

**Request for information for**  
**Co-design and Co-development**  
**Of 5:1 Pressure Ratio Three Stage All BLISK Fan**

**GTRE-- Dated October 2014**

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## ABBREVIATIONS

ALT	Altitude
BOM	Bill of Material
CDR	Critical Design Review
CEMILAC	Centre for Military Airworthiness and Certification
DRDO	Defence Research & Development Organization
GTRE	Gas Turbine Research Establishment
HCF	High Cycle Fatigue
ICD	Interface Control Document
LCC	Life Cycle Cost
LCF	Low Cycle Fatigue
M	Mach Number
PDR	Preliminary Design review
QT	Qualification Testing
RFI	Request for Information
TOT	Transfer of Technology
TAC	Total accumulated cycle
P1	Total pressure at fan inlet
T1	Total temperature at fan inlet

## Fan Specification

Major technical specification for Fan proposed to be co-designed & co-developed by GTRE and the selected partner are as follows:

Application	= Advance Turbofan experimental engine
Corr. Mass Flow rate	= 98-100 kg/s
Pr.Ratio	= 5 : 1
Isentropic Efficiency	= Greater than 84%
Surge Margin	= Greater than 25%
No. of Stages	= 3
Fan Weight	= Not more than 180 kg
Overall size	= 1) Inlet Tip Diameter not more than 820 mm 2) Length from 1 <sup>st</sup> rotor inlet hub to 3 <sup>rd</sup> stator exit hub not more than 475 mm
Fan life	= TAC life - 8000 cycles.
Technologies	= All Blisk Fan made from Ti-Alloy or any other advance light weight material like Composites .The Fan should be flutter free over the entire operating regime including high forward speed conditions ( P1 upto 200 kPa and T1 upto 360K).
Growth potential	= Indicate the increase in mass flow rate and pressure ratio possible with minimum changes to Fan basic design. Approximately 5% growth potential is expected in overall performance like mass flow rate and pressure ratio.

ii) GTRE follows MIL-5007D/E for all systems and components of engine design. Hence partner should follow MIL standard 5007-D/E for the design. If any other standards are used by the Partner, full references and details of those specifications to be provided. Partner to explain how it is planned to be implemented.

iii) Overall Fan Life - 8000 TAC cycles. It must be demonstrated at an appropriate test facility as a part of the development programme. GTRE may undertake this responsibility. These requirements must be taken into account during the design and demonstrated on a rig as a part of certification requirements.

iv) Number of hardware required - 5 (five)

v) Testing required - approximately 60 hours of aerodynamic and 30 hours of aeromechanical characterisation test simulating high P1, T1 , Over-speed and burst margin tests, cyclic fatigue tests and Bird-hit test.

### TECHNICAL RESPONSE TO RFI

Design, development, manufacturing, testing and certification of the fan will be carried out jointly by GTRE and the selected partner. The partner will take full responsibility and ensure that the design meets specifications and demonstrate it through testing

1. DESIGN AND DEVELOPMENT - Interpreted to mean design and development to meet goals of	
a) performance and operability	b) life and weight
c) safety and reliability	d) producibility
e) ease of assembly	f) maintenance
Criterion	Expected response
1.1. Design and Development effort	Partner shall provide: <ul style="list-style-type: none"> <li>a) Its perception of design and development effort required to meet programme objective.</li> <li>b) Overall programme strategy and schedules</li> <li>c) Indicate level of confidence of its proposal to current system design, architecture and interfacing requirement</li> <li>d) Indicate related materials and process technologies</li> <li>e) Provide its own assessment of work share in design and development</li> <li>f) Confirm design meets life requirements indicated through testing before certification</li> <li>g) Indicating possibility of enhancing performance.</li> </ul>
1.2. Sharing of Know-how in design methodologies and enabling tools	Partner shall indicate strategy for sharing design methodology and enabling tools for each design element in overall program effort. Partners to specifically indicate the design work share in the format given in the RFI and the list of software / design tools / material data (Not limited to providing only design allowable) available during the design phase.
2. MANUFACTURING , TESTING AND CERTIFICATION	
Criterion	Expected response
2.1. Certification Strategy	<ul style="list-style-type: none"> <li>a) Partner shall indicate its certification strategy including raw materials, forging etc.</li> <li>b) Partner to provide overall test requirements, life and safety related test requirement and component test requirements etc.</li> <li>c) Partner to confirm requirement of total number of hardware towards development and certification testing in the RFI.</li> </ul>
2.2. Infrastructure availability	Partner shall indicate availability of its test facilities for certification. Partner will specify the altitude test bed for carrying out flutter mapping test, component test rigs in their country planned to be used for Fan tests. GTRE would like to use its test facilities where it is possible. This will be arrived at with mutual agreement.
2.3. Manufacturing support	Partner to provide support for manufacturing fan components necessary for carrying out aerodynamic/aeromechanical and certification level tests.

## ANNEXURE – B

2.4.. Legacy information	Partner shall provide its plan to share legacy information for design and certification requirements.
2.5. Maintainability, Reliability and Safety	Partner to confirm that design meets requirements in the RFI under this category
<b>3. PROGRAMME MANAGEMENT STRATEGY AND STRUCTURE</b>	
<b>Criterion</b>	<b>Expected response</b>
3.1. Strategy	Partner shall provide a detailed document covering <ul style="list-style-type: none"> <li>a) The framework of partnership for design, development and manufacture of Fan</li> <li>b )Nature of contractual arrangements of the partnership</li> <li>c) Management and cost strategy for development phase.</li> <li>d) Strategy for other applications of Fan</li> </ul>
3.2. Structure	Partner shall provide a proposal for programme management
3.3. Programme Time frames	Partner shall provide its estimates for programme time frames with a first level milestone based PERT chart
<b>4. GUARANTEES , RISK SHARE AND COST STRATEGY</b>	
	<b>Expected response</b>
Guarantees risk share and cost strategy	<ul style="list-style-type: none"> <li>a) Partner approach and strategies to ensure performance guarantees</li> <li>b) Partner will provides its perception of methodologies that will allow the partnership to provide guarantees of performance, reliability, life, safety and conformance to agreed cost and time goals</li> <li>c) Partner's strategy for costing the development programme</li> </ul>
<b>5. GOVERNMENT CLEARANCE</b>	
	<b>Expected response</b>
Government clearance	Partner shall <ul style="list-style-type: none"> <li>a)Provide a detailed flow chart for the procedure for obtaining requisite government clearance</li> <li>b)Indicate anticipated time frames for each step in the procedure defined above</li> <li>c) Indicate any requirement for intergovernmental agreements that may facilitate the process</li> </ul>
<b>6. EASE OF COMMUNICATION</b>	
	<b>Expected response</b>
Documentation And communication	All documentation and communication will be in English, and indicate any special measure required in cases where internal Partner documentation and communication is in a language other than English.  Partner will also indicate its proposal on usage of IT measures to ensure rapid and secure communication during the course of the program

## 1. Introduction

Annexure C provides the necessary information, formats of response and explanatory notes for the technical response to the co-design and co-development phase of the proposal.

Reference: annexure B Criterion 1 (page - 5)

### 1.1 Design Solution and Work share (Elements of Work)

Your response will indicate the design solution and related work share to meet with the specification of the fan in Annexure A in the format of Tables: C1 and C2

**Table C1: Design Solutions**

Technical Specification	As given in Annexure -A
Conformance to performance points Indicated in Annexure A	Partner will indicate level of conformance to specifications
Life	Partner will indicate level of conformance to specifications
Weight	Partner will indicate that budgeted weight is achievable and as per the current industry standard and technologies adapted during the design .
Partner assessment of current facilities of GTRE	Based on the assessment, Partner will indicate testing roles between GTRE and partner for different tests .
Growth potential	Partner will indicate the increase in performance possible with minimum changes to Fan design.

**Table C2: Work Share**

Compressor design expertise available at GTRE	Areas where cooperation expected
<ul style="list-style-type: none"> <li>• Aerodynamic design of Fan and HP Compressor</li> <li>• Design optimization for vibration characteristics</li> <li>• Theoretical estimation of aerodynamic characteristics at design and off-design conditions</li> <li>• Mechanical Design of blades, discs, Vanes and Stress analysis of blade+ disc configurations.</li> <li>• Evaluation of critical speed based on rotor dynamic analysis</li> <li>• Aerodynamic testing of LP and HP Compressor</li> <li>• HCF testing of LP and HP Compressor blades/vanes(limited frequency range)</li> <li>• LCF testing of LP and HP Compressor rotor</li> <li>• Bird Impact test.</li> <li>• Seal design</li> </ul>	<ul style="list-style-type: none"> <li>➤ Design Support to improve efficiency and surge margin for Fan with pressure ratio 5 and above.</li> <li>➤ 3D blade design with blade tip speed greater than 500 m/s.</li> <li>➤ Design methodology for blisk design including Design tool/Software for modeling and analysis</li> <li>➤ Flutter free design</li> <li>➤ Residual Growth analysis for 115% over-speed and 122% burst margin.</li> <li>➤ Damage Tolerant design</li> <li>➤ Casing containment design</li> <li>➤ Design and analysis methodology for foreign object damage</li> <li>➤ Health monitoring algorithm for damage tolerant components.</li> <li>➤ Inspection methods for damage tolerant parts.</li> <li>➤ Repair technology.</li> <li>➤ Transient stress analysis</li> <li>➤ Design for manufacturing and industrialisation</li> </ul>

## 1.2. Knowledge Sharing

For each of the modules listed in Table C1 and C2: We understand that the design process will involve a complete sharing of information between GTRE and Partner in the areas indicated below

1. Design methods, criteria, related software and design tools.
2. Material data base (-3 sigma) used in design for every material/ manufacturing process
3. Design to manufacture including tolerance for specific manufacturing processes in terms of producibility and conformance to design intent

We would, however like to specifically understand any restrictions that will apply to the joint design, test and certification process, and request your response to specific issues in the format of Table: C3. We expect your response in this format for all areas of design such as Fan blade Flutter analysis, 3- dimensional blade design and analysis, Transient thermal and stress analysis, Impact analysis, Life evaluation etc.

**Table C3: Sharing of Knowledge**

Design Area: Aerodynamic design and Structural Integrity	Component: blisk stage 1
Design methods ,criteria and design tools & software	Will provide/ not provide
Design data base	Will provide/ not provide
Specifications, Manufacturing Methods and Quality control	Will provide / not provide
Company proprietary/Third Party/Commercial tools/software	Indicate applicability
Government restriction / Export control	Indicate applicability

Reference : Criteria 2 of Annexure B (page 5- 6)

## 2.1 Component Test and Qualification

The Partner will give a detail plan of component testing, qualification process and test result (Aero, Life, Safety etc.) to meet certification requirements. An example is given in Table: C4.

**Table C4: Module level Tests**

Sl. No.	Module &Component Test	No. of Units	Test Hours	Location/Test Facility
1.	Fan Aerodynamic			
2.	Cyclic Spin Tests (Fatigue life)			
3.	Over speed and burst test of Fan			
4.	Aeromechanical test (For Flutter)			
5.	Bird Strike and Ingestion test			
6.	Casing containment test			
7.	Any other test			

## 2.2 Guarantee for Maintainability, Reliability and Safety

GTRE and Partner will provide joint guarantee of the final product for easy maintainability, high reliability and safety. Partner shall confirm this. To achieve this, Fan should have the following features and activities:

1. Provision of boroscopic inspection ports
2. Demonstrate task time for component removal and replacement as part of maintainability.
3. Procedure will be proposed by partner to ensure all activities related to safety issues are addressed



### **2.3 Deliverables**

The partner is expected to deliver the following:

- a) Technical design report (aerodynamic and mechanical) of components designed/audited by partner. Access to any specific design/analysis tools used/needed for this project.
- b) All test reports – aerodynamic, aeromechanical and certification related tests.
- c) Five set of fan hardware to carry out above mentioned tests. However GTRE reserves the right to decide whether it takes few modules and partner should help GTRE manufacture remaining sets.
- d) Partner to provide complete manufacturing support to GTRE for parts/modules manufactured by GTRE.

### **3. Reference 3.1 -3.3 of Annexure B (page- 6)**

#### **3.1 Management Structure**

GTRE shall be the prime agency for design and development of Fan with Partner as the principle partner. You are expected to provide overall structure for the partnership, as defined above and a detailed management structure for the policy and execution of the entire programme.

#### **3.2 Development plan and Milestones**

The requirement of schedules prescribed is To+ 48 months (To = Start date of the co-design & Co-development programme). A bar chart giving details of the intermediate milestones with testing up to full certification and production release shall be indicated by the Partner. Intermediate milestones with design reviews (PDR, CDR etc.) will be defined in the overall programme activities to review progress and resolve shortcoming if any.

### **4. Reference 4 of Annexure B (Page -6)**

#### **Risk share and Cost Strategy (Budgetary Estimate)**

Partner is requested to indicate in the technical proposal their strategy for costing the development programme. Partner to provide its perception of the design and development effort through an assessment of special allocation to various tasks during design, development, test and certification. An overall budgetary estimate of cost for complete programme should be given in the response to the RFI. The cost break may be given as percentage under the following major heads:

- Cost for the design & development work share, Sharing of know-how in design methodologies and enabling tools for Fan
- Cost for certification of component including Altitude testing.
- Cost for manufacturing of parts for prototype build up, Assembly and integration of Fan
- Man hour effort
- Programme management cost:
- Any other

### **5. Reference 5 of Annexure B (page -6)**

#### **Export clearances**

Necessary clearance from the Government of the Partner country for understanding the tasks enlisted in this RFI with GTRE for co-design and co- development and transfer of technology must be assured by Partners along with their technical and commercial offer and in any case before the commencement of contract (To).

GTRE wishes to have complete understanding of the export clearance process in Partner's technical response

- Necessary formats / documentation to be submitted by GTRE in this connection may be included in the technical response
- Items for which no export clearance is required, items for which export clearance will be obtained for supply by partner, items for which export clearance will be obtained for TOT, items related to design and development such as software, data bases, design methodology, and other knowledge related items that require export clearance may be clearly classified and indicated
- The steps to be taken in partner's country to obtain necessary clearances, together with the relevant organizations that will provide clearance in their country may be indicated in the technical response.
- The time frame for obtaining all clearance may be indicated in the technical response of export clearance

#### 6. Reference 6 of Annexure B (page -6)

##### Documentation and Communication

Partner will confirm that all documentations, Correspondence and communication are done in English as indicate in Annexure –B Partner will set up a fully proven rapid and secured communication system for day to day interaction with all concerned during the entire phase of the programme.

**Table C8:- COMPLIANCE MATRIX**

#### DESIGN AND DEVELOPMENT PHASE

Sl. No.	Paragraph Title	Page No	Responded Yes / No		Remark
1	Fan Specification	4			
2	Fan Design Intent Weight – 180kg	4			
3	Fan Life	4			
4	Design Methods & Data Base sharing with GTRE team during development	5-8			
5	Component Test and Qualification	8			
6	Guarantee for Maintainability, Reliability and Safety	8			
7	Management Structure	9			
8	Development plan and Milestone	9			
9	Government Clearance/ Export License	9-10			
10	Cost strategy	9			
11	Technical response to RFI	5-6			
12	Deliverables	9			
13	Budgetary estimate	9			
14	Elements of work	7			

Note : The partner is expected to mention elements of work in budgetary estimate.