofan	AL-31FP
IAF	Mirage 2000	48	Turbofan	M53-P2
IAF	MiG-29	59	Turbofan	RD-33
IAF	LCA	12+28*	Turbofan	F404-IN-20
IAF	Rafale	3+33*	Turbofan	M88-2
Navy	MiG 29K	44	Turbofan	RD-33
Trainer Aircraft				
IAF	Hawk	99	Turbofan	Adour MK 871
IAF	Kiran MK I	85	Turbojet	Orpheus
IAF	Kiran MK II	42	Turbojet	Orpheus
IAF	Pilatus PC-7	75	Turboprop	PWC PT6A-25A
Navy	Hawk	17	Turbofan	Adour MK 871
Transport Aircraft				
IAF	DO-228	52	Turboprop	Garrett TPE-331-5
IAF	HS-748	46	Turboprop	Dart
IAF	AN-32	100	Turboprop	AI-20DM
IAF	IL-76	15	Turbofan	D-30KP
IAF	IL-78	6	Turbofan	D-30KP
IAF	Boeing 737-200	2	Turbofan	PW JT8D
IAF	Boeing Business Jet	3	Turbofan	CFM-56-7 Series
IAF	Embraer -135 /145 Legacy	8	Turbofan	RR AE-3007
IAF	C - 130 J	11	Turbofan	RR AE-2100 D3
IAF	C 17 GM3	11	Turbofan	PW F117-PW-100
Navy	DO-228	29	Turboprop	Garrett TPE-331-5
Navy	IL-38	5	Turboprop	AI-20M
Navy	P-8	8	Turbofan	CFM-56-7B27A
CG	DO-228	39	Turboprop	Garrett TPE-331-5

Operator	Type of Aircraft	Approx numbers	Type of Engine	Engine
Helicopter				
IAF	Cheetah	38	Turboshaft	Artouste IIIB
IAF	Chetak	79	Turboshaft	Artouste IIIB
IAF	Cheetal	14	Turboshaft	TM-333 - 2M3
IAF	ALH	72	Turboshaft	Shakti / TM-333 - 2B3
IAF	Mi-17	251	Turboshaft	VK-2500 PS-03
IAF	Mi-35	21	Turboshaft	TV3-117
IAF	CH-47 F - Chinook	6+9*	Turboshaft	T55-GA-714A
IAF	AH 64 E	10+12*	Turboshaft	GE T700 - GE-701
Navy	ALH	9	Turboshaft	Shakti / TM-333 - 2B3
Navy	Chetak	54	Turboshaft	Artouste IIIB
Navy	Sea King	23	Turboshaft	Gnome
Navy	Ka-28	12	Turboshaft	TV3-117
Navy	Ka-31	14	Turboshaft	TV3-117
Army	Chetak	55	Turboshaft	Artouste IIIB
Army	Cheetah	135	Turboshaft	Artouste IIIB
Army	Cheetal	16	Turboshaft	TM-333 - 2M3
Army	ALH	130	Turboshaft	Shakti / TM-333 - 2B3
CG	Chetak	19	Turboshaft	Artouste IIIB
CG	ALH	4	Turboshaft	Shakti / TM-333 - 2B3

Aeroengines comprise anywhere between 25-30% of the base cost of an air platform, by not having an indigenous capability to design, develop and manufacture its own aeroengines; India not only increases its dependence on other countries in an area of critical technology but also reduces opportunity to reduce foreign exchange outgo. There is a continuous FE outgo both in terms of royalty and spares.

Looking to the future, given the Indian Armed Force's modernization drive, a focus on defence procurement which encourages localization of manufacturing activities/indigenization, and with a preference being given to indigenously design, developed, and manufactured defence products; the aeroengine segment is one that holds immense market potential, particularly when looking at local domestic demand.



Future market demand

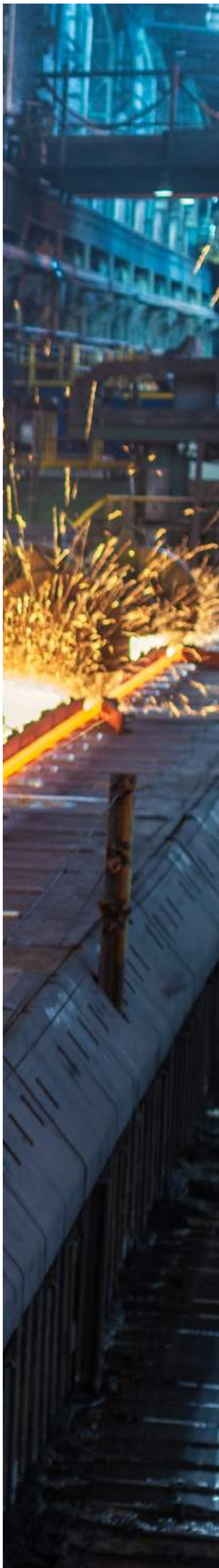
India is forecasted to spend approximately between a range of US$40.5 billion to $43.1 billion worth on aeroengines over the next 15 years, as can be seen through the programs listed in the table below.

The total engine requirement in terms of number of units could range from approximately 4,726 aeroengines to 4,863 aeroengines.

Once the platform base cost has been ascertained, we utilize a range of anywhere between 25-30% of the platform base cost (the range varies on the platform type and the complexity of onboard systems, the more complex the lower the percentage that is applied and vice versa) as attributable towards aeroengines on a unit value basis. Finally, the product of the unit value of aeroengine spend and the total number of aeroengines being procured, leaves us with an approximate of the total aeroengine spend per program. These figures are arrived on an extrapolation basis with the key assumption being an aeroengine accounts for anywhere between 25-30% of the base cost of the platform. The figures are a projection and could vary depending on a variety of different factors.

The transport aircraft segment is expected to account for 17% which is primarily driven through the Avro Replacement Program, and military transport aircraft requirement. The helicopter segment is expected to account for approximately 34.6% of total aeroengine spend, with this primarily attributed to the Naval Utility Helicopter, Naval Multi Role Helicopter programs, the KA-226 acquisition, the Indian Multi-Role Helicopter program amongst other indigenous helicopter programs. Finally, the UAV/Drones segment will account for 3% of total forecasted aeroengine spend.

Platform Type	Program	Program value (US$ Billion)	Quantity of platforms	Quantity of Engines	Estimated cost
Fighter aircraft	MRCBF	9	57	114	**US$ 20.98 billion**
	MMRCA 2.0	18	114	228	
	MMRCA 2.0*	18	114	114	
	Tejas Mk1A	5.43	83	83	
	Tejas MK2	-	200	200	
	AMCA	-	200	400	
	*Dependent on if a single-engine or twin-engine fighter wins the MMRCA 2.0 contract				
Transport Aircraft	Avro Replacement	3.15	62	124	**US$ 6.85 billion**
	Military Transport Aircraft	-	150	300	
Helicopter	Naval Utility Helicopter	3.11	111	222	**US$ 14.02 billion**
	Naval Multi-Role Helicopter	6.89	123	246	
	Ka-226T	1	200	400	
	Light Combat Helicopter	-	179	358	
	Light Utility Helicopter	-	187	187	
	Indian Multi-Role Helicopter	-	400	800	
UAV	MQ-9 Reaper	3	30	30	**US$ 1.23 billion**
	Heron	0.5	50	50	
	Heron	-	100	100	
	Predator C Avengers	-	100	100	
	Rustom-2	-	10	20	
	Nishant	-	92	92	



Existing capabilities in India

Aeroengine development and manufacturing requires a high level of technology and is quite capital intensive in nature. Currently aero engine license manufacturing in India is primarily with HAL, both for Russian and western origin power plants. Complex technologies of hot end components have been mastered and also of castings and forging including single crystal blades and variable jet nozzles. There are only three Indian entities in the Government sector who are involved in power plant development and its associated technologies. However, the outcome has been less than expected, due to long development process, capital investment in test equipment and material technologies.

At present, India's closest achievement in attaining design and development capabilities within the aeroengine segment (this is only when looking at the design and development of entire aeroengine) is embodied by DRDO (GTRE's) Kaveri Engine program. In 1986, DRDO was authorized to launch a programme to develop an indigenous power plant for the Hindustan Aeronautics Limited Light Combat Aircraft (LCA). The project had a targeted completion date of 1996, which was subsequently extended to 2009. The Gas Turbine Research Establishment (DRDO) was the lead agency tasked with developing the Kaveri aeroengine.

It is an important point to note that these design and development capabilities would primarily be seen through the public sector, in the form of certain agencies; Gas Turbine Research Establishment, Engine Research and Design Bureau (HAL), Propulsion Division of National Aerospace Laboratories (NAL).

Manufacturing capabilities

India's aeroengine manufacturing capabilities can primarily be seen through licensed manufacturing programs. This manufacturing of an entire aeroengine has primarily been seen in the public sector through the following.

1. **HAL Aero Engine Bangalore:** This facility of HAL established in 1955 has licensed manufactured from raw materials the following aeroengines:
    - Orpheus 701 and 703 for the HF 24 and Kiran trainer
    - Artouste III B for the Chetak and Cheetah Helicopters
    - Adour Mk 804s and Mk 811 for the Jaguar
    - Dart 536 2T for the Avro
    - Avon series for the Hunter and Canberra
    - Gnome for the Sea King Helicopters
    - Adour 871 for the Hawk
    - TM 333 2B for the Dhruv helicopter
    - Shakti for the Dhruv, LCH and LUH
    - In addition to manufacturing these engines for their respective platforms, the facility has also conducted maintenance and overhaul for all of the above listed engine types.

2. **Engine Division Koraput:** Engine Division Koraput was established in the year 1964 to manufacture R11F2-300 Series III engines for fitment in MiG-21FL Aircraft under licence from erstwhile USSR. In 1976 facilities were established to manufacture R25 engines for fitment in MiG-21BIS aircraft. Subsequently the Division also manufactured R29B and RD33 Engines under licence from Russia.
   Since the early 1970s, overhauling facilities were established in the Division and it has been overhauling Aero Engines of Various types i.e. R11, R25, R29 and RD33 which power MiG-21FL, MiG-21BIS, MiG-27 and MiG-29 respectively.
   Over last five decades it has manufactured more than 1300 engines and overhauled more than 7000 Aero Engines of various types. Sukhoi Engine Division Koraput was established in the year 2004 to manufacture AL31FP engines for fitment onboard the Su-30MKI Aircraft under Licence from Russia. In 2007-08 facilities were established for overhauling of AL31FP Engines.

Presently OEMs and Tier-1s use the Indian subcontinent for sourcing of aeroengine components at a Tier-II/III level. Aeroengine component sourcing into global supply chains from India is seen through a combination of Indian companies which includes private and public sector companies, foreign companies that have outsourced parts of their manufacturing to India, and joint ventures of the aeroengine OEM/Tier-I with their Indian partner that have been setup in India for production of aeroengine components.

CASE STUDY:

HTT - 40 program

The HTT-40 is an all-metal, tandem seat aircraft powered by a 1,100 hp (820 kW) turboprop engine.

By the middle of 2012 the aircraft's future was in doubt as the Indian Air Force ordered 75 Pilatus PC-7 Mk IIs to fill the role envisioned for the HTT-40. In September 2012 the Air Force indicated that it had formally rejected the HTT-40 for service based on its cost per aircraft being double that of the PC-7 Mk II, a proven aircraft, already in service worldwide. The aircraft will be used for Stage I flight training by the Indian Air Force (IAF).

HTT-40 developmental flight testing is now largely complete, although it has been delayed due to the COVID-19 pandemic. IAF test pilots from the Aircraft Systems and Testing Establishment (ASTE) are currently performing User Assisted Technical Trials (UATT), aimed at reducing the effort and time required to complete User Evaluation Trials (UET) planned for 2021. ASTE test pilots are also assessing the HTT-40's cockpit ergonomics, aircraft performance and handling (including stall characteristics). Both prototype aircraft have accumulated more than 400 flight hours during the course of 450 test flights.

While largely indigenous, the HTT-40's Honeywell TPE331-12B turboprop engine, cockpit avionics and displays, line replaceable units (LRU) and Martin-Baker Mk 16 zero-zero ejection seats are imported.

While largely indigenous, the HTT-40's Honeywell TPE331-12B turboprop engine, cockpit avionics and displays, line replaceable units (LRU) and Martin-Baker Mk 16 zero-zero ejection seats are imported.
HAL has worked hard to ensure high commonality between systems on the HTT-40 and those on LCA Tejas, HJT-16, Dhruv helicopter and licence produced Dornier Do-228. Honeywell TPE331-12B CAT B turboprop engines power both prototypes. However, obsolescence issues relating to the powerplant's engine electronic control (EEC) require the development of a new EEC or twin channel full authority digital engine control (FADEC) unit. Honeywell can deliver either solution within 24 months of the contract being signed. It now also appears that the EEC upgrade option will be selected for series production aircraft. Since 1988, HAL has been manufacturing, overhauling and repairing TPE 331-5 turboprop engines, which power licence-produced Do-228s. The airframer's engine division is also an authorised service centre for TPE331-5 engines up to series 12.

Challenges

The challenges India has faced in its quest to indigenously design and develop aeroengines can be split into major categories viz. lack of expertise and technology gaps, access to required infrastructure, funding constraints, international cooperation limitations.

Technology gaps

India's aeroengine manufacturing capabilities can primarily be seen through licensed manufacturing programs. This manufacturing of an entire aeroengine has primarily been seen in the public sector through the following.

Within the area of aero engine design, the areas that India requires experience in are the following:

- Aerodynamics, Performance Analysis,
- Estimated Characteristics at Different Speeds
- Effects of Inlet Pressure, Distortion, Flutter
- Mechanical Design Parameters for Key Parts (Disks, Blades)
- After-Burner Behaviour
- Vibration Analysis
- Control System Efficiency including Back-Up Mode
- Safety Margins Analysis

India also requires access to materials technology in super alloys, cooled blades, DS and single crystal blades, special coatings and surface treatments.

International collaboration limitations

Aeroengines require deep expertise across combustion, fluid dynamics, materials and control theory applied, tested and iterated continuously over years. Knowledge of these niche technologies are restricted to four or five major aeroengine OEMs globally and where competitive advantage is derived for them. Therefore, aeroengine OEMs are typically hesitant to share this niche technology. To understand the difficulties of international collaboration with regards to aeroengine technology, an example could be that of Safran and DRDO's proposed joint development of the Kaveri engine.

Overview of the partnership

In April of 2017 Safran, France offered to revive the Kaveri engine project through a joint development program. The proposal intended to integrate the upgraded Kaveri with the Mk1A variant of the LCA Tejas in two years' time, which are currently powered by General Electric's F404 engines. An enabler to some degree for this joint development were offset obligations that arose from the Rafale acquisition. The joint development program for the Kaveri engine envisaged investments, a portion of which (1000-1200 Crores) would be adjusted by the offsets arising from the Rafale acquisition.

Way forward

For India to gain access to the aero-engine technology it is crucial for the country to build this design capability through G2G partnership with a foreign OEM. As highlighted in the case studies of trying to collaborate with France and the US, the reason for the projects being shelved were a result of pricing and technology restrictions respectively. Partnering with a foreign OEM is crucial for GTRE to build expertise in core engine design technology. A co-development program, based on G2G agreement would allow GTRE engineers understand key technologies, the underlying physics, and advanced research techniques. This will be followed by the co-production efforts between FOEM and DPSU/ Indian Private industry as the anchor unit leading to the formation of the ancillary industries (Tier1/2 facilities) and the entire ecosystem thereafter

A Key objective of this initiative will be the development of the Kaveri engine to make it mission ready for existing/ future fighter aircraft, as this will enable in building national capability in aero-engines. The effect would be synergy between the design and production agencies in the government sector and development of an ecosystem of tier 1 and tier 2s in the private sector for these programs.

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