Thrust Areas of Research (GTMAP)

1. Materials Technologies & Potential Research Areas

GTMAP Programme, under the aegis of AR&DB solicits project proposals in the Core Areas and broad scope listed above. Materials technologies and potential research areas that have been identified as of direct and immediate relevance for project formulation may include, but not limited to, the following:

No.	Materials Technologies & Potential Research Areas
1	**Single Crystal Turbine Blades & Vanes**(Tentative alloy CMSX4)

	• Characterisation of mechanical properties & microstructure
	  ◦ Assessment of influence of crystal misorientation and low angle grain boundaries and on mechanical properties
	  ◦ Understanding thin section effect on properties of DS & SX alloys used in airfoils
	• Process modelling related to directional solidification and SX castings process
	• Newer alloy compositions based on modelling / experimental approaches
	• Development and assessment of high temperature ceramic core materials and cores
	• Development of suitable brazing materials and processes for root and tip brazing of turbine blades and pairing of nozzle guide vanes and characterisation of brazed joints – preferably on modelling driven experimental approach for selection of brazing materials and process parameters
	• Development and characterisation of CBN hard facing of shroud tips in shrouded blades
	• Process development and characterisation of laser shock peening for fir tree regions of turbine blades
	• Machinability studies – Grinding, Laser Drilling and EDM.

2	**Turbine Discs**(Target: P/M Superalloys)
	• Studies on powder characteristics and their influence on sintering and resultant microstructure and mechanical properties of P/M superalloys • Role of super and sub solvus solutionising heat treatments on mechanical properties • Laser shock peening of bolt holes and fir tree slots • Development & characterisation of aero engine rotor forgings with dual microstructure (Ti alloys) or dual grain size (Ni alloys) • Machinability studies on P/M Disc alloys.
3	**Metal Matrix Composites**(Target: SiC_f-Ti)
	• Development of technologies for SiC fibers for Ti-MMCs • Synthesis of the 25-30 micron thick carbon core fibre • Processes for deposition of SiC on Carbon Fibre (~50-70 microns radially) with emphasis on interface properties, stoichiometry, growth kinetics, uniformity etc.

	• Processes Titanium alloy deposition (Ti-64, Ti-6242, etc) on SiC fiber (~50-70 microns radially) with emphasis on interface characterisation, compositional uniformity, micro-structural aspects etc. • Scheme for draping of Ti-MMC fibers, graphite tooling, stacking methodologies etc. • Diffusion bonding of Ti-MMC fibers • Blade-MMC Ring Joining Technology preferable through solid state welding processes like linear friction welding • Micromechanics of MMCs with focus on load transfer at interfaces: modelling and experimental verification • Macro Mechanics of MMCs: Assessment of aspects like stacking sequence, volume fraction etc. through modelling and experimental approaches. • Numerical simulation and experimental testing of MMC rings.
4	**Polymer Matrix Composites**
	• Development high temperature resins for PMCs • Development of processing technologies for PMC components and characterisation of properties
5	**Ceramic Matrix Composites**(Target: C_f-SiC)
	• Development of joining technology and mechanical and micro-structural characterisation of joints • Machinability studies on composites • Methodologies for non-destructive evaluation of composites
6	**Additive Manufacturing (AM)**(Target: Superalloys & Ti alloys)
	• Component specific development of processing techniques and optimisation of process parameters • Characterisation of microstructure and mechanical properties of AMd nickel base superalloys and titanium alloys • Feasibility of realising ceramic cores for investment castings through AM route • AM as applicable for repair of gas turbine components • AM of Titanium Aluminide alloys • Machinability studies with focus on surface finish and dimensional accuracies
7	**Joining/Repair**(Target: Superalloys, Ti alloys & alloy steels)
	• Assessment of fatigue and creep behaviour of welded joints – Process-structure-property correlations • Numerical and experimental simulation and validation of welding for prediction of HAZ, RS, microstructure and mechanical properties • Blisk repair and associated technologies both Ni and Ti alloys • Rotary friction welding for gas turbine components • Joining technologies for composite materials • Repair technologies for gas turbine components
8	**Titanium Aluminides**(Target: Last stages of compressor blades)
	• Structure-property correlation studies on wrought alloys • Studies on machining aspects of wrought alloys

	• High velocity foreign object damage of wrought titanium aluminides • Machinability studies on titanium aluminides.
9	**Coatings:** The goal of these projects should be to enable better performance (higher operating temperatures, longer life and better tolerance to adverse chemical environments) of different sections of the gas turbine such as the fan, compressor, combustion chamber, high and low pressure turbine.

	• Coatings for
	  • Sliding wear and Erosion resistance (RT-600°C)
	  • Low friction (RT-600°C)
	  • Abradable liners (RT-1300°C)
	  • Oxidation resistance (RT-1500°C in the presence of oxygen, Pt substitutes)
	  • Corrosion resistance (RT-1500°C in salt, CMAS attack, role of V and S)
	  • Thermal insulation (new top coats for longer life and higher operating temperatures).
	
	• Proposals can address
	  • Synthesis (e.g., Plasma / Thermal Spray, E-beam PVD, Sputtering / Arc Evaporation, Pack Cementation, Solution Deposition)
	  • new architectures e.g., graded and multilayer coatings in top coats
	  • Microstructural and other characterisation
	  • Corrosion / Oxidation (and associated thermodynamics, kinetic models, phase stability)
	  • Mechanical reliability (wear, toughness, failure modes, different types of loading, thermal stress at high T and under simultaneous chemical attack, oxidation-creep interactions, using innovative local testing geometries and in-situ diagnostics; mechanical property degradation on sustained use, particularly oxidation-wear or corrosion-wear synergy)
	  • Burner rig experiments in air and salt environments
	  • Modeling (thermomechanical, damage evolution)
	  • Designing new coatings (chemistry, microstructure)
	  • Non-destructive evaluation (methods, damage detection
	  • Lifetime Prediction.

10	**High strain rate behaviour**
	• Property evaluation for materials prone for Foreign Object Damage (FOD) due to bird impact on frontal components, blade out on casing etc.
11	**Novel manufacturing processes**
	• Chemical / Electro-chemical milling of special features on gas turbine components – process optimisation and characterisation • Abrasive water jet machining for blade profiles, blisk blanks of superalloys, ceramics and composites and process optimisation • Ultrasonic machining, Hybrid machining etc. For gas turbine components • Flow forming of hollow shafts in superalloys – process optimisation, simulation and modelling • Abrasive flow forming, Magnetic pulse forming etc. For gas turbine components

<table>
<tr><td>12</td><td>Laser processing</td></tr>
<tr><td></td><td>Laser surface treatment, hardfacing, cladding, drilling, machining and welding of gas turbine components.</td></tr>
<tr><td>13</td><td>Materials Modeling & Simulation:
The goal of these projects should be to enable faster materials discovery, development or application by increasing modeling and simulation based decisions in every aspect of the material application cycle ranging from melting and processing to microstructure evolution and related mechanical behavior. Multi institutional collaborative proposals that address different aspects of the proposal are encouraged. Experimental validation of existing models is also encouraged.</td></tr>
<tr><td></td><td>Generic Problems
First principles based prediction of

Compliances as a function of temperature and composition in bcc Ti, hcp Ti, fcc Ni, Ni_3Al
CTE as function as a function of temperature and composition in fcc Ni, Ni_3Al
Multicomponent diffusion in hcp and bcc Ti, fcc Ni, Ni3Al

Titanium Alloys

Improved thermodynamic databases for critical alloy systems to be defined in consultation with incorporation in ThermoCalc
Modeling VAR and related micro-segregation
Physics based constitutive equations for hot flow behaviour, microstructure evolution incorporating recrystallization in two-phase alloys
Phase-field models for alpha precipitation + transformation texture in two-phase alloy based on variant selection
Dislocation core structure in alpha Ti as a function of temperature and composition with emphasis on O and Al effects
Crystal plasticity based tensile stress-strain behavior in two-phase systems
Modelling of α-precipitation and transformation texture evolution in two-phase titanium alloys
Slip Transfer across interfaces in Titanium Alloys
Crack Evolution in Titanium Alloys
Local micro-mechanical fields in Titanium Alloys through crystal plasticity approach

Nickel Base Superalloys

Dendrite arm spacing models,defect models (Freckles), Micro-segregation models and micro-segregation homogenization models
Potential development (Ni-Cr) (Ni-Ta) (Ni-Co) (Ni-Ti) (Ni-Al)
First principles based fault energies in in Ni and Ni_3Al as function of alloying additions
Gamma/gamma' interface composition and stress profile as a function of alloying additions
Modeling dislocation motion in stress and stress gradients with respect to gamma channels in Ni Base superalloys
Microstructure evolution in nickel base superalloys: Effect of alloying additions, interface composition and stress profiles
</td></tr>
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	• Cavity growth during in creep in nickel base superalloys **Others** • Modelling of microstructure and stress evolution during joining / repair of aeroengine components • Development of interatomic potentials of binary alloys as inputs for molecular dynamics simulations • Modelling and simulation of AM processes
14	**Sensors:** The projects may focus on developmental activities involving high temperature sensor materials, appropriate sensor design practices, processing techniques for sensor embedment () (on Ni / Ti based alloys and C_f-SiC substrates) assessment of sensor response and life under harsh environments and advanced remote signal/data acquisition. They could be developed as conformal-thin films for rotating parts or conventional-bulk sensors for static parts of the engine and be characterized for their response in terms of sensitivity, stability over extended exposure to intended temperatures and environments, creep, fatigue, thermal fatigue, wear/erosion, resistance to hot gases etc. Typical service temperatures could be up to 350°C in the front section of the engine and up to 700°C in the mid-sections o the engine and up to 1100°C in the rear sections of the engine.
	Development of sensor materials and sensors targeting sensing of : • Structural loads at bolt joints between the casing flanges & Rotor shaft flanges • Interface dynamic loads at Blade root / Disc, Tip shroud interface of turbine blades • Full field surface pressure on the aerofoils and vanes • Fluctuating Temperature measurement • Tip gap measurement • High frequency pressure / transient data at the hypodermic tip ends in secondary air zones of engine • Axial gap between static and rotating parts during engine operation • Mild rubs at blade tips and labyrinth seal tips • Metallic and non-metallic debris particles in the flow path

2. Steps in Submitting a Project Proposal

1. Submit a short write-up (not exceeding 4 pages) by e-mail to gtmap@dmrl.drdo.in. The write-up should contain the following:

   - Title of the proposal write-up
   - Name, affiliation and contact details (including e-mail and telephone numbers) of the investigator
   - Short background and introduction
   - Objectives and research deliverables

- A brief description of the experimental and / or modeling tools that will be used
- Broad details of specific infrastructure requirement that need to be established
- A budget estimate indicating the major heads of expenditure viz., Research Staff, Capital Equipments and Consumables

2. The short write-up will be examined by the concerned PARC. The investigator will be intimated the views / suggestions / recommendations of the PARC. If required, the investigator may be provided with details of a contact person in GTRE/DMRL for detailed discussion and finalization of speifics. Only after the short write-up is accepted by the PARC, a full project proposal is required to be submitted by the investigator. A format for the full proposal will be provided at that stage.

3. Subsequently, a soft copy of the full project proposal is required to be submitted by the investigator by e-mail to gtmap@dmrl.drdo.in.

4. The full project proposal will be reviewed by the concerned PARC. Views / suggestions / recommendations of the PARC will be intimated to the project investigator. The project investigator may also be called for a presentation of the project proposal to the PARC. If found necessary, based on the suggestions of the PARC, project proposal may have to be revised and resubmitted to PARC.

5. Once a full project proposal is considered acceptable, PARC will make a recommendation on the project to the APRT of GTMAP for a final decision. Based on the recommendation of APRT, AR&DB will process the finalized project proposal for sanction.

Note: While conceptualizing short write-ups and full project proposals, investigators may interact with Gas Turbine Research Establishment (GTRE), Bangalore or Defence Metallurgical Research Laboratory (DMRL), Hyderabad to obtain first hand information about the critical issues of materials application in gas turbine and its operating environment. Linkages with projects already completed / running under GTMAP programme are desirable and investigators are encouraged to interact with their colleagues working in associated areas. Investigators may contact Co-ordinator, GTMAP Programme for necessary coordination on these aspects. Multi institutional collaborative proposals that address different aspects of the proposal are encouraged**.**