Abstract

The development in the field of gas turbine engine from first generation to fifth generation is evident from the history. The ever changing requirement has driven continuous development in the area and has led the designers to struggle for best propelling machine to fly. In the global scenario it is evident that for keeping up with the pace of advancements in the gas turbine engine field, expertise is required for each subsystem/module. Major design houses of the world are now adopting an approach of developing expertise in a specialized area of aero engine development. Having developed the expertise in a specialized area, the complex aero engine can be developed through the joint venture route. In a country like India this new development philosophy through joint venture has been adopted in the recent past for many of the aero engine components. The critical issue for such a product to enter into the armed forces is certification and its associated manufacturing quality standards. This paper highlights the basic issues and challenges associated in a typical Indian Joint Venture for design development and Certification of aero engines and system. The paper also highlights the possible approach which can be adopted based on the real experience of certification process for a turbo shaft engine joint venture program recently undertaken in India between HAL and an OEM abroad.

Keywords: Joint Venture, Gas Turbine Engine, Qualification Testing (QT), Certification, Acceptance Test Procedure (ATP), First Article File Report (FAIR)

Introduction

Aero-engines find a wide application in military and transport aircraft for various flight mission. The past reveals that there are very few design houses who have undertaken the challenging task of aero engine development. To name a few, global leaders in this field are Pratt and Whitney USA, Rolls Royce UK, Turbomeca France, MTU Germany, NPO Saturn Russia. However the numbers of aero engines flying with aircraft in the world are very large. Depending upon the mission, there is requirement of suitable power plant. In the recent past it is obvious that the major design houses have developed their expertise for design of a module or a system depending on their strength. There has been a trend of modular development in the gas turbine engine for which the task is to focus on design of a particular module is relatively easy compared to a full engine development. This trend reveals a shift in engine development program through joint venture. The certification of joint venture aero engine program in India will be a big challenging task in this scenario. A well designed certification methodology and its associated Technology Transfer to India is the current research area for airworthiness and certification. In this paper the JV certification methodology, its requirement and TOT transfer, critical issues and a probable approach have been described in various sections.

Joint Venture Development Model

A very basic question at this stage would be “What is Joint Venture model of development and why it is being formed?” A joint venture (often abbreviated JV) is an entity formed between two or more parties to undertake an activity of developing a system together. The parties agree to create a new entity by both contributing equity, and they then share in the revenues, expenses, and control
Joint Venture Certification Methodology Requirement

One of the critical technology developments in the aviation sector is the power plant technology, without which an aircraft development programme cannot be assumed successful. The criticality of aero engines in any aero planes can be understood from the fact that an aero engine and its sub systems contributes to a major percentage of the total aircraft cost. There have been several successful joint ventures in the recent years. Today CFM-56 engine, which is the widely sold, marketed engine in civil aviation sector for aircraft like Airbus-320, Boeing-737, 800 and 900 has been developed through 50:50 partnership of General Electric, USA and Snecma, France. GE has offered the core engine with 9-stage compressor whereas the cold end components like fan and low power turbine has been contributed by Snecma, making the project very much successful. In the process Snecma has got exposure of latest design and technologies. Thus Snecma could enable itself to develop an aero engine of a six-stage high speed core engine with turbine entry temperature (TET) of around 1850 K, which powers the present generation Rafale multi role fighter aircraft for French military aviation. In nutshell, the JV program of CFM-56 has empowered M/s Snecma to develop a successful core which has the enormous potential of a number of derivatives in future. Few years back in Russia, Sukhoi super regional jet civil aviation programme required a twin engine configuration of the order of 80,000 N thrust each. The requirement has been fulfilled by M/s Snecma delivering the core engine of M88-2 engine. Subsequently the cold end component development has been completed at NPO-Saturn manufacturing facility in Rubinsk, Russia in the name of Volga Aero.

Now let us have a look on the Joint Venture Programs in India. One of the recent successful joint venture is between India (HAL) and France (Turbo-6CA) for development of a turbo shaft engine for helicopter application namely the Shakti Engine program (ARDIDEN Engine worldwide). There had been clearly defined responsibilities for development for each of the players of both countries like some LRU’s and non LRU’s for HAL and the remaining with Turbomeca. The major issue was certification of the full engine and its component by Indian certification agency along with the transfer of technology for production under various phases. Similarly other JV programs also exists in India like the Snecma-HAL JV for production of precision aero engine components; Indo Russian Aviation Limited (IRAL) is for enhancing the spares and services of Russian origin engines besides Infotech-HAL JV on engine related design issues and services. As a spin off to this joint venture is the added advantage of upgradation of the existing obsolete technologies through the expertise gained during joint venture. In this context the certification of product coming out as a result of Joint Venture is a key issue.

Joint Venture Vs General Engine Certification

The goal of certification is same for any kind of engine; however the process may take different route for a joint venture project and in house engine certification. In the licensed project the quality is only being monitored while design certification is the responsibility of the OEM. In a country like India, a few small engines have been designed, developed and certified in the past through a pragmatic approach of testing that resulted in better understanding of design issues. For Joint venture project the route of certification responsibility is totally a new experience due to exposure of latest design and technologies.

Elements of a Typical Aero Engine Joint Venture

As joint venture involves certain development of aero engine components by various engine design houses based on their expertise. There shall be clear understanding of developmental area of work by each contributor. In context of aero engine, power plant system development can be one area of work while the other areas of work could be power plant services and testing. However the categorization depends on the contract of the joint venture. In a developed country like Russia the similar approach of modular development by its small expert companies has been seen in the recent past. Each area of work can be completed by various participant of the joint venture.
For example a compressor module and combustor module can be developed by different design houses and their testing can be performed by using the facility of some other design houses. The three fundamental components of Aero Engine Joint Venture Certification shall consist of Core engine modules certification, System LRU’s certification and Non LRU certification.

Critical Issues in Joint Venture Certification

The certification of joint venture components for aero engine application is primarily driven by its use and mission requirement of the full aircraft. The technical specification stipulates the entire requirement that should be met by the component upon certification. Therefore a full fledged certification code should be carefully chosen to fulfill all the requirements for global operation. The certification code developed by different countries generally caters to their own environmental condition. However for India, the scenario is totally different with pressure and temperature and the operating environment varying significantly in the entire operating envelope. The following critical issues have to be deliberated during certification of joint venture aero-engine and its components.

- Requirement for common code of certification for global operation.
- Non-uniform availability of test facility.
- Design and Quality difference among JV participants.
- Reliability modes of certification.
- Aero Engine Lifting Philosophy.
- Manufacturing standards desired by the global partner.
- Peculiar Indian Operating conditions.

Joint Venture Certification Approach

The goal for certification is to ensure the airworthiness of the aero-engine and its components with respect to safety and mission fulfillment. Since there is no certification code of our own in India, preparation of an approach document with help of all the parties including the certification agencies will be the correct and appropriate first step in any JV project development. The approach paper can be an insight into the various details of the engine and its subsystem for which indigenous development is planned, the different technology being followed in each stages of design besides the certification requirements inclusive of specific Indian Military requirements and codes to be followed and the route map for the technology transfer on production and the operational clearances. The approach paper thus evolved can become the starting base document for any such JV development programs.

From the typical flow chart of any design development and certification programme depicted below for an aircraft and its airborne systems and subsystems, it can be seen that technical specification or requirement serves as certification driver.

The clear understanding of the Joint venture developmental area of each participant enables the assessment of individuals capability for performing certification. Suitable selection of certification code for each subsystem and modules has to be performed to reach a consolidated requirement for complete aero-engine as a system. The joint venture always involves certain critical components which needs additional focus. The critical design review is a step of intense deliberation of such critical components along with other components of aero-engine.
The test formulation is next step towards certification to ensure stipulated function of each and every component of the system in the full flight envelope. The test schedule consists of formulating performance, environmental, safety and life level test for the system as well as subsystems. The basic aim of the different test categories should be as follows:

a) Performance Tests: To prove the functionality of the aero engine and its components as per design.

b) Safety level tests: To safeguard the components in case of any abnormality (e.g., Containment test in case of rotor burst). In case of unmanned air vehicle (UAV) engines, these tests aim at safety of the ground personnel and minimizing collateral damage.

c) Lifting tests: To establish the life of the component without any failure in between. (For eg. Endurance testing, Accelerated mission testing).

d) Environmental level tests: To prove the components by external agents (humidity, corrosion, sand, saline etc.) within the flight envelope.

The integration of system and orientation of components plays a key input in test formulation. The qualification testing (QT) of actual components with all the inputs from test schedule is next step. The failure if any has to be substantiated with suitable modification. Extensive instrumentation is involved in this step to collect key parameters. At this stage it is better to test at least three identical components for sampling and performance comparison purpose. Each and every event of testing has to be properly transferred into documents and a careful analysis of the data should be performed to ensure design intent.

Analysis and Documentation

It is indeed a very important step towards certification. The design and performance deviation of various parameters obtained through extensive testing of aeroengine and its components has to be properly documented in the test report. There may be some vendors getting involved during development of a component. Hence, instrument calibration reports have to be checked one by one that have been used during testing. The Acceptance Test Procedure (ATP) or the standard of the component or the system required critically for the production stages flows from the successful Qualification Testing profiles of these components and systems. During qualification process there might be certain tests for which test facility or rig may not be available. To ensure the testing goal, the certification of developed rig is equally important to acquire accurate data for analysis.

For Non LRU’s, efforts should be made so that all the required tests should not be left out in the ATP schedule as for these items extensive qualification testing are not generally done in view of the non-critical nature of these items. For example pipe lines shall be tested for mock up fitment tests, Ball test, spring back test and Fixtures and Gauges Inspection Repeatability Tests besides the proof, burst and leakage pressure. Similarly for brackets Dimensional and Weld Inspection test should exist in the ATP.

To ensure the complete certification, a check list is very vital. The check list should be of two components the initial one and final. While the initial checklist provides the airworthiness certification direction, the final checklist ensures in fulfilling the full requirement at the final stage of certification.

Setting Up of Manufacturing Standards for the Product/Engine/System

To raise the quality of each vendor to a level of global standard is a major task before any production and technology transfer so as to ensure smooth and reliable series production of the components/system under JV. This is all the more that the global Aviations standards are far superior to the Indian manufacturing standards beside the critical aspect that any JV has an ultimate goal of aiming the global aviation market. Hence, bridging the gap of manufacturing standard between the JV partners is a very critical and vital element in any successful JV program in Indian context. The global partner generally drives the Indian partner in lifting their standards. But absence of global quality standards and the manufacturing methodology used in Indian context, it becomes a difficult proposition in lifting up their quality standards. Accordingly the standardization of the components and processes of each vendor is an essential component in any JV process. Here the certification and the airworthiness agencies of India can play a catalytic role in not only lifting and setting up the required manufacturing quality standard as per the Indian Aviation work culture but also in convincing the global partner in respecting these set standards in satisfying their regulatory agencies like EASA of Europe. Hence setting up of the base-manufacturing standard is one of the
most critical elements in any design, development and manufacture of indigenously developed items for airworthiness use.

First Article File (FAF) or First Article Inspection Report (FAIR) or DVI (Dossier Validation Index) is the most critical document for establishing the quality base for production standard and the traceability aspects for a particular component/system and hence a basis for the production clearance. A FAIR document briefly includes the following details.

- Details about the raw material, its specifications and its procurement.
- Processes involved in producing a component & where process is carried out.
- Special processes and their approvals.
- Validation of the manufacturing parameters like inspection reports.
- Dimensional, metallurgical and functional tests compliance for a component.
- Speaks about all vendors and sources including their accreditation status.

Scrutinizing these details with the help of the aeronautical certification and quality assurance regulatory agencies and setting the required FAIR with their help will be the correct methodology in any successful Technology Transfer of any JV programme. It is to be borne in mind that any production clearances of the indigenous items under development can be given not only after the successful qualification testing and setting up the ATP schedule for production but also the setting up of the First Article Production standard of FAIR.

Validation of Manufacturing Process at New Location

When TOT is spread between different phases from SKD (Semi Knocked Down assemblies) to CKD (Completely Knocked Down Kits) to full manufacture of the engine and its subsystems separate production clearances have to issued in each of these phases taking into account of all the aspects mentioned above by the certification agencies. In a typical TOT where the manufacture and overhaul of aero engines with indigenous components are involved, the validation challenges involved can be summarized as following:

a) Repeat validation of the aero engines as it involved a change of place, change in competency level and a likely change in the manufacturing process and practices. This includes a few minimal testing like a possible 150hrs Endurance Run and 50hr ATP runs for validating configuration control of the engine with the indigenous components.

b) Validation of Engine Test Bed: The calibration like cross calibration with master engine from OEM, load cell calibration and calibration of all test bed instruments are some of the critical challenges in validating engine test bed.

c) Ensuring the quality control process.

Hence for success of any JV and its subsequent smooth transfer of technology, involvement of certification regulatory agencies from its inception to final realization or womb to tomb concept is very vital.

Conclusion

The joint venture in development of aero engine is now being recognized by most of the countries involved in aerospace. The global partners have built their expertise in developing different modules of aero engine. The emergence of myriad joint venture in the field of aero engine has led to think about the certification aspects and its associated manufacturing standards by airworthiness scientists. It is indeed a basic requirement for an aero engine to fly along with the aircraft to complete the mission requirements. The critical design review, test formulation are the critical steps toward joint venture certification. The documentation and analysis plays a vital role in any joint venture development and certification. The collective and continuous effort with the designer and testing team towards Aero Engine Joint Venture Certification ensures flawless operation of the component in its flying mission. Setting up of the required quality standards in the manufacture of these JV items in India is also equally vital in any successful TOT of a JV aero engine programme with futuristic aim for a global market share besides the Indian Aviation sector.

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References


The Indian payloads are:

- **RaBIT** (Radio Beacon for Ionospheric Tomography) - For mapping Total Electron Content (TEC) of the Ionosphere.

- **LiVHySI** (Limb Viewing Hyper Spectral Imager) - To perform airglow measurements of the Earth’s upper atmosphere (80 - 600 Km) in 450-950 nm.

The Russian payload:

- **SOLRAD** - For monitoring the solar X- and gamma ray fluxes and to study solar cosmic ray flux parameters and conditions of their penetration in the Earth’s magnetosphere.

**X-Sat:**

X-sat, the third payload of PSLV-C16 is Singapore’s first satellite. Weighing 106 Kg at lift-off, X-Sat is a Mini Satellite with a multispectral camera IRIS as its primary payload. X-Sat mission mainly intends to demonstrate technologies related to satellite based remote sensing and onboard image processing.