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# KAVERI - FROM THRUST TO TRIUMPH

MR VINAYAK KUMBAR

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# KAVERI – FROM THRUST TO TRIUMPH

**Mr. Vinayak Kumbar is a Technical Research Assistant at CENJOWS**

**Introduction**

In the Brahma Giri hills within the Western Ghats at Talakaveri in Coorg (Kodagu) district of Karnataka originates a mighty river known to be by some as the lifeline of Karnataka and Tamil Nadu, “KAVERI”. Named after this is river, an indigenously designed aircraft engine to power advanced fighter jets, “The KAVERI Engine” is one of the most innovative and important endeavour. It is a testament, not only of Indian aerospace capabilities but also a symbol of India’s self-reliance, “Atmanirbharata”. Like the river Kaveri, described as the confluence of multiple sacred tirtha,[1] the engine is also a confluence of India’s scientific, technical and strategic aspirations. Driven by innovation, indigenous excellence and nationalism, the KAVERI Engine will provide trust and propulsion providing to propel India into technical leadership position. Designed by Defence Research Development Organisation (DRDO), it is a tribute to the relentless pursuit of indigenous excellence and India's commitment to achieving technological sovereignty in aerospace and defence.

## Historical Background

Initiated by the Gas Turbine Research Establishment (GTRE), a premier laboratory of DRDO, in 1986,[2] it has been a remarkable four-decade journey of relentless persuasion for technical excellence. The project is an assertion of India' Atmanirbhar Bharat initiative in crucial Aerospace and Defence sector. Throughout these 40 years, there have been several milestones and with achievement of each milestone, India took one step ahead towards its goal of self-reliance. In this section, the effort has been made to make the reader familiar with multiple factors, people, institutions, and collaborations that have contributed towards fruition of project overcoming the hurdles and challenges along the way. It all began with an initial budget allocation of about USD 306 Million (~₹ 386 Crore) in 1986[3] by Government of India (GOI) and GTRE was entrusted with the responsibility to design and develop Kaveri Engine, a low bypass twin spool turbo fan engine of 80 kN thrust class[4] under the expectation that it would integrate this engine into the Light Combat Aircraft (LCA) program.[5]

(**Fig.1** GTX-35VS Kaveri)[6]
**(Source**: defenceupdate.in)

The funding had 3 major objectives:[7]

3.1 Design of a jet engine to meet the requirement for the LCA,

3.2 Establish the country's indigenous base to design and develop critical jet engine technology and,

3.3 Test beds (testing facility for jet engines).

In the early years of the inception, several great minds played vital role in taking the project to new heights. Some of the prominent ones include Dr. T Mohana Rao, Dr. Kota Harinarayana, Dr. C.P. Ramanarayanan, and Dr. K. Tamilmani. Under their able leadership the program achieved several milestones in the years to come.

Full-scale development of the power plant was authorised in April 1989 as a 93-month programme with a budget of USD 55.3 million.[8] With the test run of the core engine module, known as "Kabini," in March 1995, the program hit its first crucial milestone.[9] It comprised of a high pressure compressor, combustor and high pressure turbine, used for demonstrating hot end parts technology and study the aero-mechanical behaviour of High Pressure spool of the Kaveri engine.[10]

(**Fig.2** Kaveri Core Engine – Kabini)[11]

(**Source**: DRDO)

The original plan was to build 17 prototype engines.[12] Ground test runs of first fully assembled prototype of Kaveri engine took place in GTRE Bengaluru in 1996 and all five ground-test examples were in testing by 1998.[13] Its test run after fitment on LCA Tejas was scheduled in 1999[14] with test on LCA Tejas in 2000.[15] But, the program hit roadblock due to some unprecedented challenges which required to be overcome to get its development back on track as per envisaged schedule. The biggest challenge faced was sanctions imposed by US post 1998 Pokhran Nuclear test which hampered transfer of critical aero-engine technologies and components from the US.[16]

(**Fig.** 3 LCA Tejas)[17]
**(Source**: grabcad.com)

**Period of highs and lows**

First major challenge was the funding which the program received at its inception. Compared to its contemporaries like General Electric 404, Euro jet EJ200, and Snecma M88, each of which received about USD one billion adjusted to year 1986 (equal to almost ₹ 1260 Crores), the Kaveri engine program got about USD 306 Million (about 386 Crores), an amount almost 3.3 times less than what others received.[18]

The design envisaged incorporation of advanced features like a full annular combustor, transonic compressors, and directionally solidified turbine blades to achieve a fan pressure ratio of 4:1 and an overall pressure ratio of 27:1, aimed at supporting super cruise capabilities. However, the Comptroller and Auditor General (CAG) India report of 2011 highlighted GTRE's limited experience and tech expertise with the GTX engine that hindered its development. Further, changes in design and material had also caused delays.[19] After, initial successful run of prototype engine in 1996, the program was marred by delays mainly due to lack of experience in the areas of aerothermal dynamics, metallurgy, and control systems. Denial of access to critical technologies post Pokhran nuclear test embargos, like single-crystal turbine blades and high-performance superalloys, essential for the Kaveri engine's development further delayed the pace of development envisaged.

Early 2000s was a period of several ups and downs, some being extremely hopeful whereas few being to a level that almost crushed the hopes. It was claimed in 2000 that five prototypes of the engine had been manufactured and tested, however, these tests revealed several deficiencies necessitating large modifications.[20]

Before heading further, it is important for the reader to know about complete technical specifications and Design features of the Kaveri engine. An effort has been made for the same below:[21]

| | |
|---|---|
| **Name**<br>**Developer** | GTRE GTX-35VS Kaveri<br>Developer Gas Turbine Research Establishment (GTRE), Bengaluru |
| **Type** | Low-bypass, twin-spool turbofan with afterburner |
| **Thrust (Dry)** | 49 to 51 kN |
| **Thrust (Wet, with Afterburner)** | Designed for 81 kN |
| **Bypass Ratio~0.16:1**<br>**Fan Pressure Ratio** | ~0.16:1<br>Design aimed for 4:1 |
| **Overall Pressure Ratio 27:1**<br>**Mass Flow Rate** | 27:1<br>78 kg/s |
| **Thrust-to-Weight Ratio 6.9:1**<br>**Weight target** | 6.9:1<br>1,100 kg |
| **Length**<br>**Diameter** | ~3.49 m<br>~0.91 m |
| **Compressor Stages**<br>**Combustor Type** | 6-stage low-pressure + 3-stage high-pressure compressor (transonic design)"<br>Full annular combustor with advanced fuel injection |

| | |
|---|---|
| **Turbine Stages**<br><br>**Turbine Blade Material** | 1 high-pressure + 1 low-pressure turbine<br><br>Directionally solidified (DS) blades |
| **Cooling Technology**<br><br>**Stator Vanes** | Internal cooling passages for high-temperature performance Variable<br>Stator Vanes First three compressor stages for optimized airflow |
| **Control System**<br><br>**Materials** | Twin-lane Full Authority Digital Engine Control (FADEC) with manual backup<br><br>Titanium alloys (Ti-6Al-4V, Ti6242, Ti6246), nickel and cobalt superalloys |
| **Environmental Adaptation** | Optimized for India's extreme conditions (hot deserts to Himalayan altitudes) |

**(Table 1 -** Technical specifications and Design features of the Kaveri engine)

**(Source:** SlideShare/Kaveri Engine)

The original completion date of December 1996 could not be met. Hence GTRE secured an extension till March 2000 based on the peer reviewed recommendations by foreign engine houses. Delayed deliveries of material like castings, difficulties in manufacturing of specific alloys, introduction of certain test like the Exploratory Altitude Test and Flight Test Bed Trials caused uncertainties. However, GTRE was unable to meet this extended target date due to changes in design and material necessitated due to design review which flagged certain flaws like suboptimal performance compressor.

A revised Probable Date of Completion (PDC), i.e. December 2004 was approved, which also got further postponed to December 2009.[22] This was justified by GTRE as its inability to freeze a design as per requirements hence, further refinements were required. Besides non-availability of certain systems from vendors, slow pace of indigenous development of associated systems was also not successful resulting in further delays.[23] The table below gives an overview of various tests and delays as of 2009.[24]

| Milestone Achieved | Originally planned | Completion date | Revised PDC | Status as on 08/09 | Delay |
|---|---|---|---|---|---|
| Core Engine demonstration | Dec 1990 | March 1995 | | Achieved | 4 years + |
| Full Engine demonstration | June 1992 | September 1995 | | Achieved | 3 Years + |
| High Altitude tests | June 1994 | | June 2006 | Not Achieved | |
| Preliminary Flight Rating Test | December 1995 | | December 2007 | Not Achieved | |
| Type test | June 1996 | | June 2008 | Not Achieved | |
| FTB | September 1998 | | May 2007 | Not Achieved | |
| Production Clearance | December 1996 | | December 2009 | Not Achieved | |

**(Table 2**. Status of various tests as of 2009)[25]
**(Source:** CAG report 2009, GOI)

In the above-mentioned table, the first milestone of Core Engine (KABINI) demonstration as already mentioned earlier was achieved. The second milestone of first full engine demonstration was also achieved. The delays that the program faced were attributable to multidimensional factors as mentioned earlier as well. The period spanning from 2000 to 2007 was truly filled with challenges and hurdles that were uncalled for. Yet the relentless attitude adapted by our brightest of minds involved in the program pushed through. However, there were more such obstacles to be faced in the upcoming years.

**Kaveri's Technical Barriers to Tejas' Performance Goals**

The primary objective of funding the Kaveri program was to build an engine that would be a suitable power plant to propel the Tejas Light Combat Aircraft (LCA), which was a collaboration between Aeronautical Development Agency (ADA) and Hindustan Aeronautics Limited (HAL) to replace the aging MiG-21 fleet of the Indian Air Force. It was initiated around the same time as Kaveri in around 1983.[26] But due to multiple reasons the engine was not quite able to meet the demands.[27] The weight of Kaveri engine required to fly the LCA should not exceed 1100 Kg. The first assembled Kaveri K1 engine's weight was around 1424 Kg. Hence, GTRE started focusing to reduce the weight to the required levels. However, it was not possible due to delay in the development of the component assemblies or modules, polymer composites, design and freezing. As of January 2009, the weight was around 1235Kg. The development of Compressor, Turbine and Engine Control System faced delays, despite increase of around 186 Crores in its cost. There were mechanical failures in the performance of compressors. Also, the GTRE was unable to finalise the design of the turbine blades. The tests carried out to evaluate the engine itself have revealed the following deficiencies:

| SL. No. | Nature of test | Cost (Crores) | Status (till 2009) |
|---|---|---|---|
| 1 | Component Testing | 142 | Despite nine years having passed since initial sanction, most of the tests including EAT, OAT, PFRT, QT have not been completed. |
| 2 | Kaveri Compressor Drum Test | 6 | The test was delayed. It was completed only in September 2009. The test was mandatory for proving airworthiness and after its successful completion only, the components could be cleared for fitting into the engine. |
| 3 | Altitude test | 127 | Not even a single altitude test which was essential for assessing whether an engine can actually fly an aircraft, was completed. |

| | | | |
|---|---|---|---|
| 4 | Flight Test Bed trials (FTB) | 39.60 | No FTB trials on Kaveri engine could be conducted due to delay in manufacturing of critical components of the engine. |

**(Table 3.** Deficiencies revealed by evaluation tests)[28]
**(Source:** CAG Report 2009, GOI)

In mid-2004 the engine failed its high-altitude tests in Russia ending the hopes for its introduction with the first production batch of Tejas fighter jets.[29] As the failures continued through the first half of the 2000s decade, the engine had undergone 1700 hours of tests and had been sent twice for high altitude tests to Russia by February 2008.[30] As a result of such discrepancies and delays the Kaveri Engine was officially delinked from Tejas LCA in 2008[31] which later on adopted the American GE F404 engine.[32]

Amidst all these dream shattering failures, there came a ray of hope when One of the Kaveri prototypes (K-9) was successfully flight-tested at the Gromov Flight Research Institute in Moscow on November 4, 2010.[33] Though the test results were promising, but the 2011 CAG report[34] came as a blatant shock. It highlighted the program's cost overruns, with only two out of the six milestones having been met. It is to be noted that these issues have already been explained in detail previously. A 2010 Ministry of Défense report identified technological complexities, the lack of critical equipment, the denial of technologies by technologically advanced countries, the lack of test facilities in the country, and the non-availability of skilled manpower as key reasons for the repeated delays in the Kaveri project.[35] DRDO virtually abandoned the project by 2014.[36]

### 2016: The Revival

Collaboration with Safran (France) in 2016 paved the way for reviving the almost abandoned project. France offered to spend 1 billion Euros as a part of Dassault Rafale's offsets deal and proposed a joint-venture plan with DRDO to quickly revive the Kaveri engine programme and make the first upgraded power plants airworthy. In November 2016, CP Ramanarayanan, Director General for Aeronautics Cluster of DRDO confirmed that the collaborative deal with the French company "Safran" Aircraft Engines, had been sealed for the upgradation of Kaveri and making it airworthy for testing by 2018.[37] It is to be noted here that one more important milestone was achieved when a derivative of the Kaveri, the Kaveri Marine Gas Turbine (KMGT), was successfully developed to meet the Indian Navy's propulsion needs, demonstrating the program's adaptability.[38] It was tested successfully for the first time in 2008. The engine has been tested to its potential of 12 MW at ISA SL 35°C condition, which is the requirement of Indian Navy for propelling the SNF (Rajput) class of ships,[39] but the core Kaveri engine still lacked the single crystal blade technology and advanced superalloys needed for high-performance applications.

**(Fig.** 4 Kaveri Marine Gas Turbine)[40]
**(Source**: DRDO)

Eventually, the DRDO shifted focus to developing a dry version of the Kaveri engine suitable for UAV applications. The current dry version of the Kaveri engine produces approximately 49 to 51 kN of thrust. This thrust level is suitable for UAV applications like the Ghatak, India's stealth UCAV program.[41] The dry variant passed the high-altitude test in 2023.

(**Fig.5** Ghatak UCAV)[42]
(**Source**: -IADNEWS)

(**Fig.6** Kaveri Dry Engine)[43]
(**Source**: Defence.in)

The high-altitude tests were conducted successfully last year at the Central Institute of Aviation Motors (CIAM) in Russia, simulating an altitude of 13,000 m (42,651 ft). During these trials, the dry-Kaveri engine also managed to generate 48.5kN of thrust, much more than the benchmark target of 46kN that it had to demonstrate for UAV applications.[44] The focus has been on enhancing the dry thrust and designing a new fan with high inlet pressure distortion tolerance. With a 3.4:1 pressure ratio and supporting 78 kg/s mass flow across three stages, the enhanced design parameters have given the hope for integrating the dry variant with possible advanced versions of upcoming stealth UAVs similar to the one previously mention earlier.[45]

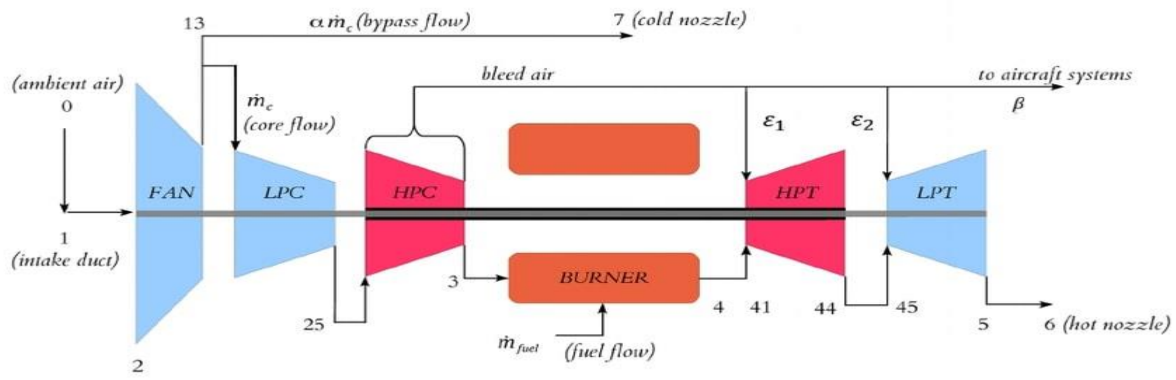
It is also important to mention here at this point that a history was created when Godrej & Boyce Mfg. Co. Ltd. won a contract from GTRE in September 2022 by which it would manufacture all eight modules of six Dry Kaveri engines, marking the first time, a private Indian firm is involved in producing jet engine modules.[46] Overall 2022-2023 turned out to be a year of triumph for the program.

The first quarter of 2025 started off extremely well when Godrej & Boyce Mfg. Co. Ltd. Delivered 2 of the total 8 Kaveri Derivative Engines (KDE) to GTRE,[47]although the original delivery was planned for late 2024 and complete deliveries projected by August 2025. Dry Kaveri engine being manufactured by Godrej Aerospace is a 48 kN thrust engine without an afterburner.[48]

**Kaveri: An Engineering marvel in the making**

It is now time for us to look at the components that make up the Kaveri engine. In this particular section effort has been made to present the readers with modules of the Kaveri engine, some more technical and design parameters other than the ones mentioned earlier and also the most recent developments, achievements and some unfortunate setbacks that have taken place.

As we know by now, Kaveri is a Low bypass, Twin spool "Turbofan"[1] Engine. Given below is a simple to understand schematic diagram of such an engine



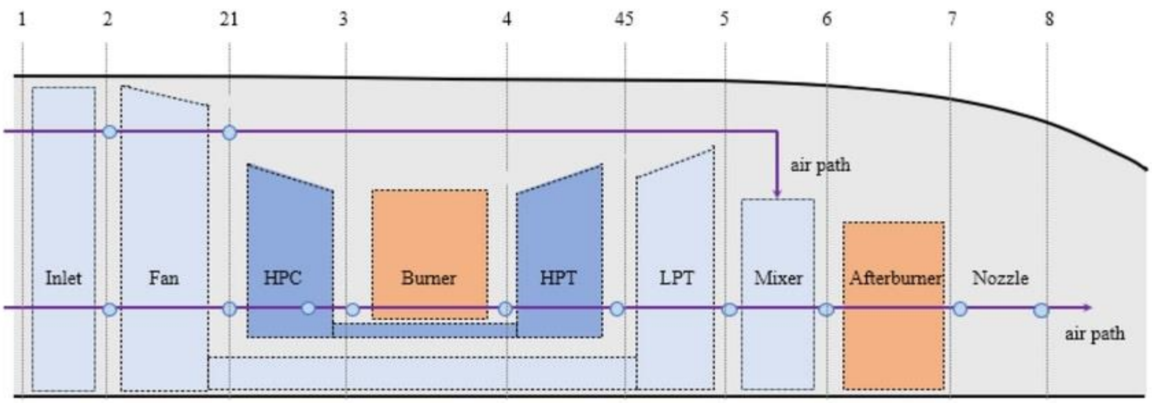

(**Fig 7.** Twin spool Turbofan engine with an afterburner)[49]
(**Source** – ResearchGate publication)

Combination of an engine compressor and high-pressure turbine that drives it using a connecting drive shaft is commonly known as a "Spool". In a dual-spool engine, the compressor and high-pressure turbine are both split into two segments. Each compressor segment is driven by its corresponding turbine using two separate drive shafts, with one inside the other.[50]

Now we move ahead into the working aspect of the engine. A low bypass, twin spool turbofan engine works on a principle of Jet propulsion. The incoming air is captured by the engine inlet (0-1). Some of the incoming air passes through the fan (2-13) and continues on into the core compressor (13-25-3) and then the burner (3-4), where it is mixed with fuel and combustion occurs. The hot

[1] Turbofan - The core engine is surrounded by a fan in the front and an additional turbine at the rear.

exhaust passes through the core and fan turbines (4-41-44-45-5) and then out the nozzle (5-6). The rest of the incoming air passes through the fan and bypasses (13-7), or goes around the engine.[51] The air that goes through the fan has a velocity that is slightly increased from free stream. So a turbofan gets some of its thrust from the core and some of its thrust from the fan. The ratio of the air thatgoes around the engine to the air that goes through the core is called the bypass ratio.[52] Now to this apparatus, an afterburner is added to provide an increase in thrust, usually for supersonic flight, take off and for combat situations.[53] Kaveri engine is also an example for a low bypass twin spool turbofan engine with an afterburner.




(**Fig 8**. A turbofan engine with afterburner)[54]
(**Source**: YouTube)

We now take a look at components/modules of Kaveri engine. It consists of:

Low-Pressure Compressor
High-Pressure Compressor
Full Annular Combustor
High-Pressure Turbine
Low-Pressure Turbine
Afterburner
Exhaust Nozzle and,
Engine Control System.


(**Fig 9**. Modules of Kaveri engine)[55]

(**Source** : drdo webinar)

Below presented are a few components of Kaveri engine.[56]

**(Fig 10)**

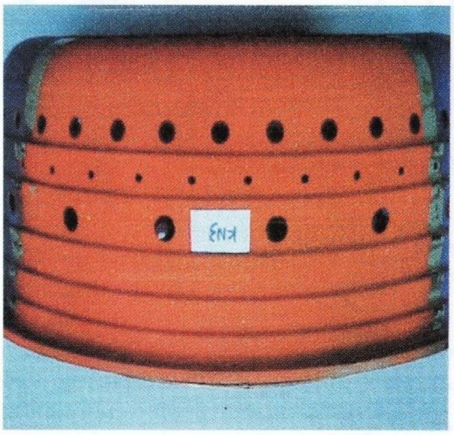
**(Fig 11)**

**(Fig 12)**

(Fig 13)


(Fig 14)

(Fig 15)



(Fig 16)

(Fig 17)

(Fig 18)

(Fig 19)

Fig 10 - Single Crystal Turbine Blade
Fig 11 - Nozzle
Fig 12 - High Pressure Turbine Blade
Fig 13 - Low Pressure Turbine Blade
Fig 14 - Low Pressure Turbine Blades
Fig 15 - Nozzle Actuator System
Fig 16 - Thermal Painted Combustor
Fig 17 - High Pressure Turbine Rotor
Fig 18 - Ring Forging
Fig 19 - High Pressure Compressor

(**Source for fig 10 to fig 19** – X Handle / Varun55484761)

Now we take a look at what goes behind the screen i.e., the testing facilities that our country proudly possess which are the pillar stones in the development of such majestic marvels by providing a solid rock foundation for the necessary research to take place in the most efficient and convenient ways. Below listed are few such test facilities located across various parts of the country.

Aeronautical Development Establishment
National Wind Tunnel Facility
Central Manufacturing Technology Institute
Gas Turbine Research Establishment
Compressor test facility
Combustor test facility
Turbine test facility
Flow visualization facility
After burner combustion test facility
Heat transfer studies facility
High mass flow high pressure air supply facility and many more

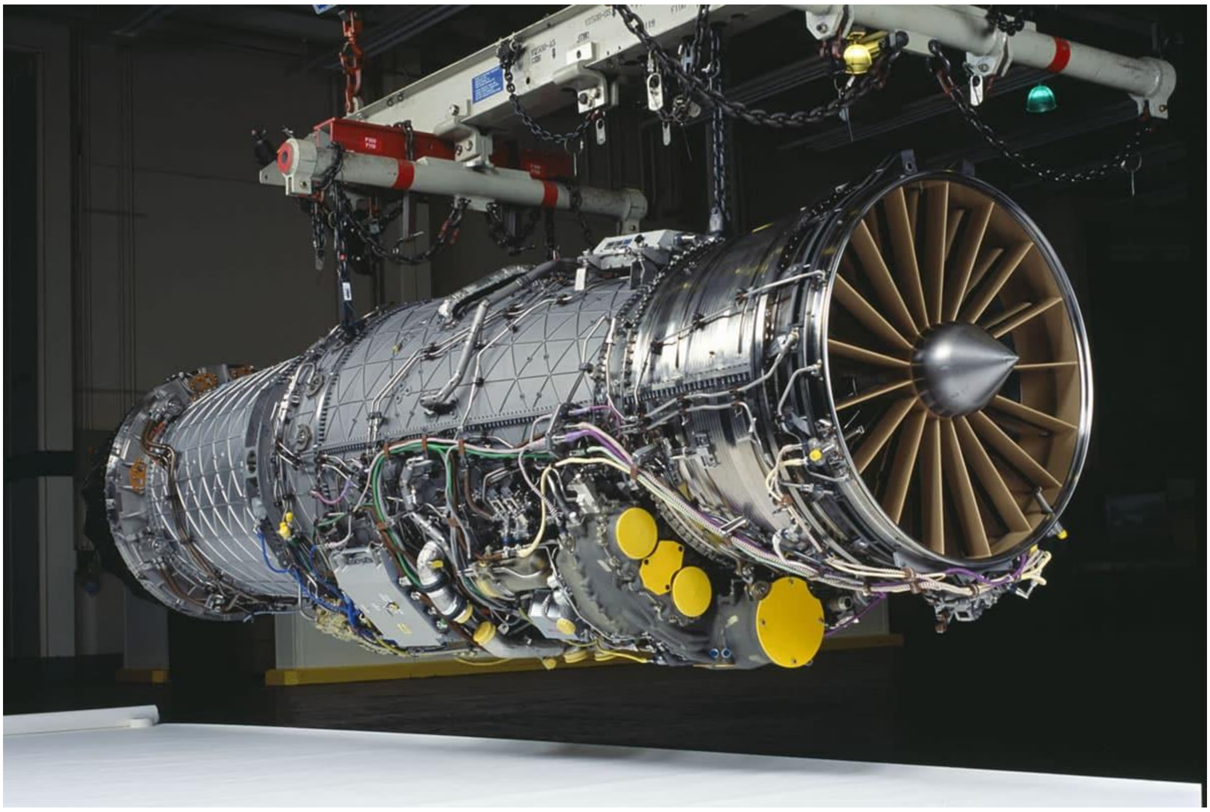
**Kaveri: GE F404: GE F414: AL-31FP - A Comparison**

| Parameter | Kaveri[57] | GE F404[58] | GE F414[59] | AL-31FP[60] |
|---|---|---|---|---|
| **Design Parameters** | | | | |
| Engine Type | Low-bypass twin-spool turbofan with afterburner | Low-bypass single-spool turbofan with afterburner | Low-bypass twin-spool turbofan with afterburner | Low-bypass single-spool turbofan with afterburner |
| Bypass Ratio | 0.16:1 | 0.34:1 | 0.25:1 | 0.59:1 |
| Overall Pressure Ratio | 27:1 (target) | 26:1 | 30:1 | 20.8:1 |
| Fan Pressure Ratio | 4:1 (target) | 4:1 | 4.2:1 | 4:1 |
| Turbine Inlet Temperature | ~1,427°C | ~1,500°C | ~1,700°C | ~1,400°C |
| Weight | 1,180 kg | 1,035 kg | 1,110 kg | 1,570 kg |
| Length | ~3.9 m | ~3.9 m | ~3.9 m | ~4.9 m |
| Diameter | ~1 m | ~0.89 m | ~0.89 m | ~1.2 m |
| | | | | |
| Dry Thrust | 49.2 kN | 53.9 kN | 62 Kn | 74.5 kN |
| Wet Thrust (Afterburner) | 73-75 kN | 84 kN | 98 kN | 122.6 kN |
| Thrust-to-Weight Ratio | ~6.2:1 | ~8.1:1 | ~8.9:1 | ~7.8:1 |
| Specific Fuel Consumption | ~0.85 kg/kN·h (dry) ~1.8 kg/kN·h (wet) | ~0.83 kg/kN·h (dry) ~1.77 kg/kN·h (wet) | ~0.81 kg/kN·h (dry) ~1.78 kg/kN·h (wet) | ~0.88 kg/kN·h (dry) ~1.95 kg/kN·h (wet) |

| | | | | |
|---|---|---|---|---|
| Materials | Directionally solidified blades; Kaveri 2.0 targets single-crystal blades | Nickel-based superalloys, blisks | Single-crystal blades | Nickel-based superalloys, titanium |
| Financial aspects and Current Induction | | | | |
| Current Use | DRDO Ghatak UCAV, Kaveri Marine Gas Turbine (KMGT) | HAL Tejas Mk1/Mk1A, F/A-18 Hornet, T-7A Red Hawk | F/A-18E/F Super Hornet, HAL Tejas Mk2 (planned) | Su-27, Su-30 MKI, J-11 |
| | | | | |
| | | | | |
| Development Cost (Est.) | ~₹3,000 crore (~$360 million) | ~$1 billion (1970s-1980s) | ~$1.5 billion (1990s) | ~$500 million |
| | | | | |
| Year of Completion | 2010 (initial testing) | 1983 | 1998 | 1985 |
| Year of Induction | Not yet inducted. planned for Ghatak UCAV | 1983 (F/A-18), 2003 (Tejas) | 1999 (F/A-18E/F), 2026-2028 (Tejas Mk2 planned) | 1985 (Su-27), 2002 (Su-30 MKI) |

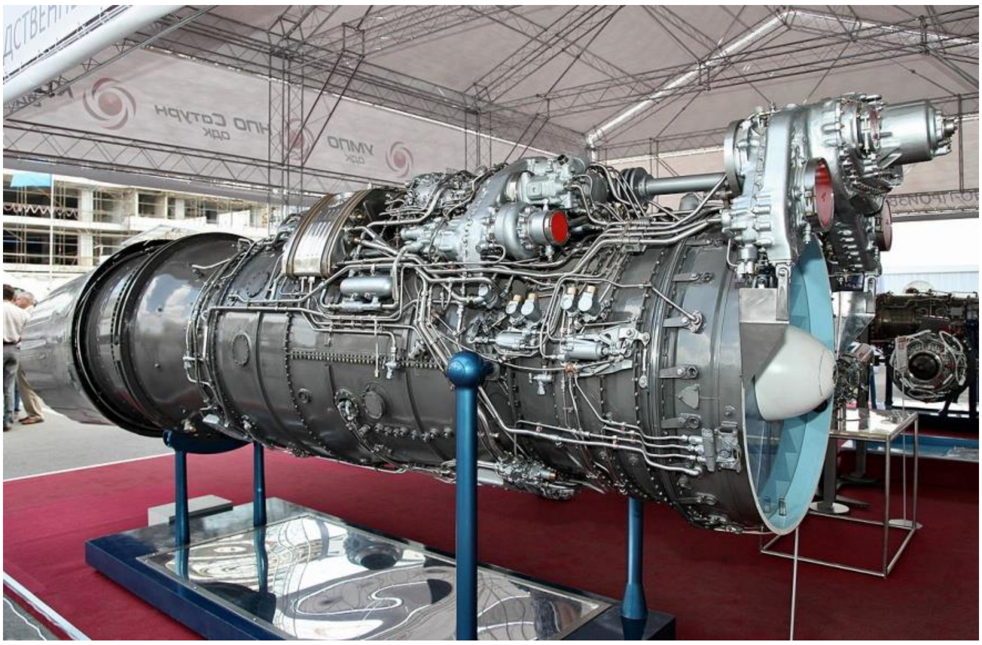
(**Table 4** – Comparison between Kaveri, GE F404, GE F414 and AL-31FP)

(**Source**: Author’s compilation from SlideShare, and GE Aerospace)



(**Fig 20**. F404 Engine)

(**Source** : Asia pacific defence partner)



(**Fig. 21** AL-31FP Engine)

(**Source**: HandWIKI)

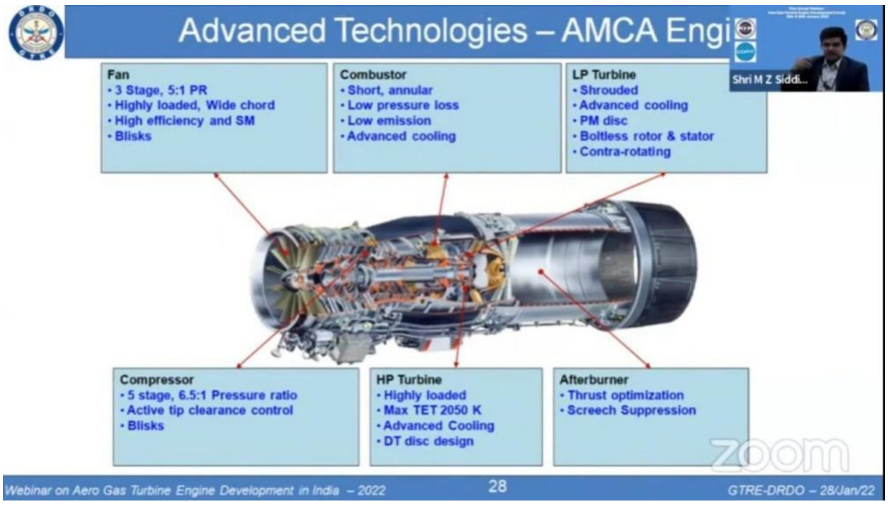
(**Fig. 22** F414 Engine)
(**Source**: Hindustan Times)

**Kaveri 2.0: Overcoming current obstacles**

This program includes the **K9** and **K10** engines, which are being designed to solve the constraints of the original Kaveri engine. The K9 engine serves as a prototype and test bed for the validation of new technologies within a bound flight envelope, whereas the K10 engine is intended to be a production-standard model that is developed with outside collaboration and is designed to provide 90-100 kN of thrust for future aircraft.[61] Kaveri 2.0 incorporates technologies that would improve the thrust capabilities. It is anticipated to achieve a dry thrust of 55-58 kN and a combined afterburner thrust of 90-100 kN, which is in line with engines such as the GE F414. The performance is further improved by making use of advanced materials, including titanium alloys, for lightweight components and nickel-based superalloys for high-temperature portions such as the turbine blades.

**What future might have in its bag?**

The Kaveri engine program, a cornerstone of India's aerospace self-reliance, need to prioritize overcoming technical, financial as well as over reliance on outside sources challenges to achieve what it was planned for if not for a more special one. Collaboration with global partners should be deepened to access critical technologies, while simultaneously increasing resources for research and hence development within the country for the same which is essential for enhancing thrust and performance. Increased investment in indigenous test facilities will ensure development and self-reliance. The success of the Kaveri Marine Gas Turbine and dry Kaveri for UAVs, like Ghatak, highlights the program's flexibility, which should be leveraged to diversify applications. Engaging private industry, as seen with Godrej Aerospace, can accelerate participation, innovation and production. A clear roadmap, with phased milestones and adequate funding, is vital to meet the targets for Kaveri 2.0, enabling integration into future aircraft like the AMCA, thus cementing India's technological sovereignty.




(**Fig**.**23** Advance Technologies for AMCA)[62]
(**Source**: DRDO Webinar)

**Geopolitical Implications**

The Kaveri engine program, one of India's most crucial steps towards self-reliance in a sector that can prove to be a game changer for its aerospace capabilities, is proving out to be a great asset in ensuring India's geopolitical dominance and strategic independence. The program's success or failure carries an inevitable implication for Bharat's defence prowess, regional influence, and a noticeable position in the global aerospace domain. By bringing out a reduction in reliance on foreign technology while simultaneously maintaining strategic partnerships and joint ventures, the Kaveri engine program can prove to be a symbol of stability in an otherwise unstable world as we see of today.

Import of technologies related to aerospace and defence specially that of aero engines has been a vulnerability for decades. There is a risk of disruptions in supply chain due to the present and unforeseen turbulences in the geopolitical arena considering the quantitative aspect of imports. Post Pokhran sanctions were one such disruption as mentioned earlier which denied some most crucial key technologies that was much needed for the program. A successful indigenisation in this regard would bring the most required shift that would shield India from external pressures, such as those sanctions or export controls enhancing its strategic independence and autonomy in a region full of adverse neighbours.

India's position in Indo – Pacific is one such aspect that can be strengthened by our own Kaveri. Being a region marked by a constantly rising tensions, particularly between China and the United States portrayed by few as hotspot of regional powers having a capability to bring global turbulences. India achieving self-reliance in this sector is a much needed one to place an effective counter on Chinese WS-10 and WS-15 engines. It will provide a boost to India's defence capabilities by powering some crucial and advanced aircrafts as mentioned earlier in this brief. Considering volatile situation along Line of Control (LOC) and the Line of Actual Control (LAC), a strong air superiority can provide the much-needed confidence that we as a nation need to assert global dominance. A successful Kaveri engine would also shift the dynamic of negotiations to that of assertion by giving the much-needed position of strength. A fully indigenous Kaveri would reduce enabling it to dictate terms in future collaborations which were not in play for earlier mentioned ones such as with SAFRAN[2] and such. India has a great potential exporter of aerospace technology which is currently dominated by Western powers and Russia also while opening markets in Southeast Asia, Africa, and the Middle East, where countries seek affordable alternatives to Western or Chinese systems. By exporting indigenous engines, India could foster strategic partnerships, countering initiatives like that of Belt and Road Initiative and enhancing its soft power. This aligns with India's broader foreign policy goals of promoting a peaceful and stable international order and strengthening ties with nations in same boat that of us through forums like the Quad, I2U2 and such others.

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[2] SAFRAN – A French multinational corporation specialising in Aerospace and Defence technologies.

## Conclusion

The Kaveri engine program stands as a rock-solid testament to India's relentless commitment to technological sovereignty and self-reliance in the aerospace and defence sectors. What began as a hunt for indigenously developed engine by Gas Turbine Research Establishment (GTRE) under the able guidance of the Defence Research and Development Organisation (DRDO), this ambitious endeavour, spanning over nearly four decades, etched a remarkable narrative of innovation, perseverance, and in a way scientific patriotism. From its inception in 1986 to its recent milestones in 2025, the Kaveri engine represents the spirit of Atmanirbhar Bharat, being a symbol of India's aspiration to master the art of aero-engine development filled with complexities that have been challenging the human kind especially the scientific community. The journey having witnessed several significant achievements such as the successful testing of the Kabini core engine, the development of the Kaveri Marine Gas Turbine (KMGT), and the high-altitude trials of the dry Kaveri variant for unmanned aerial vehicles (UAVs) like Ghatak, has showcases India's scientific prowess and engineering genius. The collaboration with Godrej & Boyce Mfg. Co. Ltd. in 2022, resulting in the fruitful delivery of two Kaveri Derivative Engines (KDE) in April 2025, marks a historic milestone, appreciating and highlighting the involvement of private industry in this critical domain and reaffirming the program's forward momentum. These accomplishments, underpinned by the dedication of luminaries like Dr. T. Mohana Rao and Dr. Kota Harinarayana, to name a few reflect a confluence of vision, technical excellence, scientific prowess and strategic ambition, propelling India closer to its goal of indigenous aerospace dominance.

But one cannot ignore the fact that, the Kaveri program's journey has not been without its own fair share of challenges, and it is necessary that we acknowledge these with a measured and a rational perspective. Having suffered from a significant underfunding, with an allocation of $306 million, which was substantially less than its global counterparts like the GE F404 or Eurojet EJ200, receiving about $1 billion. This financial constraint, along with the post-1998 Pokhran nuclear test sanctions, restricted access to critical technologies such as single-crystal turbine blades and high-performance superalloys, stalling progress at crucial junctures. The 2011 Comptroller and Auditor General (CAG) report laid down additional shortcomings, including personnel shortages, limited experience in aerothermal dynamics, fruitless increase in spending by a significant amount and delays in design finalization, which pushed the project's timeline far beyond its original 1996 completion target. Perhaps most critically, India's reliance on foreign testing facilities, such as those in Russia for high altitude trials, underscores an unfortunate dependency on external infrastructure and raises questions about the authenticity of self-reliance which we are advocating so relentlessly. The lack of advanced indigenous test beds for exploratory altitude tests, flight test bed trials, and other critical evaluations has been a matter of concern, subtly undermining the pace of development and exposing the limitations of India's domestic aerospace infrastructure and necessary investment.

However, one has to stay hopeful about these setbacks, acknowledging the Kaveri program's resilience and work smartly so as to find a pathway forward. To fully realize its potential, India must adopt a multifaceted strategy that balances collaboration with self-reliance. Deepening partnerships with global leaders, as seen in the revival period mentioned in this brief, can provide access to most necessary cutting-edge technologies while fostering knowledge transfer to boost indigenous capabilities. Simultaneously, there is an urgent need for a substantial hike in investments in domestic test facilities such as advanced compressor, turbine, and afterburner test rigs that are essential to reduce reliance on foreign infrastructure and accelerate development cycles. Encouraging private industry participation, as exemplified by Godrej Aerospace's role, should be scaled up to drive innovation, enhance production capacity, and diversify applications, such as those mentioned earlier. A clear, phased roadmap with adequate funding, critical peer reviews, and rational as well as realistic milestones will be crucial to ensure the Kaveri 2.0 program aiming for 90 to 100 kN thrust, meets the demands of future rays of hopes like the Advanced Medium Combat Aircraft (AMCA). By addressing these challenges with strategic foresight, India can transform the Kaveri engine from a symbol of thrust to a dream come true triumph.

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### References

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[1]Bhatt, G. P., and J. L. Shastri, eds. The Skanda Purana Vol. 25 (230.21-30, p. 638) : Ancient Indian Tradition and Mythology. Delhi: Motilal Banarsidass, [n.d.]. PDF. Archive.org, https://dn721609.ca.archive.org/0/items/the-skanda-purana-vol-25-ancient-indian-tradition-and-mythology/The%20Skanda%20Purana%20Vol%2025%20-%20Ancient%20Indian%20Tradition%20and%20Mythology_text.pdf

[2]Admin. 2025. "Kaveri Engine: A Glass More Than Half Full, but India Needs Kaveri 2.0 for AMCA and Tejas Mk2 - Indian Defence Research Wing." Indian Defence Research Wing. June 6, 2025. https://idrw.org/kaveri-engine-a-glass-more-than-half-full-but-india-needs-kaveri-2-0-for-amca-and-tejas-mk2/.

[3]Alphadefense.In. 2024. "GTRE Kaveri Engine – Progess From 2011 CAG Report." Alphadefense.In. June 19, 2024. https://alphadefense.in/index.php/2024/06/18/gtre-past-present-and-future/.

[4] "Kaveri | Defence Research and Development Organisation - DRDO, Ministry of Defence, Government of India." n.d. https://www.drdo.gov.in/drdo/kaveri.

[5] Chawla, Sameer. 2025. "Analysing the Indian Defence Budget 25-26 Part 2 | Blog | Monk Prayogshala." Monk Prayogshala. April 28, 2025. https://www.monkprayogshala.in/blog/2025/4/28/analysing-the-indian-defence-budget-25-26-part-2.

[6] Defenceupdate. 2019. "KAVERI Engine: - the Dawn of Jet Engine Indigenization in India." Indian Defence News. April 15, 2019. https://defenceupdate.in/dawn-jet-engine-indigenization-india-kaveri/.

[7] Chawla, Sameer. 2025. "Analysing the Indian Defence Budget 25-26 Part 2 | Blog | Monk Prayogshala." Monk Prayogshala. April 28, 2025. https://www.monkprayogshala.in/blog/2025/4/28/analysing-the-indian-defence-budget-25-26-part-2.

[8] Saenitk. 2022. "July 2022 – SAE-NITK." SAE-NITK. July 24, 2022. https://saenitk.wordpress.com/2022/07/#:~:text=PAST%20DEVELOPMENTS,required%20procuring%20blades%20from%20SNECMA.

[9] ———. 2022b. "SAENITK." SAE-NITK. July 24, 2022. https://saenitk.wordpress.com/author/saenitk/#:~:text=PAST%20DEVELOPMENTS,required%20procuring%20blades%20from%20SNECMA.
[10] "Technologies and Products | Defence Research and Development Organisation - DRDO, Ministry of Defence, Government of India." n.d. https://www.drdo.gov.in/drdo/technology-cluster-links/labs-products-detail/1077/173.

[11]("Technologies and Products | Defence Research and Development Organisation - DRDO, Ministry of Defence, Government of India," n.d.) "———." n.d. https://www.drdo.gov.in/drdo/technology-cluster-links/labs-products-detail/1077/173.

[12] Sinha, Amartya. 2023. "Indigenous Combat Jets and Kaveri Turbofan Engine: All About IAF'S New Aerospace Plan." India Today, May 16, 2023. https://www.indiatoday.in/amp/india/story/indigenous-combat-jets-and-kaveri-turbofan-engine-all-about-iafs-new-aerospace-plan-2380107-2023-05-16?utm_source=chatgpt.com.

[13] Ibid.

[14] Ahlawat, Sumit. 2024. "India'S Indigenous Fighter Jet Engine Dream One Step Closer to Reality as Kaveri Approved for Inflight Testing." EURASIAN TIMES, December 26, 2024. https://www.eurasiantimes.com/crucial-breakthrough-as-kaveri-engine-approved/?utm_source=chatgpt.com.

[15] Ibid.

[16] Sinha, Amartya. 2023. "Indigenous Combat Jets and Kaveri Turbofan Engine: All About IAF'S New Aerospace Plan." India Today, May 16, 2023. https://www.indiatoday.in/amp/india/story/indigenous-combat-jets-and-kaveri-turbofan-engine-all-about-iafs-new-aerospace-plan-2380107-2023-05-16?utm_source=chatgpt.com.

[17] "Free CAD Designs, Files & 3D Models | the GrabCAD Community Library." n.d. https://grabcad.com/library/tejas-india-s-light-combat-aircraft-1.

[18] Alphadefense.In. 2024. "GTRE Kaveri Engine – Progess From 2011 CAG Report." Alphadefense.In. June 19, 2024. https://alphadefense.in/index.php/2024/06/18/gtre-past-present-and-future/.

[19] Ibid.

[20] Comptroller and Auditor General of India. 2010. "Report on the Audit of the Ministry of Defence, Air Force, Navy, Coast Guard, and Associated Units for the Year Ended March 2009." https://cag.gov.in/webroot/uploads/download_audit_report/2010/Union_Compliance_Defence_Air_Force_and_Navy_16_2010.pdf.

[21] Drdo. n.d. "Engine Kaveri." SlideShare. https://www.slideshare.net/slideshow/engine-kaveri/72606577.

[22] Comptroller and Auditor General of India. 2010. "Report on the Audit of the Ministry of Defence, Air Force, Navy, Coast Guard, and Associated Units for the Year Ended March 2009." https://cag.gov.in/webroot/uploads/download_audit_report/2010/Union_Compliance_Defence_Air_Force_and_Navy_16_2010.pdf.

[23] Ibid.

[24] Ibid.

[25] Ibid.

[26] Viewpoint: New Indian HAL Tejas light multirole fighter Aviation By Colton Jones Jan 24, 2016

[27] Comptroller and Auditor General of India. 2010. “Report on the Audit of the Ministry of Defence, Air Force, Navy, Coast Guard, and Associated Units for the Year Ended March 2009.” https://cag.gov.in/webroot/uploads/download_audit_report/2010/Union_Compliance_Defence_Air_Force_and_Navy_16_2010.pdf.

[28] Ibid.

[29] “India Flight Tests Kaveri Engine in Russia.” n.d. https://www.spacedaily.com/reports/India_flight_tests_Kaveri_engine_in_Russia_999.html.

[30]2023d. “Indigenous Combat Jets and Kaveri Turbofan Engine: All About IAF'S New Aerospace Plan.” India Today, May 16, 2023. https://www.indiatoday.in/india/story/indigenous-combat-jets-and-kaveri-turbofan-engine-all-about-iafs-new-aerospace-plan-2380107-2023-05-16.

[31] Chopra, Air Marshal Anil. 2017. “LCA Tejas: Still a Long Way.” Indian Defence Review, December 1, 2017. https://indiandefencereview.com/lca-tejas-still-a-long-way/.

[32] Dutta, Amrita Nayak. 2023. “Why GE’S Jet Engine for India’S Tejas Is a Big Deal.” The Indian Express, June 23, 2023. https://indianexpress.com/article/explained/ges-f414-jet-engine-lca-tejas-boeing-super-hornet-8678400/.

[33] 2024c. “India’S Indigenous Fighter Jet Engine Dream One Step Closer to Reality as Kaveri Approved for Inflight Testing.” EURASIAN TIMES, December 26, 2024. https://www.eurasiantimes.com/crucial-breakthrough-as-kaveri-engine-approved/.

[34]2010b. “Report on the Audit of the Ministry of Defence, Air Force, Navy, Coast Guard, and Associated Units for the Year Ended March 2009.” https://cag.gov.in/webroot/uploads/download_audit_report/2010/Union_Compliance_Defence_Air_Force_and_Navy_16_2010.pdf.

[35] . 2010b. “Report on the Audit of the Ministry of Defence, Air Force, Navy, Coast Guard, and Associated Units for the Year Ended March 2009.” https://cag.gov.in/webroot/uploads/download_audit_report/2010/Union_Compliance_Defence_Air_Force_and_Navy_16_2010.pdf.

[36] Ibid.

[37] 2023d. “Indigenous Combat Jets and Kaveri Turbofan Engine: All About IAF'S New Aerospace Plan.” India Today, May 16, 2023. https://www.indiatoday.in/india/story/indigenous-combat-jets-and-kaveri-turbofan-engine-all-about-iafs-new-aerospace-plan-2380107-2023-05-16.

[38] n.d. https://www.drdo.gov.in/drdo/technology-cluster-links/labs-products-detail/1589/173#:~:text=Labs&text=Kaveri%20Marine%20Gas%20Turbine%20engine,from%20providing%20a%20clean%20environment.

[39] . DRDO develops marine gas turbine engine, Oneindia, By staff - Published: Thursday, July 17, 2008, 13:22 [IST]

[40] "Kaveri Marine Gas Turbine | Defence Research and Development Organisation - DRDO, Ministry of Defence, Government of India." n.d. https://drdo.gov.in/drdo/kaveri-marine-gas-turbine.

[41] Defence Science Library. 2024. "Newspaper Clippings." Https://Www.drdo.gov.in/. https://www.drdo.gov.in/drdo/sites/default/files/drdo-news-documents/NPC25to26Dec2024_0.pdf.

[42] Bansal, Shantanu K. 2021. "India May Early Induct Ghatak UCAV Amid Tensions With China." - IADN. October 29, 2021. https://iadnews.in/india-may-early-induct-ghatak-ucav-amid-tension-with-china/.

[43] "48 kN Thrust 'Dry Kaveri' Engine for Ghatak UCAV Set for Flight Testing on IL-76 Platform in Russia Next Year." 2024. Defence News India. December 28, 2024. http://defence.in/threads/48-kn-thrust-dry-kaveri-engine-for-ghatak-ucav-set-for-flight-testing-on-il-76-platform-in-russia-next-year.12048/.

[44] . ———. 2024d. "India'S Indigenous Fighter Jet Engine Dream One Step Closer to Reality as Kaveri Approved for Inflight Testing." EURASIAN TIMES, December 26, 2024. https://www.eurasiantimes.com/crucial-breakthrough-as-kaveri-engine-approved/.

[45] Ibid.

[46] The Hindu Bureau. 2023. "Godrej Aerospace to Make 8 Modules of DRDO Turbojet Engine." The Hindu. February 20, 2023. https://www.thehindu.com/business/godrej-aerospace-to-make-8-modules-of-drdo-turbojet-engine/article66532378.ece#:~:text=Godrej%20&%20Boyce%2C%20the%20flagship%20company,An%20error%20has%20occurred.

[47] "Flying High India's New Defence Kaveri Engine | DSA." n.d. https://www.dsalert.org/article/flying-high-indias-new-defence-kaveri-engine.

[48] "Godrej Aerospace Delivers 2 Modules of Kaveri Derivative Engine (Dry Kaveri) Engine; 6 Additional Modules Under Development." n.d. https://www.indiandefensenews.in/2025/04/godrej-aerospace-delivers-2-modules-of.html#:~:text=In%20September%202022%2C%20the%20Defence,derivative%20engine%20without%20an%20afterburner.

[49] Tai, Vin Cent, Phen Chiak See, Cristinel Mares, and Kjetil Uhlen. 2012. "Optimisation of Energy and Exergy of Two-Spool Turbofan Engines Using Genetic Algorithms." July 3, 2012. https://www.researchgate.net/publication/228103019_Optimisation_of_energy_and_exergy_of_two-spool_turbofan_engines_usinggenetic_algorithms.

[50] GE Aviation. n.d. "What Is a Spool and Why Does It Matter?" https://www.geaerospace.com/sites/default/files/t901-what-is-a-spool.pdf.

[51] " n.d. https://www.grc.nasa.gov/www/k-12/airplane/aturbf.html.

[52] "Turbofan Engine." n.d. https://www.grc.nasa.gov/www/k-12/airplane/aturbf.html.

[53] "Afterburner." 2022. SKYbrary Aviation Safety. June 19, 2022. https://skybrary.aero/articles/afterburner.

[54] "Building a Turbofan Twin Spool Engine - Full Metal Aircraft Jet Engine Kit." n.d. YouTube. https://www.youtube.com/shorts/WkeNArSWq1Q.

[55] "GTRE Kaveri Engine." 2022. Strategic Front Forum - Indian Defence and Strategic Forum. January 30, 2022. https://www.strategicfront.org/forums/threads/gtre-kaveri-engine.93/page-42#post-212014.

[56] 2025. X (Formerly Twitter). 2025. https://x.com/Varun55484761?t=Ew9VuGPfc4oRrzCtFZs_9w&s=09.

[57] https://www.slideshare.net/slideshow/engine-kaveri/72606577.

[58] "F404 Engine | GE Aerospace." n.d. https://www.geaerospace.com/military-defense/engines/f404.

[59] "F414 Engine | GE Aerospace." n.d. https://www.geaerospace.com/military-defense/engines/f414.

[60] Kudal, Mohit. n.d. "Assembly of Al31 Fp." SlideShare. https://www.slideshare.net/slideshow/assembly-of-al31-fp/244326541.

[61] Chacko, Joseph P, and Joseph P Chacko. 2025. "Kaveri 2.0 Overcoming Limits to Power India's Aircraft." Raksha-Anirveda.com. April 8, 2025. https://raksha-anirveda.com/kaveri-2-0-overcoming-limits-to-power-indias-aircraft/.

[62] Sengupta, Prasun K. 2022. "Turbofan & Turboshaft R & D Challenges for India." Blogspot.com. 2022. https://trishul-trident.blogspot.com/2022/06/turbofan-turboshaft-r-d-challenges-for.html.