

## **CHAPTER V: RESEARCH AND DEVELOPMENT ORGANISATION**

### **5.1 Inordinate delay in fruition of Kaveri engine**

**Despite almost two decades of development effort with an expenditure of Rs 1,892 crore, GTRE is yet to fully develop an aero-engine which meets the specific needs of the LCA. The successful culmination of the project to develop an aero-engine through indigenous efforts is now dependent upon a Joint Venture with a foreign vendor.**

#### **Introduction**

In order to overcome the attrition of combat aircraft in the Indian Air Force (IAF) during the 1990s and beyond, the Government sanctioned in August 1983 the development of a multi-role Light Combat Aircraft (LCA), at an estimated cost of Rs 560 crore. Accordingly, there was a corresponding demand for a suitable engine for powering the LCA. Feasibility studies carried out in India and abroad revealed that there was no suitable engine available anywhere in the world, though Rolls Royce RB-1989 stage D and GEF404-F2J engines, by and large, met the requirement, provided certain concessions were granted in the Air Staff Requirements (ASR). At this point of time, the Gas Turbine Research Laboratory was already working upon an aero-engine project, the GTX 37<sup>1</sup> engine, since 1982.

In August 1986, a feasibility study was carried out jointly by Aeronautical Development Agency (ADA), Hindustan Aeronautics Limited (HAL) and Gas Turbine Research Establishment (GTRE) for evaluating the GTX-37 engine. The feasibility study indicated that the GTX-37 engine would, after certain rescheduling, meet the requirements of the LCA. GTRE accordingly, in

---

<sup>1</sup> A Research and Development project for building a gas turbine engine which was expected to find application in future indigenous combat aircraft programmes.

December 1986, submitted a project proposal for the development of the Kaveri engine. GTRE further proposed that it would be desirable to prove the newly designed airframe of the LCA with a proven engine first. Subsequently, the prototypes would be flown with the GTX-35<sup>2</sup> engine, as soon as this engine was type certified and cleared for the flight. Based on the above proposal, Government sanctioned a project in March 1989 at a cost of Rs 382.81 crore with the probable date of completion (PDC) as December 1996, for the design and development of Kaveri engine.

The Kaveri Engine Project was sanctioned with the following basic objectives:

- Designing and developing the GTX-35 engine to meet the specific needs of the LCA.
- To create a full fledged indigenous base to design and develop any advanced technology engine for future military aviation programmes.
- The engine so developed was to establish its performance integrity in various categories of tests prescribed by the aero-engine industry world over.

Given that the development of the Kaveri engine is critical to the establishment of indigenous expertise in the field of aerospace engineering, audit examined the Kaveri Engine Development Project (KEDP) from the initiation of the project till date (with emphasis on the period 2002-08), and the achievement of the goals and objectives set in the project, with reference to economy, efficiency and effectiveness. The audit findings were forwarded to the Ministry in November 2008; their reply was received in January 2009 and has been taken into account while finalising the audit findings. Findings of the audit study follow:

## **I Time and cost over-run**

In developing an aero-engine for the LCA, GTRE faced a multi-dimensional challenge of developing a highly sophisticated and complex deliverable from a background which was significantly deficient in the required expertise and

---

<sup>2</sup> Later renamed as Kaveri engine

experience in the area. Audit scrutiny revealed that in so far as turbo fan technology of engines, GTRE had only a very limited experience of the GTX engine behind it. At the time of sanctioning of the project, GTRE had to nearly double its sanctioned strength of trained manpower to cope with the target. Even today, the institute is beset by shortages in the scientific and technical branch personnel which are affecting the progress of the project. Owing to inadequate planning, many elements of the project viz. Flight Test Bed Trials and altitude testing were not conceptualised /included in the initial project proposal and were added later only at the insistence of the IAF.

In the absence of realistic planning and programme formulation which took into account constraints of scope, time and money, the development of the Kaveri engine has been beset by delays in almost all vital components of the engine. When the original completion date of December 1996 could not be met, GTRE secured an extension till March 2000 based on the recommendations of a peer review 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. However, GTRE was unable to meet this extended target date also due to changes in design and material flowing from (a) design review, (b) flaws in design of a particular part like the compressor or (c) failure in performance. Although a revised PDC, i.e. December 2004 was approved, ultimately, the PDC was further postponed to December 2009. The justification for extension was the same once again as GTRE was unable to freeze a design as per requirements and further refinements were required. Besides non-availability of certain systems from vendors, indigenous development of accompanying systems was also not successful as a result of which there were delays.

Milestone	Originally planned date	Completion date	Revised PDC	Position as on 08/09	Delay
Core Engine demonstration	12/90	3/95	-	Achieved	4 yrs plus
Full Engine demonstration	6/92	9/95	-	Achieved	3 yrs plus
High Altitude tests	6/94	-	12/06	Not achieved	15 yrs
Preliminary Flight Rating Test	12/95	-	12/07	Not achieved	14 yrs
Type test	6/96	-	6/08	Not achieved	13 yrs
FTB	9/98	-	5/07	Not achieved	11 yrs
Production clearance	12/96	-	12/09	Not achieved	13 yrs

All in all, only two out of six milestones prescribed could be achieved and those too, with delays ranging from 3 to 15 years. Over all, the project has been already delayed by over 12 years.

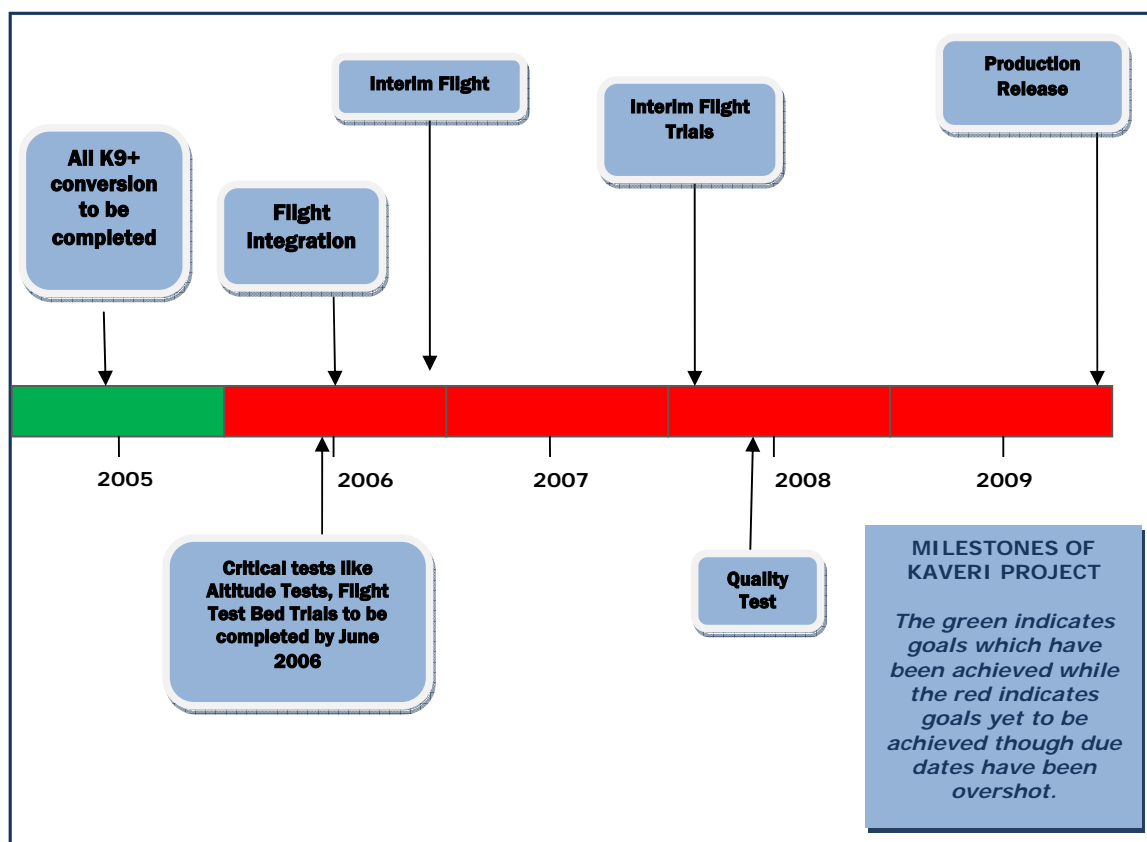
Financially also, the project has witnessed steep cost increases. The initial sanction of the Government stipulated that the KEDP was to be executed at a cost of Rs 382.81 crore {Foreign Exchange (FE) Rs 155.39 crore}. Subsequently, there were five revisions in the cost of the project, whereby, the project cost was revised to Rs 2,839 crore (FE Rs 1,730 crore). As of March 2010, there has been a 642 *per cent* increase in project costs and 1,013 *per cent* rise in foreign exchange element since inception.

Accepting the facts, the Ministry of Defence (Ministry) stated, in January 2009, manpower was an issue and that the depleting strength of skilled and expert manpower could not be replenished at the same rate. The Ministry sought to explain that the KEDP was an extremely complex technological effort and owing to inadequate knowledge and available data, the cost projections were not appropriate in the beginning. The Ministry, however, defended the development effort by asserting that the experience gained has made GTRE realise that such development work is really costly and time consuming manifold in comparison to the estimates projected. Ministry further stated that no engine house was willing to part with their development experience for the benefit of GTRE as they viewed GTRE as a competitor.

## **II Tardy progress in Full-design intent**

The engine development was to address all associated issues of design, manufacturing, development testing, material development, airworthiness certification and production. This technology intensive programme sought to demonstrate technologies component-wise in the core engine (C series) and the full engine (K series). As the development of the engine has progressed, the engine has been rebuilt many times. Thus, though the project started with the presumption that 10 prototypes would be built, this was later modified to 42. At present, GTRE has developed seven Kaveri engines and three core engines along with necessary spares manufactured mostly in India and assembled at GTRE.

KEDP has been reviewed twice in 2000 and 2004, since its inception by the competent financial authority (CFA). The latest approval granted by CFA in November 2004 prescribed target dates for critical activities in order to achieve key milestones of flight trials of the Kaveri engine. A primary goal was conversion of five existing Kaveri engines (K5 to K9 series) to K9+ standard so as to realize K10, which is the full design intent of Kaveri engine. However by August 2009, only two engines have been upgraded to K9+ standard as against the scheduled date of May 2005. The details of important milestones are indicated in the chart.

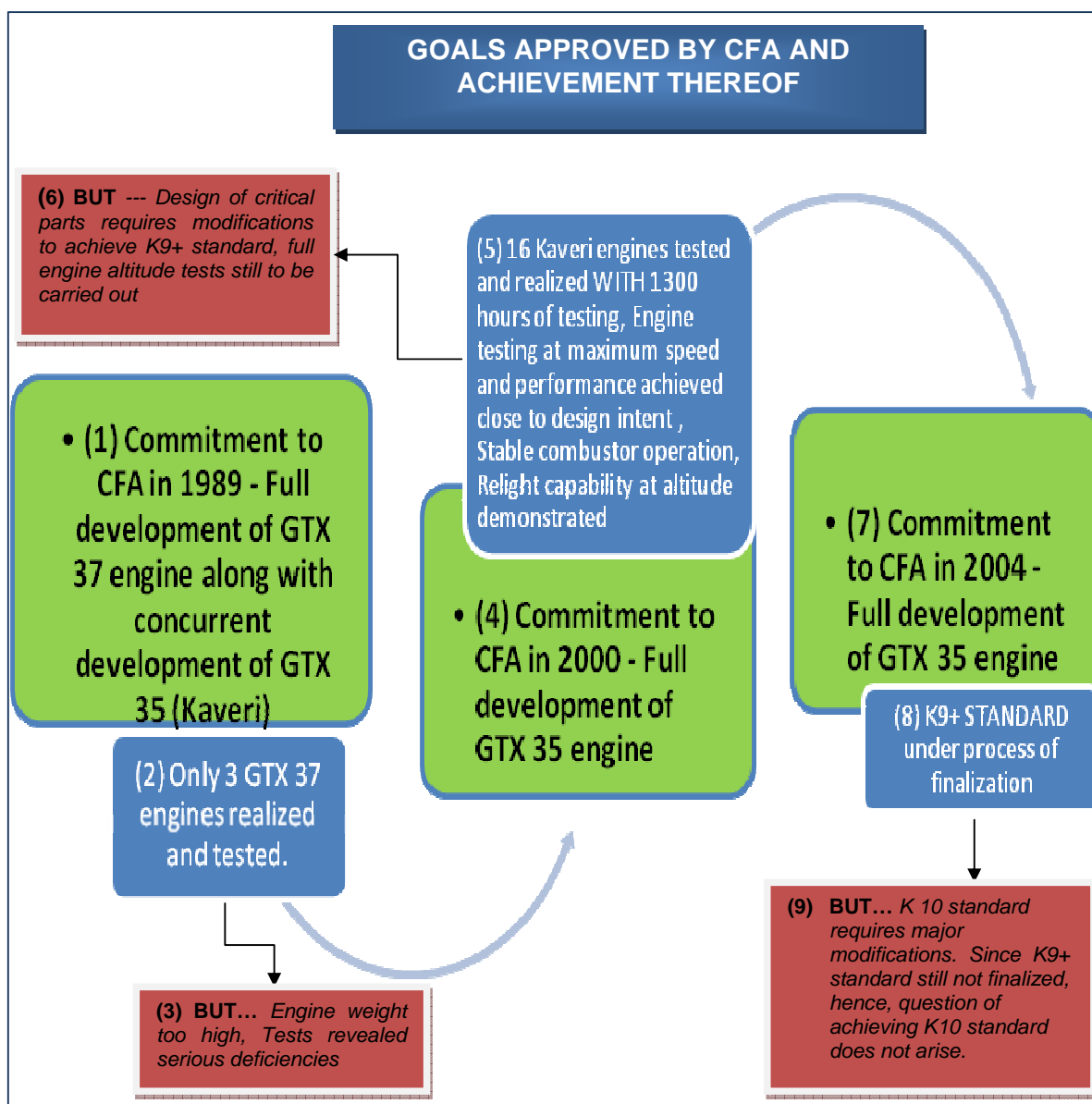


Audit scrutiny revealed that despite being unable to achieve primary goals, GTRE made new commitments to the CFA. Rather than highlighting actual outcomes, both in 2000 and 2004, GTRE focused more on activities undertaken like infrastructure created, conduct of various trials and partial successes in attaining associated goals as illustrated below.

**Illustration 1:** 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. It was further claimed that the designed engine was marginally short of the full design which would be realized by 2004. In 2004 again, the proposal stated that the full design intent, i.e a flight worthy K10 engine, would be realised by the revised PDC of December 2009.

**Illustration 2:** The main proposal of 2004 claimed that the programme had reached a reasonable level of maturity and, therefore, suggested that at this stage possibilities of combining with modules of other proven engine builders

could be exploited to expedite development. The annexures to this main proposal, however, showed that almost all critical components like compressor, combustor and turbine needed re-designing. The non-achievement of goals is illustrated below:



Ministry stated, in January 2009, that the revisions in cost and extensions in time were sought based on the situation for sustaining the project and were inescapable. They further stated that GTRE provided all facts and figures to the CFA for cost/PDC revisions with proper technical and financial justification. Ministry added that though GTRE has not been able to deliver the engine for LCA, however, they have reached a stage where two leading engine houses have come forward to collaborate in the project.

Audit, however, reiterates that the actual status of development of the engine was not clearly intimated to the CFA as is brought out above.

### **III Shortcomings in the engine developed**

Despite incurring an expenditure of Rs 1,892 crore (Annexure-III) as of March 2010, the engine developed has many problems.

- ✘ The weight of Kaveri engine required to fly the LCA should not exceed 1100 Kg. The first assembled Kaveri K1 engine weighed around 1423.78 Kg. Therefore, GTRE embarked on a weight reduction plan as early as July 1993. However, due to delay in development of the component assemblies/modules, polymer composites, design and freezing, GTRE has not been able to achieve the derived weight in the engine and, as of January 2009, the engine weighs 1235 Kg.
- ✘ Certain critical and crucial activities for successful development of Kaveri, viz. development of Compressor, Turbine and Engine Control System, have been lagging behind despite increase in cost by Rs 186.61 crore.
- ✘ GTRE has been unable to freeze the design of the turbine blades, the compressor has witnessed mechanical failure in performance and the engine control system is not flight-worthy.



Ministry stated, in January 2009, that the target of reducing engine weight by 135 Kg is expected to fructify only around production phase.

Testing of the existing engines has also indicated short-comings. Various tests have to be undertaken at stages in order to test the different modules of the Kaveri engine for quality, efficiency and endurance. Audit found that critical tests for components have not been carried out owing to the absence of facilities. More significantly, tests carried out to evaluate the engine itself have revealed the following deficiencies:

SL. No.	Nature of test	Cost	Status
1.	Component Testing	Rs 142 crore	Despite lapse of nine years since original sanction, most of the tests, including EAT, OAT, PFRT, QT have not been completed.
2.	Kaveri Compressor Drum Test	Rs 6 crore	The test delayed was completed only in September 2009. The test is mandatory for proving airworthiness and only after its successful completion can components be cleared for fitment into engine.
3.	Altitude test	Rs 127 crore	Not even a single altitude test, which is essential for assessing whether an engine can actually fly an aircraft, could be completed on Kaveri engine.
4.	Flight Test Bed trials	Rs 39.60 crore	No FTB trials on Kaveri engine could be conducted (as of July 2009) due to delay in manufacture of critical components of the engine.

Accepting the facts, the Ministry stated that delays in tests like EAT<sup>3</sup>, OAT<sup>4</sup>, PFRT<sup>5</sup> and QT<sup>6</sup> have increased the project cost quite substantially and that GTRE is putting all efforts to bridge the gap as early as possible. The

<sup>3</sup> EAT – Exploratory Altitude Test  
<sup>4</sup> OAT – Official Altitude Test  
<sup>5</sup> PFRT – Preliminary Flight Rating Test  
<sup>6</sup> QT – Qualification Test

Ministry added that the Altitude test on K8 engine is slated for 2009, however, FTB trials cannot commence till the performance of engine modules are proven to the desired level.

#### **IV Inadequate Monitoring of the Project**

The KEDP is monitored by a three-tier-structure which has the Aero-Engine Development Board (AEDB) at the top, followed by the Programme Management Board (PMB) and the Project Management Board (PJMB). The boards consist of members drawn from the DRDO, Ministry of Defence and Indian Air Force. Audit noted that meetings of AEDBs were not held as per the prescribed schedule of once in six months and there were delays in holding the meetings ranging from 3-12 months. Considering that AEDB was the highest level of monitoring mechanism and was responsible for monitoring the activities of KEDP, the fact that there were significant gaps in between its meetings is indicative of inadequate control.

The Ministry stated that there had been some delays in holding the meetings of the Apex Board which was beyond the control of GTRE since the members of the Board were from various Ministries and Departments.

#### **V Indigenous objective not achieved**

While trying to achieve long-term objective of self-reliance, establishing expertise in defence acquisitions, there is a need to achieve a realistic balance between the existing capacities in the country with the urgency/timelines involved in the planned acquisition. Alternative paths of development like entering into a joint venture with an established engine house with transfer of technology were not explored before embarking on this ambitious period. In general, GTRE has sought technical opinion on various aspects of design, manufacturing and testing from various foreign agencies. For instance, Snecma of France has been involved in the Project since very inception in various Critical Design Reviews (CDR) and have been paid Rs 4.07 crore till September 2001. In June 2000, the project suffered a major setback due to mechanical failure of the new compressors rotor blade. This necessitated a CDR and the review conducted in September 2001 led to a number of useful

design inputs. Snecma, was extended an invitation to participate in either joint development or in providing design assistance, which was declined. Instead, Snecma proposed a joint development partnership for Kaveri in September 2001. However, GTRE did not accept the offer on the plea that this would necessitate the abandonment of all the indigenous efforts made so far.

Notwithstanding the stand taken by them in September 2001, GTRE, seven years later (2008) is seeking a proposal from Snecma for a Joint Venture (JV) involving co-design and co-development of an aircraft engine. Ironically, though GTRE obtained the approval of the CFA in 2004 for extension of the PDC of indigenous development of Kaveri engine to December 2009, it started the process of entering into a JV with an established foreign engine manufacturer in 2005 itself. Given that the Request for Proposal floated for this purpose clearly states that the vendor would be in a lead role for development of combustor, compressor and turbines and GTRE would be only in an assist role, it is evident that GTRE is not adhering to the original sanctioned goals regarding indigenisation.

The Ministry stated, in January 2009, that since the original performance of Kaveri engine is not adequate, Joint Venture engine was proposed. Besides, in order to meet the enhanced performance of LCA, GTRE had to seek help from foreign engine houses and finally chose Snecma as the partner. Through this, higher level technologies would be available though the core will also be used for improving the remaining modules of GTRE.

## **VI LCA will not fly with Kaveri**

The prime objective has not been achieved and GTRE has not been able to deliver an engine that could power the LCA. Meanwhile, 41 GE engines for the LCA have been procured at a total cost of Rs 883 crore. HAL the manufacturer of the LCA, has an option for purchasing 98 more engines from General Electric, USA

## **VII Conclusion**

The Kaveri Engine Development Project is an ambitious project aimed at indigenisation of the propulsion system for LCA. However, the prime objective of the project has not been achieved and GTRE has been unable to deliver an engine that could power the LCA despite a cost overrun of 642 *per cent* and delay of about 13 years. The project is now faced with the alternative of entering into a joint venture with a foreign house for further development of the engine. Even after about two decades, since its sanction, the probable outcome of the project vis-à-vis its objectives in near future cannot be foreseen clearly.

**New Delhi**  
**Dated:**

**(GAUTAM GUHA)**  
**Director General of Audit,**  
**Defence Services**

**Countersigned**

**New Delhi**  
**Dated:**

**(VINOD RAI)**  
**Comptroller and Auditor General of India**