ARCHIVED REPORT

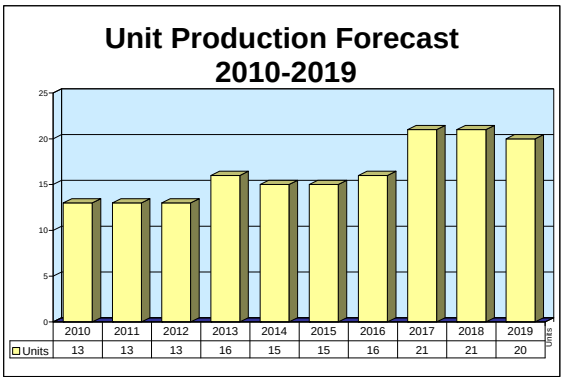
For data and forecasts on current programs please visit

www.forecastinternational.com or call +1 203.426.0800

GTRE GTX-35 - Archived 6/2011

Outlook

- General Electric F414 and Eurojet EJ200 under consideration to replace GTX-35
- GTRE and Snecma have teamed to finish GTX-35 development



Orientation

Description. Two-shaft, axial-flow, augmented aviation turbofan engine. Major emphasis is on the GTX-35VS (also referred to as the GTX-35V) turbofan engine. The GTX-35VS engine is also known as the "Kaveri."

Sponsor. Engine work has been partially sponsored by India's Ministry of Defence through the Gas Turbine Research Establishment (GTRE).

Program Management. GTRE; Bangalore, Karnataka, India.

Power Class. Approximately 11,376 lbst (50.6 kN) dry and 18,210 lbst (81.0 kN) augmented.

Status. In the later stages of engineering development.

Total Produced. As of April 2010, at least 12 GTX-37/35 engines had been fabricated for bench testing and further concept/hardware definition.

Application. Light combat aircraft, including trainers; tactical support aircraft.

Model Variant	A/B Thrust Rating	Application	Units per Airframe
GTX-35VS (Kaveri)	18,210 lbst (81.0 kN)	HAL Light Combat Aircraft (LCA) (Tejas)	1

Price Range. Estimated in 2010 U.S. dollars at $2.7-$2.9 million. It is currently not known what the engine's price will be if it becomes available in 2011.

Competition. The GTX-35VS (Kaveri) engine, rated at 18,210 lbst, will face competition from such engines as the GE F414, Klimov RD-33, Snecma M88, Eurojet EJ200, and Volvo RM12B – all of which are currently in production.

GTRE GTX-35

Contractors

Prime

Hindustan Aeronautics Ltd - Engine Division, Bangalore Complex	http://www.hal-india.com, PO Box 9310, C V Raman Nagar, Bangalore, 560 093 India, Tel: + 91 80 5243628, Fax: + 91 80 5244686, Prime

Comprehensive information on Contractors can be found in Forecast International's "International Contractors" series. For a detailed description, go to www.forecastinternational.com (see Products & Samples/Governments & Industries) or call + 1 (203) 426-0800.

Contractors are invited to submit updated information to Editor, International Contractors, Forecast International, 22 Commerce Road, Newtown, CT 06470, USA; rich.pettibone@forecast1.com

Technical Data

Design Features. The GTRE/HAL GTX-35VS (Kaveri) engine has the following design features:

Fan. A three-stage transonic fan, designed for good stall margin.

LP Compressor. Three-stage transonic LP compressor with transonic blading. Fixed inlet guide vanes.

HP Compressor. Six-stage HP compressor with variable inlet stator vanes on the first two stages. Overall engine compression ratio is approximately 21.0:1.

Combustion System. Convergent-divergent short annular system with step diffuser.

HP Turbine. Single-stage heavily loaded HP turbine, initially using directionally solidified (DS) cooled blades. Incorporation at a later date of single-crystal (SC) cooled blades and thermal-barrier coatings.

LP Turbine. Single-stage heavily loaded LP turbine. Initial use of directionally solidified blades, perhaps later replaced by SC blades.

Accessories. A Full Authority Digital Engine Control (FADEC) system has been developed by HAL's Lucknow Division in conjunction with Smiths Group plc in Chelteham, Gloucester, U.K.

Dimensions. While the dimensions/weights of the GTX-35VS (Kaveri) engine have not been released, at a thrust-to-weight ratio of 7.8:1, the augmented engine is estimated to weigh slightly more than 2,330 pounds (1,056 kg).

Performance. The GTX-35VS (Kaveri) engine has the following performance parameters:

	Metric Units	U.S. Units
Thrust, with A/B	81.0 kN	18,210 lbst
Thrust, unaugmented	52.0 kN	11,690 lbst
Thrust-to-Weight Ratio	7.8:1	7.8:1
Overall Pressure Ratio	21.5:1	21.5:1
Bypass Ratio	0.161:1	0.161:1
Air Mass Flow	78 kg/sec	171.9 lb/sec
TET	1,214-1,427°C	2,217-2,600°F

Variants/Upgrades

GTX-37-14U. The GTX-37-14U augmented turbojet is the initial GTX-35 engine variant. Development began in 1977. This model was quickly supplanted by other variants with different designs.

GTX-37-14UB. The GTX-37-14UB is a turbofan variant based on the original turbojet core; it has a bypass ratio of 0.2:1. The variant was rated at over 20,000 lbst (89 kN). Originally proposed for the LCA, this engine variant was not selected owing to its large frontal area.

GTX-35. The GTX-35 is the straight turbojet, initially intended for the LCA. This variant was not selected

either, due to its very high specific fuel consumption (SFC).

GTX-35VS. The GTX-35VS (Kaveri) engine (also referred to as the GTX-35V) is an improved turbofan engine designed for use in the production-standard LCA aircraft. The engine is of modular design. The first preproduction-standard engine ran in 1991. When this variant becomes available (perhaps in 2011), it will be the standard-offered engine for the LCA.

Program Review

Background. India's Gas Turbine Research Establishment (GTRE) was formed in 1959 in Kanpur, and relocated in 1961 to Bangalore. It is one of the largest R&D facilities administered by India's Ministry of Defence through the Defence Research and Development Organization (DRDO). It is involved in the study of, for example, variable-geometry compressors, high-intensity combustors, high-pressure-ratio centrifugal compressors, structures, and control systems. In addition, it conducts combustion research using flow-visualization techniques, does data processing, and performs real-time engine simulation.

The early aero-engine work in the GTX series was aimed at the GTX-37, an engine developing 9,920 lbst (44.12 kN) dry and 14,550 lbst (64.72 kN) with afterburner. The current activity is focused on the GTX-35VS, a refined version of the GTX-37 developing 11,380 lbst (50.61 kN) dry and 18,750 lbst (83.4 kN) with afterburner. All materials for the GTX-35VS are being supplied by the Indian firm Mishra Dhatu Nigam (MIDHANI) in Hyderabad; alloys include titanium, aluminum, nickel, and zirconium. Development work has largely been moved to Russia's Moscow-based Central Institute for Aviation Motors.

In early 2003, GTRE disclosed that it expected the first fully certificated GTX-35 to be approved for installation on its intended host aircraft, the LCA (see below), sometime in 2007. The announcement followed a decision to build a rebladed prototype and (starting in 2004) conduct full-scale testing of the new design. Low-pressure ratios and vibration problems were cited as the reasons for this redesign effort. Meanwhile, the Russian facility was expected to conduct about 250 hours of high-altitude simulations and other tests using the current prototypes.

HAL GTX-35 Applications. The sole intended application of the GTRE/HAL GTX-35VS (Kaveri) engine is the Indian Light Combat Aircraft (LCA).

Indian Light Combat Aircraft. The LCA is a single-engine, single-seat, delta-wing, high-performance, multirole combat aircraft whose airframe is being designed in India, with production to be done by HAL's aircraft unit. The aircraft is intended to have a maximum T-O weight of 18,740 pounds (8,500 kg) and a maximum level speed of Mach 1.6. The aircraft program's concept was approved in 1978, and in 1983, the Indian government gave the go-ahead decision. The program was officially launched in 1985.

The initial engines for the LCA program's two prototype aircraft are GE Aircraft Engines F404s (F404-GE-F2J3).

While the LCA program appears to have selected the 18,210-lbst (81.0-kN) GTRE GTX-35VS (Kaveri) engine for production-standard LCA models, the Eurojet EJ200 (at 20,250 lbst [90 kN]) was offered as an interim engine until the GTX-35 becomes available. The Snecma M88 has also been offered as an interim engine. India had claimed that it would wait until the GTX-35 was available before initiating series production of the LCA, while using the GE F404 for aircraft flight testing on 13 prototypes and technology demonstrators.

Recent reports circulating in India imply that the Indian Air Force may be losing much of its enthusiasm for the program (which has already been over 22 years in development); the aircraft's operational clearance is not realistically anticipated much before 2012. Critics of the project also claim that HAL is unlikely to build more than 10 aircraft per year if the program goes forward, meaning that the planned complement of 200 LCAs would not be in service until some time after 2030.

Problems with the Kaveri have been well documented, and it is expected that the first 20 or so production aircraft would be powered by GE F404s.

Forecast International believes that the LCA/Tejas program is a prime candidate for cancellation. Ultimately, the flying prototypes may serve as testbeds for another indigenous aircraft, the Medium Combat Aircraft (MCA).

India continues to be wooed by Western and Russian manufacturers vying for a new 126-unit fighter requirement, and all the while India is building Sukhoi Su-30s under license. Should the LCA program be terminated, either (or both) of those projects could be expanded.

It is difficult to gauge the Indian government's current commitment to the LCA program in light of its problems. At this time, we will assume it will continue

GTRE GTX-35

in the interests of national pride and expanding the country's technology base.

However, Forecast International believes that only about half of the originally planned 200 aircraft will be procured, and we are projecting that initial deliveries will begin at the end of 2011.

Related News

Built for Indian Air Force, Kaveri Engine Chosen for Navy Ships – The Indian Kaveri aircraft engine lacks the muscle needed by India's Tejas light combat aircraft, which the engine was designed to power. But the engine's technology will not be wasted. The Indian Navy is snapping up the Kaveri for powering its growing fleet of warships. The Navy has officially informed the Gas Turbine and Research Establishment (the DRDO laboratory that developed the Kaveri) that naval warships will need 40 Kaveri Marine Gas Turbines (KMGTs) over the next 15 years. In an important signal of its support, the Navy has agreed to fund 25 percent of the cost of the KMGT project. (*Business Standard*, 9/09)

Timetable

Month	Year	Major Development
	1959	GTRE established
	1978	LCA concept proposed
	1983	Indian government gives LCA go-ahead decision
	1983	LCA program officially launched
Mar	1989	GTX-35 approved for full-scale engineering development
	1995	LCA rolled out
	2001	First flight of LCA with GE 404
	2002	Second LCA prototype makes its first flight
	2007	HAL orders 24 additional GE F404 engines
Thru	2016	Continued production of LCA engine

Worldwide Distribution/Inventories

As of April 2010, at least 12 GTX-35 engines had been assembled for testing and further hardware definition. Apart from the engines being tested and evaluated in the **Russian Federation** at the Central Institute for Aviation Motors, other engines are believed to be located in **India**.

Forecast Rationale

The GTX-35 appears to be on the verge of cancellation, and might be replaced by another engine on the Tejas fighter (Light Combat Aircraft). After a development program lasting over 20 years without producing a successful engine, the GTX-35 may, instead of powering an aircraft, find itself supplying power on Indian Navy vessels. In early 2008, India's Defense Research and Development Organization (DRDO) had teamed with Snecma to help complete development of the Kaveri for the LCA program.

F404s Sourced from General Electric

GE provided its F404-GE-IN20 engine for LCA prototypes and the initial series-production aircraft. Flight testing showed the F404 had insufficient thrust and didn't meet the design specifications, so the search for a higher thrust engine began. Two potential candidates are being considered: GE's F414 and Eurojet's EJ200. The commonality between the F404 and F414 leads us to believe it has the upper hand, as it would minimize the program delay. India's air force reportedly needs 88 Tejas fighters to be in service by 2017 to replace the large number of MiG-21s being retired. The IAF schedule calls for the Tejas to reach IOC by the end of 2010 and full capability by 2012. Needless to say, switching engines so late in the program will complicate matters and make meeting the Air Force's deployment schedule a challenge.

We believe the LCA will ultimately fly with either the F414 or EJ200. In light of this, we are forecasting that 117 engines will be produced (in addition to the F404s for the initial production aircraft) for the LCA from 2010-2019.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR UNIT PRODUCTION												
Designation or Program		**High Confidence**				**Good Confidence**			**Speculative**			
	Thru 2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**Total**
GE - Aviation												
F404 -GE-IN20 Military <> India <> LCA												
	9	13	12	12	9	0	0	0	0	0	0	46
MFR Not Selected												
LCA Engine Military <> India <> LCA												
	0	0	1	1	7	15	15	16	21	21	20	117
Total	9	13	13	13	16	15	15	16	21	21	20	163