Research Areas in Space

A Compendium
For Preparing Project Proposals

RESPOND Programme

Indian Space Research Organisation, Bangalore

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Contents

1.0 Introduction

The Indian Space Research Organisation (ISRO) has evolved a programme through which support is provided for conducting research and development activities related to Space Science, Space Technology and Space Application to academia in India. This programme of Research Sponsored by ISRO is called RESPOND. The main objective of the RESPOND Programme is to establish strong links with Academic Institutions in India to carry out quality research and developmental projects which are of relevance to space and to derive useful outputs of such R&D to support ISRO programmes.

To enable faculty to prepare suitable proposals of relevance to Space programme, a detailed list of R&D areas/sub areas/topics/problems have been worked out as per major programmes of ISRO and the same has been given in this document. *The concerned ISRO/DOS centre to be approached by the faculty/researcher is given in the brackets after areas/sub areas/topics/problems. The faculty/researcher may select a suitable topic/problem and prepare the proposal after discussing with the experts from concerned ISRO/DOS centre/unit and submit the proposal to the concerned Space Technology Cell for consideration*.

Sl. No	List of ISRO/DOS Centre/Units referred in the document
1.	Vikram Sarabhai Space Centre (VSSC)
2.	Satish Dhawan Space Centre (SDSC), SHAR
3.	Liquid Propulsion Systems Centre (LPSC)
4.	ISRO Satellite Centre (ISAC)
5.	Space Applications Centre (SAC)
6.	National Remote Sensing Centre (NRSC)
7.	Indian Institute of Remote Sensing (IIRS)
8.	Physical Research Laboratory (PRL)
9.	ISRO Inertial Systems Unit (IISU)
10.	Laboratory for Electro Optics Systems (LEOS)
11.	National Atmospheric Research Laboratory (NARL)
12.	Semi Conductor Laboratory (SCL)
13.	Space Physics Laboratory (SPL)

2.0 Launch Vehicle Programme

A	Area	Mission Analysis and Simulation (VSSC)
A 1	**Estimation of Gaseous Radiation for Interplanetary Missions:** Gaseous radiation is significant in re-entry from interplanetary mission when entry velocity is greater than 1.5 km/s. Both equilibrium and non-equilibrium air radiation have to be modeled for the estimation of radiative heating. Number densities of various chemical species, translational, rotational and vibrational temperatures of heavy particles and electrons are to be evaluated for modelling emission and absorption characteristics of air under these conditions. The proposed study is for evaluating radiation heating under these conditions.	
A 2	**Estimation of Heat Flux Distribution in the Vicinity of Protrusions on the Cone (Cylinder Body Under Varying Mach Number and Reynolds Number Conditions (Experimental &Theoretical):** There are established procedures to estimate heat flux at different regions of a launch vehicle, which are essentially axi-symmetric clean configurations. The presence of protuberances like DMRJ engine modules, wire tunnels, fins, etc , will enhance heat flux locally due to shock wave interference with boundary layer. Analysis using CFD methods and possible evolvement of engineering solution in terms of geometric and flow parameters will help in estimating the heart flux near proturberances. Results substantiated by carrying out experiments will give confidence in using the model for configurations with protrusions on cone cylinder body.	
A 3	**Flow-thermal Simulation of Hypersonic Air Intake**: 3 D parametric geometry is to be created using VSSC supplied air intake configuration with identified variable geometric parameters. To predict complex flow field in the presence of shock-boundary layer interaction and heat transfer, 3D numerical simulation is to be carried out using Computational Fluid Dynamics (CFD) Software with wall friction & wall heat transfer. Based on air intake operation condition specified by VSSC for each simulation, boundary conditions and initial conditions are to be generated. Structured multi-block meshing is to be used for grid generation. Simulations are to be carried out converging o grid independence & interaction independence. Post processing includes (a) generation of Control plots & pallets for identified flow parameters at specified locations and (b) computation of specified parameters like mass flow rate, pressure recovery, mass capture ratio, skin friction, heat transfer etc.	

A 4	**Wing body reentry vehicle optimization studies**: Wing body reentry vehicle is a reusable launch vehicle concept to reduce the satellite launch vehicle cost drastically by safely returning the launch vehicle back to earth surface after the satellite/payload insertion in required orbit for re-launch. During reentry, the vehicle has to pass through low density atmosphere to high density atmosphere, High hypersonic Mach number to low subsonic mach number during touchdown and it also encounter viscous flow regime and pass through laminar to turbulent flow regimes. The key aerodynamic and aero-thermodynamic design aspects are optimum heat flux, heat load, load factor, less than 4g deceleration, sufficient payload bay, down range and cross range capability, good longitudinal and lateral- directional aerodynamic stability, adequate control surface effectiveness, reduced TOPS cost. The optimum external aerodynamic design must fulfill the some of important objectives given above. Re-entry module is used for scientific mission, or to bring back astronauts from space back to earth. Re-entry module can be a ballistic/or semi ballistic concept with minimum control. The key aerodynamic and aero thermodynamic parameters are minimizing the maximum heat flux, heat load and 'g' force with optimum stable aerodynamic shape for the purpose. The module must be free from any dynamic stability issues, must have less dispersion in the down range and cross range, both soft landing on land and sea has to be considered within the design.
A 5	**Large Eddy Solver (LES) – for aerospace application:** Large eddy simulations are presently the need of the hour with increased computing power and using parallel computing. LES resolves all the range of large eddies without the use of any turbulence model and it is been used for simple problems so far, but presently publications are available on the application of LES for launch vehicle with jet, aircraft etc, LES compressible solver is to be developed for a generalized grid with high order schemes for convective terms. It can have both full LES and wall modeled LES. The solution acceleration techniques like dual time stepping with multi-grid or other methods can be adopted. The LES is intended to get unsteady data over aerospace vehicle, jet interaction studies, and high angle of attack studies.
A 6	**NS RANS solver development:** Navier-stokes RANS solver is used for the design and analysis of aerospace vehicles. The code need to have both implicit and explicit solving capacity and must work in parallel mode using MPI and/or using GPU for faster turnaround time. The code must perform comfortably well in

	both compressible and incompressible regime and must have various schemes like Roe, AUSM+, HLLC, SLAU for convective terms computations. The various established turbulence models like SA, SST, realizable k-epsilon, RNG model must be available for selection. The code must work on generalized grids. Acceleration techniques must be available like multi-grid, dual time stepping, RK methods and accuracy must minimum second order. The solver must have further scope of introducing high temperature effects, combustion model.
A 7	**Flow Visualization Technique:** Following flow visualization techniques are to be developed: 1) Qualitative Flow field visualization: Qualitative flow visualization of nozzle jets interaction using Glow Discharge Method. 2) PIV and stereoscopic PIV: Qualitative and quantitative measurements of flow field information such as velocity profile/vorticity associated with double delta wing, capturing of stream wise vorticity generation and its strength over RLV like geometries at angles of attack. Lift off jet impingement studies of launch vehicles using PIV. Studies of scramjet flame holding strategies such as cavity flow physics using PIV. Vortex enhanced mixing studies in typical scramjet combustion chambers.
A 8	**Development of a MDO Tool for Aerospace Applications:** The aerospace problems are complex and often require interactions among different disciplines. Due to non-linear dependencies of various disciplines, conventional optimization procedures do not result in system optimum. As the name suggests, Multidisciplinary Design Optimization (MDO) involves optimization of the system by coupling two or more disciplines together. For example, structure design software could be NISA software and trajectory design software could be written in Fortran. The MDO tool has to suitably wrap these programs.
A 9	**Re-entry Trajectory Design and Analysis of Two Closely Following Bodies with a Possibility of Break ups:** Re-entry trajectory design is complex as large amount of heat has to be dissipated and structural integrity of the body has to be ensured. Design becomes challenging when two bodies closely follow each other. This typically occurs in one of the missions where crew module and cryostage enters the Earth's atmosphere and are in close vicinity. The possibility of cryostage breakup during the re-entry is to be analyzed. Number of pieces during the break-up is to be evaluated based upon detailed structural analysis of the cryo stage components. The survivability of these pieces and the effect of impact of these pieces on the ongoing crew module are to

	be assessed.
A10	**Hybrid solution methodology with a combination of Cartesian grid and meshless method for high sped turbulent viscous flow solution from Cartesian mesh:** Cartesian mesh has tremendous advantage in completed automated grid for complex geometries. However the near wall resolution to obtain skin friction and heat flux is not possible without some special near wall treatment. The solution proposed is to have a mesh less method for near wall solution and standard Cartesian mesh solution away from wall. The starting point is the Cartesian mesh over the geometry. The necessary code for near wall resolution with meshless method to obtain viscous solution is the key research work in this. It should be noted that there is a Cartesian mesh near the wall which can be used to generate points.
A11	**Aerodynamic Design and Prediction Methodology of the Grid fins:** A prediction method has to be developed for the estimation of aerodynamic characteristics of grid fin-body combinations at subsonic to supersonic Mach numbers regime. Aerodynamic effect of depth-to-height ratio, web thickness, web leading edge angle, cell width-to-height ration and various isolated cell shapes has to be studied.
A12	**Development of analytical tool for low thrust interplanetary mission trajectories:** Spacecraft trajectories are obtained from the integration of the spacecraft's equations of motions, which contain terms for the external forces that are acting on the spacecraft and for the thrust force. The convergence behavior of trajectory optimization methods depends on an adequate initial guess of the solution, which is often hard to find. An efficient analytical tool can provide with good initial approximation which can reduce exhaustive numerical computation.
A13	**Multi-body Dynamics Simulator:** Launch vehicle simulations require solving multi-body dynamics for addressing scenarios such as space transportation missions, crew module ejection, stage separation, booster/strap-on separation, satellite separation etc. All individual bodies having its own inertial systems and are bound to possess independent mass-inertia characteristics, propulsion systems, aerodynamic properties, guidance and control algorithms, control power plants etc. Simultaneous solving of translational and rotational dynamics for each body (during ascent and descent phase) is required with real-time plotting of trajectory parameters and other critical states. Software model can follow modular or component architecture whereby system modules

	can be plugged in and used as required.	
B	**Area**	**Aerospace Structures (VSSC)**
B 1	**Automated Acoustic Emission Data Analysis Through ANN:** AE monitoring is being used for the integrity evaluation of various flight hardware during their proof pressure test for example Titanium Gas Bottles, Aluminium, Maraging steel and 15 CDV6 chambers etc. Implementation of an automated AE monitoring with Neural Network for the Real time integrity evaluation of the hardwares helps in minimizing the AE expertise and speed up analysis. AE criteria based on the values of various AE parameters like amplitude, duration, counts, energy etc. from the test results of similar hardware will be the input for the automated integrity evaluation.	
B 2	**Development of Automated/Semi-Automated Method for Strain Measurement Using Photo elastic (Birefringent) coatings:** Photo elastic coating technique has good potential for whole field strain measurement on prototypes. In a laboratory set up, the Photo elastic fringe orders are manually measured using a reflection polariscope and a digital compensator. In an industrial set up manual reading of fringe orders are not possible. Moreover, due to problems associated with glare and extraneous lighting, using a single circular polarizing sheet over the coating is beneficial. The work envisaged is the development of portable compact equipment based on computerised digital optics capable of whole field strain measurement from photo elastic coating fringe data.	
B 3	**Studies on the different aspects of Digital Image Correlation Technique for measurement of displacement and strain:** The state of the art technique of Digital Image Correlation Technique for measurement of displacement and strain makes use of a random pattern painted on the surface. The various aspects like the intensity maps of the pattern, illumination, orientation, curvature of the surface etc affect the accuracy of measurement. The degrees to which these affect the results have to be studied and parameters bench marked. The calculations need to be carried out in polar or cylindrical coordinate systems and required codes developed. The development envisaged is better understanding of the various aspects when the technique is applied in an industrial scenario.	
B 4	**Development of Digital Holographic Microscope for MEMS Characterization, Deflection and Shape Measurement:** To characterize the performance and reliability of Micro and Nano Electro Mechanical Systems like sensors, actuators and controls under static and	

	dynamic conditions a robust non-destructive quantitative measurement tool has to be developed. Digital holographic interferometry technique presently used for testing of macro structures is to be adapted to the application in micro and nano structures. Digital holographic microscope, loading fixtures for micro sensors and phase map generator for deformation mapping, 3D profile measurement, micro material property measurement etc. are to be developed and validated by testing of MEMS and NEMS intended for the future ISRO programs.
B5	**Strain Measurement at High Temperature (800^{O}C and Above) :** Realisation of a suitable methodology including sensor system and data acquisition/analysis for measurement of strain on space structural components at temperatures higher than 800^{o}C.
B6	**Development of Sandwich Structures With Negative Poisson's Ratio Honeycomb Core:** The core with negative Poisson's ratio improves the shear strength and resistance to piercing for the core and keeps inserts more intact in sandwich structures. The geometry of core and skin material/processing provides negative Poisson's effect for the sandwich structures as reported in literature. This will help to increase the load carrying capacity of the sandwich structure.
B7	**Damage tolerant designs for laminated composite structures used in aerospace structures:** The initiation and propagation of manufacturing induced or service induced damage in the structural design of laminated composites are of primary concern for aerospace structures. The laminated composite wing and fuselage structure with low transverse strength, low inter-laminar shear strength and no plastic deformation are more susceptible to damage growth. A stress based criterion can determine the locations of potential damages followed by fracture analysis to predict the initiation of delamination. Based on suitable failure criterion, the failure is predicted. A thorough understanding is required to predict the multiple complex failure mechanisms in composite structures which are used especially in aerospace industry such as the wing structure. Virtual Crack Closure Technique (VCCT), Cohesive Zone Modelling (CZM) and Progressive Failure Analysis (PFA) are the techniques used to predict the failure followed by the experiments to validate the criterion. A series of aerospace materials ranging from the metals to composites has to be tested and predictions through analytical and numerical method have to be carried out for the better understanding for future requirements.

B8	**Development of Finite Element Software for Inflatable Structures:** For space applications, structural weight should be the minimum possible. At the same time it should serve the purpose for which it is meant. Inflatable structures have become increasingly popular in recent years for a wide range of space applications. An inflatable structure not only has lower weight but also can be folded when it is not in use giving it the advantage of minimum storage space. It can be unfolded to the required size and shape as and when required. Applications of such structures in space applications are solar sail boom, airship, antennas etc. The finite element to suit such applications needs special treatment in the formulations. Because the deformations of such structures depend on the applied load, inflation pressure and the constitutive law of fabrics. Beam element and shell elements are widely used finite elements for structural applications. This study is proposed for the development of beam and shell finite elements, which can be used for inflatable structural applications.
B9	**Development of 3-D Contact Element with Friction:** The structures which are made for the launch vehicle and other space applications are made of several segments and joined together to give the required shape and size and also meet the design and functional requirements. Structures are made of segments having the flexibility to separate as and when its purpose is served. Two different segments made of same materials and /or of different materials are joined together with bolted/clip joints. When such structures are subjected to loadings the gaps between the two bodies either open or close, depending on the nature of the loading. Load is transferred from one body to the other if the gap between the two bodies closes. To study such structures connected with joints contact elements are required. This project is proposed for the development of 3-D contact element with friction for the application for both bodies deformable.
B10	**Development of Analytical Techniques for the Design of Impact Resistant Structures :** In the future missions of ISRO like reusable launch vehicles, human space flight, etc., the structural components will be subjected to impact loads during orbital and landing operations. These structures should be designed with highest probability of human, package and critical component survival. Design and analysis methodologies including structural, material and environment modelling needs to be established for effective design of impact resistant structures. Analytical methodologies to assess response of human body and critical packages to impact load needs to be developed.

B11	**Active Noise Control for Composite Payload Fairings :** Acoustic loads are one of the important environments for launch vehicles. The acoustic load transmission into the vehicle, particularly inside the heat shield needs to be attenuated for the proper functioning of satellite. The magnitude of acoustic loads transmitted to the payload is a function of external environment as well as design of payload fairing and its sound absorbing treatments. At present, passive acoustic blanket is used to reduce the internal acoustic field. The use of composite payload fairing has the advantage of reducing mass, but it has detrimental effect on acoustic levels inside the payload fairing especially at low frequencies. Passive approaches for acoustic attenuation are limited at low frequency because of sound absorption is limited in low frequencies. Active control offers an attractive approach for low frequency acoustic noise attenuation inside payload fairing. The proposed study is to develop structural actuators such as piezoelectric patches for noise control inside composite payload fairing.
B12	**Dynamic Modelling and Analysis of Human Body Exposed to Vibration Environment During Space Flight :** In manned mission, human body may be exposed to various severe environments for a long time. This may be detrimental to life or may cause illness/fatigue to the body. One of the major environments is vibration. Therefore, it is essential to study the influence of vibration on human body and necessary to find solutions to prevent such environment. To understand the effect of vibration on human body, it is required to generate three-dimensional dynamic model of the human body and carryout dynamic analysis for human biomechanical responses. The human body shall be idealized using beam, spring and mass elements to represent the various dynamics of the body. The model needs to be validated with the available literature / test results.
B13	**Development of Constitutive Equations for Nano Composites :** Constitutive equations have to be developed for composites containing both functionalised and non-functionalised nanotubes using continuum modelling technique. The elastic properties of both composite systems amorphous and crystalline polymer matrices with various nanotube lengths (continuous / short discontinuous), volume fractions and orientations are to be evaluated.
B14	**Fracture Studies on Textile Composites :** Textile Composites are being used in the aerospace industries, specifically in the areas of impact resistant structures and hot structures. The

	increased use of these materials calls for the proper understanding of their fatigue behaviour. To ascertain the endurance of structural components made of Textile composites, fatigue and fracture studies on materials and structures are essential. A suitable method to perform the progressive fibre/matrix failure analysis has to be established in the presence/absence of defects useful for life estimation.
B15	**Structural Health Monitoring Through Classification of Strain Patterns Using Artificial Neural Network:** Structural health monitoring technology has become an important approach to increase the safety and reduce the maintenance costs of high performance composite structures used in aircraft and re-entry vehicles. There is a requirement to develop the tools to detect damages such as fibre failure, matrix cracking, de-laminations; skin-stiffener de-bonds in composite structures. Neural network is one of the tools. Tool will be used to classify sensor malfunctioning and structural failure(s) based on the observed static strain patterns of the healthy and unhealthy structures. Analytical and experimental studies have to be made to validate the adopted methodology.
B16	**Geometric, Kinematic and Finite Element Modelling of Large Deployable/ Inflatable/Unfurlable Structures in Space :** Large antenna reflectors and other structures are being used in increasing numbers for satellite applications. The sizes range from dia.5.0m and upwards to 20.0m.During Launch phase these reflectors will be stowed so that launch envelope interfaces requirements are not violated. In space these structures get deployed by suitable mechanism of energy release like inflatables, Unfurlable , Unfoldables etc. A suitable model need to be developed (a) To capture Geometry of these structures in space (0g condition) and in ground(1g condition) (b)To capture and model the kinematics of the members /linkages involved and (c)Finite element modelling of the structure to capture its dynamic, Static and Thermal distortion behaviour under space conditions.
B17	Fracture based design model of composite structures/pressure vessels
B18	Stress free joints for hot structures
B19	**Nano meter level measurement setup with all associated analytical software and hardware fully integrated, meant for specimen level as well as assembly level evaluation of the payload and camera structure:** An increasing demand for high-quality, low cost Earth imagery has led to

	the requirement for improved structural stability of the satellite instruments providing the imagery. This translates into camera structures capable of maintaining very high levels of dimensional stability order of few micron (<10μ) for a length of 1m over their lifetime. CFRP[1] have emerged as one of the best materials for dimensionally stable space structures. The "theoretical" zero CTE[2] is only approximated as well as the manufacturing precision allows. So in ultra stable structure where micron level dimensional stability is required, there is an obvious need for quantitative assessment of the magnitude of change in dimensions. We are in need of a nano meter level measurement setup with all associated analytical software and hardware fully integrated, meant for specimen level as well as assembly level evaluation of the payload and camera structure.	
B20	Light weight fast retractable cryo arms with highly reliable mechanisms to mount on movable Umbilical Tower (For Third Launch Pad) **(SDSC)**	
B21	Thermo structural analysis for the integrated engine **(LPSC)**	
C	**Area**	**Propulsion (LPSC,VSSC & SDSC)**
C1	**Microgravity Slosh Analysis (VSSC)** Liquid sloshing dynamics under micro gravity field experiences different problems from those encountered under gravitational field. Gravitational potential has a stabilizing effect, wherein it brings the liquid volume towards the bottom of its container. When this body force diminishes, the liquid volume can assume any location inside its container in an unpredictable manner. This problem causes reorientation of the liquid in its container and poses difficulty in moving and handling, as the body forces are almost negligible. Analysis tools have to be developed for studying the liquid sloshing in low gravity environment.	
C2	**Development of Hydrogen Peroxide Based Propellant Systems (VSSC)** Hydrogen peroxide based propellant systems (monopropellant and bipropellant with RP1) have several advantages over conventional liquid propellants. However, this requires (i) development of 98% H_2O_2 (ii) development of method for safe storage of 98% H_2O_2 which involves development of suitable stabilizers (iii) development of suitable catalyst for decomposition of H_2O_2.	
C3	**Development of Cubane and Substituted Cubanes for High Energy High Density Propellant Fuel for Rocket Applications (VSSC):** Positive heat of formation of cubane and substituted cubanes and their high density render them potential candidates for fuels for semi-cryo engines.	

	Considerable improvement in specific impulse has been predicted for these fuels in comparison with RP-1 type hydrocarbon fuels. However, their syntheses in required quantities and propellant formulation are challenging tasks.
C4	**Enrichment of H_2O_2 to Rocket Grade H_2O_2 (SDSC)** : H_2O_2 available in the market with 50% concentration has to be converted to Rocket Grade H_2O_2 i.e H_2O_2 with at least 80% and above concentration for getting high pressure and high temperature in combustion chamber
C5	Propellant formulation with ingredients of Nano size **(SDSC)**
C6	Supersonic film cooling of nozzle divergent **(LPSC)**
C7	Annular spiked nozzle divergent for TSTO applications **(LPSC)**
C8	Droplet modelling in cryogenic injectors **(LPSC)**
C9	Development of a throttleable injector element for future liquid engine designs **(LPSC)**
C10	Development of an analytical mathematical model to study Feed line coupled-flow related-low frequency instabilities in liquid engines **(LPSC)**.
C11	Development of a hot gas Variable Flow Regulator for cryogenic engine **(LPSC)**
C12	Ignition modelling & analysis of throat film cooling for Semi Cryogenic Thrust Chamber **(LPSC)**
C13	Regenerative cooling analysis with kerosene for Semicryogenic thrust chamber to study coking characteristics **(LPSC)**.
C14	Transient thermal modelling of Semicryogenic engine**(LPSC)**
C15	Development of foil bearings for high speed cryogenic turbopumps **(LPSC)**
C16	Development of damper seals for turbopumps **(LPSC)**
C17	Prediction model for vibration in Turbopumps considering the effects of unbalance, constraints, fluid forces, seals, internal clearances (housing/shaft/bearing) etc. **(LPSC)**
C18	Mathematical modelling of liquid migration under Zero ‘g’ condition and the associated heat transfer with warm tank wall and pressurent gas is

	essential to predict the rate of pressure build up in LH2 tank **(LPSC)** In cryogenic propulsion Stage residual liquid migration in LH2 tank is generally observed after engine shut down. This causes higher tank pressure due to mixing of liquid hydrogen with warm pressurent gas and heat transfer with warm tank wall.
C19	Modelling of plasma and its dynamics inside hollow cathode in Electric Thruster **(LPSC)**
C20	Measurement of Plasma/Plume parameters of Stationary Plasma Thruster and pulsed Plasma Thruster **(LPSC)**
C21	Prediction of life of hollow cathode and reduction in life due to poisoning **(LPSC)**
C22	Non contact type measurement of thruster anode liner erosion and prediction of thruster life **(LPSC)**
C23	Electronics and Signal processing of Ultrasonics used for spacecraft propellant gauging using Ultrasonic Flow meter **(LPSC)**
C24	The monopropellant hydrazine thrusters are used in reaction control system of IRS projects. The monopropellant hydrazine thrusters use the principle of dissociation of hydrazine using catalyst to produce the exhaust gases. These exhaust gases are expanded through the nozzle to produce thrust. The complete hydrazine dissociation model for the monopropellant thruster is required for thruster design and optimization. Based on the dissociation model, the complete thermal modelling of the thruster to be carried out **(LPSC)**
C25	The monopropellant hydrazine is highly corrosive, carcinogenic and not environmental friendly. The alternate green propellants such as Amonium Di Nitramide (ADN), Hydroxyl Ammonium Nitride (HAN) based monopropellants are under studies. The green propellant formulation and its detail properties, dissociation phenomenons are essential to replace the existing hydrazine system. Development of suitable catalyst for the green propellant **(LPSC)**
C26	Flow modelling in Dual Bell Nozzle for Liquid Rocket Engines **(LPSC)**
C27	Life cycle prediction of thrust chamber for reusable regeneratively cooled liquid engines **(LPSC)**
C28	Heat transfer characterization of kerosene with Aluminium Nano particles **(LPSC)**

C29	Liquid film cooling study of thrust chamber with kerosene for LOX/Kerosene semi-cryogenic Engine **(LPSC)**	
C30	Modelling and analysis of throat film cooling for semi cryogenic Engine Thrust Chamber **(LPSC)**	
C31	Multi plume interaction studies of clustered Engines **(LPSC)**	
C32	Characterization of Heat transfer parameters in Gel Propellant Engines **(LPSC)**	
C33	Modelling of film cooling / sweat cooling in Liquid Rocket Engines **(LPSC)**	
C34	Combustion modelling & combustion instability modelling of liquid rocket Engines **(LPSC)**	
C35	Combustion studies on Gel Kerosene& Gel kerosene with Aluminium Nano particles **(LPSC)**	
C36	Numerical modelling of nonlinear thermo acoustic instability in liquid rocket Engine **(LPSC)**	
C37	Optimization of passive suppression devices for thermo acoustic instability in liquid rocket chambers **(LPSC)**	
D	**Area**	**Control Systems (VSSC)**
D1	**Development of Control algorithms for autonomous mobile robotic manipulator:** The research proposal is for developing advanced control algorithms for an *autonomous mobile robotic manipulator* which consists of a six degree of freedom (6 DOF), robotic manipulator mounted over a four wheel mobile robot with the wheels having independent drive and steering control. Conventional control and intelligent control shall be hybridized to develop a hierarchical control and vision-based control for robots. The control algorithm provides *dynamic coordination* of manipulator arm joints and mobile robot wheel drives to execute precision tasks in unstructured environments using multiple sensor feedback. With the development of *multilayered control architecture*, the robot should be able to automatically compute its motions from the high level description of tasks. The proposed study also needs to develop algorithms for *Simultaneous Localization and Mapping* for the navigation and locomotion of mobile robot.	
D2	**Rendezvous and docking:** To achieve docking during the final phase of the mission, the relative	

	position and velocity of the target spacecraft and chaser spacecraft has to be brought to zero. To ensure proper alignment of the docking port, the relative angular orientation needs to be precisely aligned. Moreover, relative angular rate of the target and chaser are to be very close to zero for successful docking. Simultaneous control of the translational and rotational dynamics is required to achieve the docking conditions.
D3	**Piezoelectric actuators for position control applications:** Piezoelectric materials produce voltage when stress is applied. This effect is also reversible in manner, i.e. a voltage across the sample will produce stress within the sample. Because of this reversible property, piezoelectric materials can act both as sensor as well as actuator. Piezoelectric actuation can be used in precision (small strain, fast response time) applications. One application envisaged is the precision position control of mirrors used in optical structures of satellites. Procurement and characterization of Piezoelectric actuation capability of piezo stack actuators and Macro Fibre Composite (MFC). MFC is a specific configuration of piezo electric patch where the patch is flexible and can be bonded over curved structures. Development and demonstration of closed loop control algorithm for precise position control of an object mounted over a tubular composite tripod structure.
D4	**Design and analysis (static & dynamic) of a planetary rollerscrew:** Planetary rollerscrews having double nut configuration are used in high power electromechanical actuators for converting the rotary motion to linear. The scope of project includes Mechanical design of the rollerscrew based on input requirement which includes detailed specification and outer dimensions of Rollerscrew. Generation of 3D CAD model Kinematic analysis and estimation of slip Static analysis (Finite Element Analysis), stiffness and efficiency Dynamic analysis (Using solvers like ADAMS) Fabrication drawing of all components
D5	**Modelling, simulation, analysis and design of a controller for a robotic manipulator having five degree of freedom for lunar mission:** Robotic manipulator having five degree of freedom forms part of a lunar exploration rover. The scope of project includes, Generation of a mathematical model and its analysis which includes forward and inverse kinematics, work space analysis, trajectory planning, static and dynamic analysis. Design of a controller and simulation of certain

	predefined tasks. Hardware realization of the controller (control electronics to drive the manipulator). Experimental demonstration of the predefined tasks (Robotic manipulator will be provided for this purpose)
D6	**Design, analysis and experimental verification of a force and slip controller for the object grasp by an under actuated three fingered robotic hand:** Design of force and slip controller (including selection and procurement of appropriate sensor / sensors). Simulation of grasp (Spherical, Cylindrical & Planar) with objects of various sizes and shapes. Experimental demonstration of grasp (Spherical, Cylindrical & Planar) with objects of various sizes and shapes (Under actuated robotic hand will be provided for this purpose)
D7	**Design and development of 25kW quadruplex BLDC motor with quadruplex hall sensor sets:** 25kW quadruplex BLDC motor with quadruplex hallsensor sets is planned as a driver for linear electro-mechanical actuators generating high actuation forces. The scope includes Design of motor and controller for the input requirements Modelling and analysis using finite element analysis software to validate the motor performance Generation of fabrication drawings and PCB layout Procurement of components needed for the motor and controller Realisation, assembly and testing of motor and controller
D8	**Design and analysis of harmonic drive:** Harmonic drive replaces the conventional gear train of the rotary actuator The scope includes Mechanical design of the harmonic drive for the input requirements Modelling and quasi-static analysis using finite element analysis for the tooth mesh conditions [for stress, strain and stiffness] Kinematic and kinetic analyses using ADAMS like software Tooth profile optimization for maximizing performance Generation of fabrication drawings Procurement of components (like elliptical bearings, circlip, etc, needed for the assembly) Realisation, assembly and testing

D9	**Design and development of Dual redundant 22.5^{o} stepper motor :** 22.5^{o} stepper motor with is planned as a driver for the rotary actuator. The scope includes Design of motor for the input requirements Modelling and analysis using finite element analysis software to validate the motor performance Generation of fabrication drawings Procurement of components Realisation, assembly and testing of motor	
D10	**Control Algorithm for Multi Axial Vibration Testing :** Vibration testing is done to ensure that the flight structures and system will work satisfactorily in its service environment. In conventional vibration testing the vibration in each axis is separately simulated using single axis shakers using vibration controllers. But to simulate the actual vibration condition in flight, techniques to be developed to excite the structure in all the three axes simultaneously using three shakers in mutually perpendicular axes. For this a special vibration controller to control all the three shakers is required. The proposed work is to develop the control algorithms for sine and random multi shaker vibration testing. All the required algorithms have to be developed, implemented with suitable DSPs (Digital Signal Processor) and tested.	
E	**Area**	**Aerospace Materials (VSSC & LPSC)**
E1	**Development of solders for use in cryogenic applications:** Most of the conventional solders which are tin based become brittle at cryogenic temperatures. For cryogenic applications it is necessary to design alloys with good soldering characteristics and also having ductility at cryo temperatures.	
E2	**Development of Process Technology to coat SiC chopped fibres with BN and Carbon:** SiC fibre reinforced composites are suitable candidates for thermo-structural components of reusable launch vehicles and air breathing engines. In order to maintain the integrity of the composite for a longer duration under loading these fibres need to have suitable coating before incorporating intro the matrix. In addition reinforcing the coated fiber leads to proper adhesion aids in stress release. Thus the proposed work serves a base to develop fiber reinforced composites for various thermo-structural	

	applications.
E3	**In plane and through thickness anisotropy in Li containing Aluminium Alloys:** Al Li alloys are known to possess in plane and through thickness anisotropy which make it difficult for designers to effectively utilize them in structural applications. The scope of the study includes in plane and through thickness anisotropy properties like tensile strength and fracture toughness and suggest measures to minimize it.
E4	**Sub microstructure characterization of Al-Li alloys:** Al Li alloys are being developed as a potential candidate for the future propellant tankages and structural material for the launch vehicles and satellites. These alloys are strengthened by T1 precipitates which need to be uniformly distributed throughout the matrix avoiding the sub grain boundaries for optimum cryogenic properties. The scope of the work is to evaluate the sub microstructures under different thermo mechanical treatments using TEM and EBSD to optimize mechanical properties.
E5	**Development of Processing Maps for High Temperature Aerospace alloys:** High temperature materials are being developed or the futuristic launch vehicles like RLV, TSTO, SSTO, HSP missions of ISRO. High temperature deformation processing of these materials is complex and posses many challenges to manufacturers. The scope of the work include development of flow stress data as a function of strain, strain rate and temperature for these materials as well as processing maps useful for the identification of flow instabilities.
E6	**Development of coating/manufacturing technology for friction stir welding tool for welding of 3mm thick stainless steel sheets:** Friction stir welding of Aluminium alloys is handy in terms of tool material and expected axial and feed forces. Vital part in this technology being tool development, for carrying out friction stir welding of materials like steel / titanium, appropriate tools are to be looked into. Hardened tool-steels with proper coating to withstand service temperatures up to 700^0C and also that will not form compounds / intermetallics with the material to be welded are to be developed and studied.
E7	Evaluation of Ceramic matrix composites based on SiC and ZrB_2 for behaviour under water vapour containing environments at high temperatures and development of suitable coatings to improve the

	performance.
E8	**Simulation, Modelling and Design of UHF, L and S band Antenna in 2D EBG structures with high – permittivity (k>60) low-loss (<0.001) ceramics:** Generally, low-k substrates are preferred for antenna applications due to less confinement and surface wave effects. However, for UHF, L and S bands, the size reduction is possible only with high-k substrates, which have surface wave effects that limits the Performance of antenna. EBG concept can be very effectively applied to design 2D periodic dielectric structures that at small in size as well as don't have surface wave.
E9	**Oxidation behaviour of advanced high temperature coatings for super alloys and Ti-based intermetallic alloys:** Intermetallics such as Gamma TiAl and super alloys are considered as good candidate alloys for high temperature applications due to several advantages. However, these alloys can be used at high temperature with good coatings covering bond coat along with TBC ceramic coatings. Although several coatings were developed and published in the literature, still the coatings couldnot protect the base alloys especially at high temperature. Currently, application of coatings based on methods such as magnetron sputtering, EB-PVD and HVOF are reported to provide good bonding and oxidation resistance along with intermediate coatings using variations in surface preparation, anodizing etc. Hence the above topic involves developing a superior oxidation resistant coating and understanding the mechanism of oxidation and scale growth using TGA and extensive surface analysis studies.
E10	**Development of nano composite coatings for corrosion protection of light alloys such as Aluminium and Magnesium:** Aluminum and magnesium alloys are widely used in the aerospace industries due to light weight and other properties. However, they are prone to corrosion in the environment containing chlorides. Hence these alloys are mostly used in coated conditions covering single and multiple layered coatings of epoxy and polyurethane. Currently nano composite coatings are reported to show good barrier corrosion properties and hence show more advantages than the traditional coatings. Hence the above work is aimed to develop dispersion of nano particles in the above coatings and to study their performance using polarization, impedance and other surface characterization techniques to understand their prospective mechanisms against corrosion
E 11	**Structural Health Monitoring of Composite Structures using Optical**

	fibres with Bragg Grating sensors: Optical fibres with Bragg Grating sensors are the leading candidate technology for Structural Health Monitoring (SHM) since they have minimal mass penalty for extremely large numbers of sensors. There are many advantages like compatibility with the composites, low Electro Magnetic Interference (EMI), multiple sensing capabilities with a single fibre etc. This sensor technology will be highly useful in present as well as our future launch vehicle applications. Supply of optical fibres with Fibre Bragg Grating (FBG) *sensors* inscribed at required locations. Support for embedment/surface bonding of sensors for subsurface/surface strain monitoring of composite components. Demonstration of strain and temperature sensing with data recording in a computer on specimen and component levels. Development of interrogation techniques for multiple Fibre Bragg Grating sensors embedded in a single fibre.
E 12	**Development of Miniature Specimen Test Techniques:** Miniature specimen test techniques enable the evaluation of mechanical properties using extremely small volume of the material. For characterization of C/C composites and CNT based composites this method is to be adopted considering the cost involved in the realization of specimens. The reliability and accuracy of the parameters obtained by different miniature specimen test methods are established by modelling them. Finite Element analysis is used to convert the experimental load-deflection curves into stress-strain information, which in turn gives information on ductility, strength etc., (Data Inversion Technique). A complete simulation of these test techniques using Finite Element Modelling (FEM) helps to improve the accuracy and demonstrate the validity of these test methodologies.
E13	**An Inelastic Finite Element Model of Multidirectional Carbon-Carbon Composites to predict the material characteristics and behaviours:** Multidirectional C-C composites (3D, 4D) are composite material wherein the reinforcing fibres act as reinforcement at various directions. 4D C-C composites has found successful applications in solid rocket nozzles especially as ITE's. The material behaviour of nD C-C composites is highly anisotropic and shows nonlinear elastic behaviour. Most of the work carried to assess the behaviour of multidirectional C-C composites is evaluated through destructive testing; hence limited data is generated for the mechanical properties. In this context few works are carried (especially by SAFRAN group) to theoretically predict the mechanical behaviour of the material and corresponding material properties associated with this class of material. Since at VSSC, nD C-C composites are envisaged to have application as SRM throat inserts and also as TPS material for certain

	applications, it is essential to initiate the micromechanical model studies to theoretically predict the material behaviour vis-a-vis the mechanical properties. An elastoplastic finite element model, including homogenised mono-axial stiffness can predict the material properties as has been referred in many literatures. Presently available tested material properties can further aid to verify the model if developed for such studies.
E 14	**Mathematical model of Interaction of gas phase with carbon perform during Isothermal CVI process:** One of the most promising and common methods of fabrication of thinner Carbon-Carbon composites is through vapor phase densification of porous structure of carbon fibers acting as reinforcement. During CVI process, the vapors of the hydrocarbon namely methane, propane etc decomposes to produce the desired carbon matrix within the pores of the preform and thereby increases the density. The density aimed after the final densification is based on the targeted mechanical and thermal properties required for the specific use of application of the product. Practically, the major hindrance of realization of C-C products through CVI process is the long processing duration required to achieve the desired density. Furthermore the process must be intermediately interrupted to permit surface machining or heat treatment at high temperature in order to open the pores for further densification. Under this consideration, a comprehensive numerical modelling is essential to optimise the processing parameters to achieve the required density and also to reduce the long process duration.
E15	**Development of Thermoplastic Elastometers for LCVG for Space Suit:** Liquid Cooling & Ventilation Garment (LCVG) of space suit requires a "wicking material" which allows one-way water transport. Material usually used is a block copolymer based on polyethylene oxide (PEO) soft segment and Polyether-ester block amide (PEBA) hard segment. The polymer should have high tear strength, toughness and water vapour transmission.
E16	**Development of Addition Curing Silicone Binder Resin Systems Along With Its Catalyst:** These polymers are used for thermal paints for satellite components. The proposal involves indigenous development of silicone polymers with pendant hydrosilyl (-SiH) and vinyl groups and suitable platinum catalyst soluble in these silicone polymers.
E17	**Ceramic Supported Lithium Hydroxide (LiOH) For Human Space Flight Programme:** Lithium hydroxide is useful for the removal of carbon dioxide produced by

	human metabolism in the crew cabin of a manned spacecraft. For efficient absorption of carbon dioxide, surface area of LiOH particles should be maximum. This can be achieved by supporting LiOH particles on a highly porous ceramic material.
E18	**Development of Catalysts for Splitting of Carbon Dioxide:** Atmosphere of Mars is reported to comprise mainly (95%) of carbon dioxide. It is suggested that oxygen for propulsion (for return flight to Earth) can be produced in Mars by catalytic splitting of carbon dioxide into carbon monoxide and oxygen. Another method is to reduce carbon dioxide using hydrogen (transported from Earth) to produce oxygen and methane. Development of catalysts for these reactions and optimisation of reaction conditions will go a long way in realizing Mars explorations.
E19	**Synthesis and scale up of Energetic Nitrate Binders for Solid Propellants:** Synthesis, characterization and scale up in 5 Kg batches for use at VSSC. Evaluation of the binders will be done at VSSC. Eg:- Polyglycidyl Nitrate (PGN) and Poly Vinyl Nitrate(PVN).
E20	**Modelling of polymer derived nanoceramics:** Most of the inorganic materials synthesized from polymer thermolysis retain amorphous structure up to 2000°C. Structural characterization of these materials at atomic level is required to achieve better understanding of their properties. Using structural modelling and computational studies details of atomic structure can be obtained which will further enable meaningful interpretation of experimental data. Generally Continuous random networks with well defined local coordination of all atoms are considered for molecular dynamics simulations to locate the minimum energy structures. These structures are further subjected to optimization and annealing scheme using DFT methods as implemented in Vienna ab initio Package (VASP) to get improved structural features.
E21	**Advanced characterization techniques for polymer derived nanoceramics:** Scope: Preceramic polymers usually organometallic compounds are the precursors for the fabrication of advanced ceramics. They possess high temperature properties such as thermo-oxidative stability, radiation resistance, fire resistance, chemical inertness and resistance to free radical cleavage which make them suitable precursor materials for high temperature applications. Organometallic precursor molecules provide a novel path for controlling composition, homogeneity, atomic distribution and microstructure of the ceramic materials. Microstructural characterization of

	these ceramics require in depth understanding about the bonding of the constituent elements in the preceramic polymer. Advanced characterization techniques for polymer derived ceramics include High-resolution transmission electron microscopy (HRTEM), Field Emission Scanning Electron Microscope (FESEM), High Temperature TGA up to 2400°C under inert atmosphere, Electron Energy Loss Spectroscopy (EELS), X-ray Photoelectron Spectroscopy (XPS), Raman spectroscopy, nanoindentation and high temperature XRD.
E22	**Composite process modelling – to capture warpage, shrinkage, spring back, and other moisture/curing induced deformations of Autoclave Cured - Prepreg based Fibre Reinforced Composites:** Composite products for satellite structure applications are mostly realised by Autoclave curing Processes. The prepreg lay up is completed on a tool/mould under room temperature conditions. The curing is completed under higher temperatures of the order of 175^0c.The product is cooled to room temperature before extracted. The high temperature curing and the cool down back to room temperature induce curing stresses in the composite part. After extraction from the tooling these stresses along with the inherent anisotropy of the composite manifest itself in the form of warpage/shrinkage, spring back and other deformations of the composite part. A detailed model need to be worked out to capture and predict such behaviour - especially for regular geometries like Flat , Conical, Paraboloid , C shaped , L shaped & Tubular sections (round/square/ rectangular cross sections)- considering anisotorpy of the composite as well.
E23	Parametric study for the impregnation of 2D/3D performs by RTM/RIM method
E24	Drilling techniques/technology for drilling of miniature size holes of dia less than 10 microns in super alloys for a depth of 1.0mm **(LPSC)**
E25	Micro machining of metals to provide low mass flow rates (>0.1 SCM) of Xenon gas for EPS application **(LPSC)**
E26	Metallurgical studies on Copper - Nickel dissimilar metals EB weld interface **(LPSC)**
E27	Development of Vacuum Brazing Technique for joining carbon fiber reinforced Silicon Carbide (C-SiC) to Columbium and C-SiC to Titanium **(LPSC)**
E28	Development of ceramic material with higher electrical insulation at high temperature **(LPSC)**

E29	Development of materials/alloys including coatings for high pressure oxygen environment **(LPSC)**	
E31	Development of graphene based sensors **(LPSC)**	
E32	Development and characterization of oxygen, moisture and nitrogen absorber (non heating type) for flight use **(LPSC)**	
E33	Theoretical & Experimental evaluation of 3D weld porosity effects on integrety of welded structures (pressure vessels & thrust chambers) **(LPSC)**	
E34	Development of thermal barrier coating with Nano materials **(LPSC)**	
E35	Development of ceramic coating to prevent metal burning in high temperature and oxygen rich environment **(LPSC)**	
E36	Thermal barrier coating studies to reduce the heat flux in semi cryogenic Engine Thrust Chamber **(LPSC)**	
F	**Area**	**Power Systems (VSSC)**
F1	**Simulation & Analysis of Different Humidification Methods for Hydrogen and Oxygen Gases with Regard to Space Applications of Fuel Cells:** The study involves simulation & analysis of different humidification methods for hydrogen and oxygen gases with reference to flow rates, dew point, size, weight and power requirement in microgravity environment. Methods for using product heat and water for humidification are also to be analysed.	
F2	**Analysis of Different Gas-Water Separation Techniques for Oxygen and Hydrogen Gases with Regard to Space Applications of Fuel Cells:** The study will be about analysis of different techniques for separation of liquid water from exhaust hydrogen and oxygen gases at variable flow rate in microgravity environment	
F3	**Study of Water Permeation Characteristics of Fuel Cell Proton Exchange Membrane Under Different Operating Conditions:** Optimum water balance across PEM is crucial in getting required performance from PEM type fuel cells. Balancing of electro-osmotic drag and back-diffusion of water provides the required optimum water balance. Study the influence of various parameters such as membrane type, membrane thickness, temperature, stack clamp force, saturation level, etc on the water balance of PEM fuel cells.	

F4	**Developing a Model for Bipolar Plate to Optimise the Gas Flow Field with Regard to Water management and Current Distribution:** Fuel cell performance is controlled mainly by bipolar plate flow field geometry. A reliable model enables faster design fine tuning and scale-up. The proposal aims at development of a reliable model.	
F5	**Design, fabrication, testing and realization of Programmable High Voltage Power Supply (Programmable HVPS):** The project aims at design and development of programmable High voltage power supply. The Programmable HVPS has 5V as input voltage. There is also a reference input which determines the output voltage. There must be multiple outputs and the voltages must be programmable from -5kV to 5kV and must vary proportionally with input reference voltage. Specifications of programmable HVPS are: Voltage input : 5 V Voltage output : -5kV to 5kV, multiple outputs but Proportional to input reference Voltage. Reference input : 0 to 5V range Power output : < 5W Card Size : 80mm x 80mm approximately Operating Temperature : -55^{o}C to 125^{o}C	
G	**Area**	**Avionics (VSSC)**
G1	Wireless data acquisition from sensors mounted in launch vehicles and spacecraft	
G2	MEMS sensors – Acoustic, Shock and Accelerometer	
G3	Programmable interconnect element for development of aerospace qualified FPGAs.	
H	**Area**	**Safety Engineering (SDSC)**
H1	Dispersion analysis of solid rocket motor exhaust gases	
H2	Dispersion analysis of liquid propellant leakage or spillage scenario	
H3	Fire Modelling using CFD	
I	**Area**	**Gravity Gradiometer (IISU)**
I 1	Design and Development of Gravity Gradiometer using atom interferometry	

	techniques in a double MOT set up with laser cooled Rb atoms.	
J	**Area**	**Precision Relative Navigation and Attitude reference System (IISU)**
J 1	Design, Development and Qualification of a Fully Autonomous Videometer based high precision relative navigation and attitude reference system for space docking experiment – system consisting of retro reflectors, illuminators, camera, complex image processing algorithms involving state observers, filtering algorithms, etc. for range, range rate, Line Of Sight (LOS), relative attitude determination.	
K	**Area**	**Ultrasonic Motor (IISU)**
K 1	Design of compact ultrasonic motor for micro actuators	
K 2	Design of a micro manipulator which uses the ultrasonic motor	
K 3	Development of an ultrasonic motor including fabrication techniques, manufacturing, development of excitation electronics.	
K 4	Assembly of the motor with the manipulator and demonstration of the same.	
L	**Area**	**Smart PCBs - Stress Strain Sensitive Films (IISU)**
L 1	Design of multilayer PCB with integral stress/strain sensitive films	
L 2	Development of the strain/stress sensitive film embedded PCB	
L 3	Demonstration of the insitu stress measurement during vibration of the randomly populated SMART PCB, in the vibration shaker.	
M	**Area**	**Accelerometer (IISU)**
M 1	Design of compact microwave cavity resonator	
M 2	Design of compact microwave cavity resonator with One of the sides (wall) movable.	
M 3	Design of the movable wall which is sensitive only to Acceleration. Acceleration induced changes in the dimension of the cavity alters the resonance frequency.	
M 4	Design of microwave excitation and detection schemes for the above resonator.	

M 5	Development of cavity resonator and microwave electronics	
M 6	Development of fabrication technology for realizing the microwave cavity resonator	
M 7	Development of compact electronics including microwave generator, and detector.	
M 8	Assembly of microwave cavity resonator with the electronics.	
M 9	Demonstration of accelerometer principle	
N	**Area**	**Vision Aided Inertial Navigation System - Image Processing (IISU)**
N 1	To extract Range, Range Rate & Angular Rate from Image Sequence for Autonomous Navigation using Vision Sensors	

3.0 Satellite Communications Programme

A.	**Area**	**SATCOM Technology (SAC)**
A.1	**Sub area**	**Payloads and navigation.**
A1.1	**Ultra Low power RF Transceiver:** Ultra low power RF transceivers pose considerable design challenge. Few transceiver system architecture, suitable for ultra low power implementation, are UWB based systems and Frequency Hopping Spread Spectrum. Low power circuit design techniques include, current reuse topology, direct modulation and demodulation, MEMS based transceiver. Other low power system architecture and circuit design techniques for RF transceiver are required to be investigated and implemented.	
A1.2	**Development of temperature dependent models of PHEMTs, MHEMTs and InP HEMTs, their validity at cryogenic temperatures and application in design of LNAs for DSN in S, X and Ka-band :** Presently limited data and models are available for simulation of active microwave circuits over temperature range including cryogenic temperatures. Circuits are designed at ambient and their response is studied practically at these temperatures. If proper models of basic devices are available over temperature and frequency of operation, it will be helpful in designing circuits optimized for cryogenic temperatures.	
A1.3	**Nonlinear Device Modelling and Advanced Design Techniques for RF and Microwave Power Amplifiers:** Power output, efficiency, linearity and compactness and are key figures of merit for communications transmitters. Achieving competitive performance in such equipment is therefore a challenge that has to be met through state-of-the-art techniques for designing, manufacturing and testing the power amplifiers used in these transmitters. There is a need for theoretical and experimental work to address specific problem areas, such as: a) Theoretical and behavioural modelling of RF and microwave power devices b) Measurements on nonlinear devices • Fixture development • De-embedding • Load Pull techniques • Nonlinear behavioural models e.g. X-Parameters c) Determining model parameters from measurements d) Performance simulation and optimization of given topologies	

	• Small signal performance including stability • Large signal performance e.g. power, efficiency, nonlinearity • Stability in nonlinear domain e) Study and implementation of improved topologies and approaches • Multiport amplifiers for multibeam satellites • Harmonic termination • Optimization for specific signal structures e.g. SATNAV signals f) Linearity improvement • Linearizers • Dynamic biasing g) Thermal Design
A1.4	**Design of active input filter for switching power supply:** An input filter is an essential and critical circuit elements in DC/DC converters for payload equipments. It should be designed to achieve the required EMI compliance as per the conducted emission limits defined in the latest revision MIL-STD-461. The brute force passive filter designed to achieve the necessary compliance is usually very bulky and attributes for large space and size in the power converter package. An input filter with low mass and volume can be designed by inductor and capacitor values enhancement techniques using active devices. Also, impedance of the input filter must be designed to compensate for the negative input of power converter. A project on active input filter design shall be aimed at defining the filter requirements, synthesis of the filter circuit for the desired performance, developing the step by step design methods for realizing the input filter for given attenuation and impedance characteristics and practical verification of the design on a specific DC/DC Converter.
A1.5	**Development of Microwave Photonics terminals for free space optical link design, simulation & analysis:** • It is anticipated that future trends in satellite communications will make it essential to implement very high bandwidth data links between different satellites. Examples would include LEO-GEO links for transfer of remote sensing data, GEO-GEO links for networking applications, internetworking of micro satellite clusters etc. • Optical Inter-satellite Links are now poised to grow rapidly in the coming years. There is a new surge of OISL-related interest projected applications are foreseen in many areas, including high bandwidth data relays, real-time transmission of earth observation data, internetworking of satellite constellations, military communications, signals intelligence and monitoring,

	and many others. • Microwave photonics is an integration of optoelectronics with microwaves. It offers very large bandwidth, high data rate, small size, low mass, low prime power, negligible interlink interface and improved control mechanism. Some novel, opto-microwave devices are optical modulator, photo detectors, mixers, frequency converters, optical sources, optical amplifiers, laser terminal for operational inter satellite links. Design, simulation & analysis can be proposed for such type of components. • In this case, many new optical devices or optical technology applications will be needed. Bandwidths ranging into the gigabit region are envisaged by using the future optical transponders. • To explore and develop in the core areas involved in the free space optical link design. Comparative link parameters have to be established for the optical transmitters and receivers for different optical links starting form short distances (100s of meters) to LEO to LEO or LEO to GEO etc with varying data rates. Accordingly hardware has to be developed for optical transmitters and receivers. A comparative study of different tracking mechanisms having the hardware suitable for working in space environments with sufficient power margins have to be envisaged.
A1.6	**Simulation of IRNSS system:** • IRNSS will be transmitting a composite signal for which standard equipments are not available for evaluation and characterization. Hence it is proposed to capture the RF signal and develop offline processing algorithms and software modules for measurement and estimation of specific parameters required for IRNSS navigation and composite signal. This requires the study of CDMA signal correlator, code and carrier tracking loops, extraction of timing and data information etc. • Simulating navigation scenario for seven satellite IRNSS constellation with navigation message formulation, soft breadboard payload model and propagation environment modelling. • Interference and compatibility analysis for impact of GNSS signals on IRNSS signals and vice-versa by receiving the GNSS signals from other constellations as well. • Error classification and characterization of PVT solution for IRNSS.

B	**Area**	**SATCOM Applications (SAC)**
B.1	**Sub area**	
B 1.1	**Design, Simulation and Development of Low Power S-band transceiver ASIC (all analog) with inbuilt synthesizer for ground SATCOM terminals:** The ASIC may contain a low noise RF front-end with inbuilt downconverter with output at low IF with adequate gain stages to meet the digital baseband requirements and could also cater popular PSK modulator/quadrature mixer with output at S-band.	
B 1.2	**Design, Simulation and Development of Carrier Cancellation techniques for optimal spectrum utilization:** This project should aim at using digital signal processing techniques to develop equipments which uses the same BW for Transmission and Reception to & from satellite with minimal or no increase in transmit power requirements.	
B 1.3	**Design, Simulation and Development of Signal Processing Techniques for improving the probability of ship detection in Space (Satellite) based AIS:** The project should be aimed at providing either a ground or space based implementation of DSP algorithms to avoid or recover messages reaching from large number of SOTDMA cells within the coverage of Satellite based AIS Rx for improvement in ship detection probability.	
B 1.4	Design, Simulation and Integration of spectrum sensing techniques like Cognitive Radio (CR) for effective resource utilization in popular satellite networks	
B 1.5	Use of Compressive Sensing in Satellite Communication for Broadband Data Communication	
B 1.6	Design, Simulation and Implementation of Doppler Compensated PSK Modems with Higher order Coding to meet the communication requirements of LEO satellites and for Indian Data Relay Satellite System	
B 1.7	**Design, Simulation and Development of ASIC for popular broadcast/communication standard like DVB-SH/DVB-RCS:** The design could be in two parts with one catering to RF Front-end up to S-band as stated above and another for the physical layer implementation like Modem, channel coding & data handling protocols etc.	
B 1.8	**Design, Simulation and Implementation of software based Low-Bit Rate**	

	Speech Codec for toll quality speech: The target in this project should be to provide a Vocoder which offers TOLL quality speech at low bit rate to meet the requirement of emergency voice communication at low data rates using miniature terminals with minimal power requirements.	
B1.10	**Long RS code generation:** IRNSS Signal and data structure is designed and finalized. However the length of the RS code is debated for possibility of spoofing without breaking the encryption algorithm. This requires generation of very long code for RS signal compared to the one suggested in the ICD document.	
B1.11	**Message Authentication Scheme with Elliptical Curve Cryptography (ECC):** IRNSS RS signal is protected by code encryption. Some GNSS systems are having message authentication facility along with code encryption. The frame work of message authentication scheme can be prepared for future use. Elliptical curve cryptography which is the latest in the field can be studied and implemented for the same.	
B1.12	**Customized block cipher and stream cipher algorithm development:** The algorithms used for RS signal design to provide anti spoofing capabilities are to be certified by SAG, Delhi for defense use. This requirement calls for customized algorithm development since SAG gives lowest grade to commercial algorithms.	
B1.14	**S**atellite **M**obile **R**adio Talkgroup (SMR)	
B1.15	Short (Pre-amble less) Burst Demodulator – For SATCOM Networks	
B1.16	**Satellite Access Control (SAC):** Using Appropriate Signaling Protocols and relevant on-board processing technologies, it should be possible to devise mechanisms for well defined controlled access of Satellite Transponders. This will help in prevention of un-authorized access of Satellite Resources and can provide a handle to prepare a frame-work for effective time-sharing of Satellite Resources resulting in efficient Satellite Spectrum management.	
C	**Area**	**Mechanical Engineering Systems (SAC)**
C.1	**Sub area**	**Structural and Thermal Analysis**
C1.1	**Development of Reconfigurable reflectors using Smart materials and**	

	Smart structural systems: To develop Mechanically Active Antenna reflectors which can illuminate different land masses by Reconfiguring the skin of the reflector, by using Two-way Memory trained radial and circumferential strands of Shape Memory Alloy(SMA) wire Actuators as smart back up devices. Using this approach a DVM for 1.0M diameter C-band parabolic reflector is being developed for CATF testing after demonstrating successfully the Proof-of- concept on 0.4m diameter parabolic reflector. This approach may have possible spin-off applications and may waive off the requirement of imported Antenna pointing Mechanism nowadays being used for achieving rigid body movements of the reflector for covering different land masses.
C1.2	**Usage of new materials for developing Light weight spacecraft reflectors:** To develop Light weight Metalized Antenna reflectors using Contemporary light weight and low CTE 30% carbon reinforced Poly Ether Ether Ketone (P.E.E.K) / bare PEEK combinations using Vacuum Forming Technique as an alternative to conventional CFRP reflectors developed in Autoclaves using Co-curing techniques. A 0.4m diameter parabolic reflector using PEEK material is under development as a proof-of-concept. This approach may make SAC stand alone in the field of developing reflectors without any external support. This approach may have possible spin-off applications in developing light weight SCATT. reflector in lieu of CFRP or Aluminum options.
C1.3	**Metallization of Fusion depositable materials, carbon composites / ceramics and development of segmented mirrors:** Fusion deposited materials are emerging as a novel alternative for manufacturing precise and complex shapes for the future space industry and particularly for satellite components. While it has the advantages of producing virtually any shape that can be imagined, utilization of this manufacturing technique is limited to successful development of metallization and electroplating on the Fused Deposited Components. The work here involves developing Silver and Gold plating on Fusion Deposited ABS as per the space qualified procedures.
C1.4	**TDP Support in analysis & development of RF MEMS based switches:** The Structural analysis in the electrostatic field is supported in the precise displacement domain for 2 microns type of central deflection of the gold bridge of the RF-MEMS switch using the Coventorware Multi-physics software as per the detailed Boundary conditions and material properties to be furnished by the new FAB set-up at SCL Chandigarh. Two options of the switches are under taken for preliminary structural analysis and completed. Some modifications in

	design are in progress as per the recent visit to SCL FAB and the geometry is expected for analysis runs.	
C 2	**Sub area**	**Antenna System - Mechanical**
C 2.1	**Development of Inflatable antenna for Space use:** Inflatable antenna offers very light weight option i.e. very high ratio of size to stowed weight for large deployable spacecraft antenna. Material selection, Inflatable structure design, development of inflation system, fabrication techniques etc will be the area of technology development.	
C2.2	**CFRP feed systems:** Feeds are subjected to thermal loads and structural loads. Also present practice of using metallic feed result into weight penalty. CFRP feed system will provide light weight thermally & structurally stable solution for onbord system.	
C2.3	**Development of Graphite mould for CFRP reflector:** Presently CI mould is used for the fabrication of CFRP reflector. The advantage of Graphite mould is that it will be having CTE matching with CFRP material of reflector leading to better surface profile on reflector. Also the realization cycle time will be reduced in case of Graphite mould.	
C 3	**Sub area**	**Optical Payloads - Mechanical**
C3.1	**Development of Nano-polishing technology for metal mirror:** Metallic mirror machining by diamond turning process is being successfully used for precision surface profiling. Surface finish achievable is not adequate for the best performance of the instrument in visible wave length range. It is required to develop the Nano-polishing process to achieve surface finish commensurate with similar mirror made out of ceramic material.	
C3.2	**Development of High capacitance bad conductive lining material:** High resolution telescope has very large aperture for incoming beam. It is challenging to take care of unwanted sun radiation intrusion, especially for GEO Imaging instruments, during dawn and dusk phase of orbit. It is required to develop polymers which do not conduct the heat across the thickness but it can withstand very high temperature. This would protect the metering structure from rise in temperature in any circumstances.	
C3.3	**Development of precision sensors for feedback loop in auto focus system:** Metering structure for large focal length telescope, required to provide very	

	high dimensional stability under harsh thermal environment specially in GEO orbit. To compensate the thermo-structural behavior, auto-focusing mechanism is the way out. Linear dimension measurement sensor technology is required to be developed for giving the feed back to the focusing mechanism. It is required to be kept outside the field of regard as a parallel feedback system.	
C3.4	**Shape Memory based actuation system for various deployment/shutter mechanism:** Different mechanisms will be required to be developed for payload operations. Development of shape memory alloy based mechanism will make simplified and reliable payloads. Special type of shape and programming technique is to be developed.	
C3.5	**Embedded structural health monitoring system:** Large dimensionally stable telescope structures required to be maintained strain free throughout the operational life. A SHM systems using many sensors like fiber Bragg Grating, Nano-accelerometer, Nano-temperature sensors etc, to be developed which can also be embedded into the composited structure.	
C3.6	**Carbon fiber based efficient thermal strap development:** Heat dissipation through conventional conductive material like Cu, is not adequate to handle the handle zone where high heat density heat dissipation exists. Carbon Nano-tube or carbon fiber strap can be used to transfer heat very efficiently with efficient weight saving. Technology also can be developed to embed the fiber in printed wire board to diffuse the heat from high heat concentrated zones.	
C3.7	**Micro-heat pipe design and development:** Research is required to design and develop optimized micro heat pipe, which can be efficiently used to maintain the temperature of certain components like detectors, of which performance is very much sensitive to temperature.	
D	**Area**	**Electronics Support Services (SAC)**
D.1	**Sub area**	
D1.1	**Film Bulk Acoustic Resonator based RF filters:** Film Bulk Acoustic Resonator (FBAR) is used in high frequency RF filters because of its very high Q factor and low temperature coefficient. The scope of the research will include fabrication & modelling of FBAR and design of filter using FBAR. S-band filters are required for both space and ground application.	
D1.2	**Semiconductor device (GaAs PHEMT, MHEMT, InP & GaN based)**	

	modelling (linear, non-linear, noise) including statistical process variation and temperature dependence: Very few MMIC foundries give complete device models, which are required for simulation and design of MMICs, especially in non-linear simulations like frequency converter, frequency multiplier, gain control amplifier, voltage controlled oscillators. In most of the cases limited models are available from foundry. Scalable models including linear, noise, non-linear, statistical process dependence and temperature dependence needs to be developed which can be integrated with EDA software.
D1.3	**Development of temperature dependent models of PHEMTs, MHEMTs and InPHEMTs, their validity at cryogenic temperatures and application in design of LNAs for DSN in S, X and Ka-band:** Presently limited data and models are available for simulation of active microwave circuits over temperature range including cryogenic temperatures. Circuits are designed at ambient and their response is studied practically at these temperatures. If proper models of basic devices are available over temperature and frequency of operation, it will be helpful in designing circuits optimized for cryogenic temperatures.
D1.4	**Non-linear stability analysis of multi-transistor MMIC:** Though nonlinear stability is an established field, presently no microwave CAD software is available which can easily predict the stability of a nonlinear circuit and they do in linear case. For multi-transistor MMIC, presently few alternative methods like, convergence of harmonic balance simulator, S11 at all the active device points etc. are used, which are time consuming and empirical in nature. CAD software to easily predict nonlinear stability is desirable.
D1.5	**Application of exact synthesis methods in design of microwave and millimeter wave non- linear circuits:** Design of microwave circuits and components uses both non-synthesis and exact synthesis methods. Exact synthesis methods are generally used in filter and matching circuit designs. This design method is extended to linear active microwave circuit design where input and output of the active device is approximated by simple equivalent circuit. There is a need to extend this powerful exact synthesis method to non-linear microwave circuit design, like mixer, modulator, frequency multiplier etc., which will lead to best optimized designs requiring less time for computer optimization. Use of non-uniform transmission lines in synthesis method may also lead to interesting solution.
D1.6	**Wafer level packaging technology:** Ka-band receiver MMIC SoC containing GaAs MEMS, as well as other MMIC

	and MEMS based devices (designed and developed by SAC) need wafer level packaging for maintaining performance and size advantage of chip. Heterogeneous integration and packaging at the MMIC wafer level is an attractive and enabling technology, following reference projects one such development.	
D1.7	**Development of Electron Beam / LASER Beam Sensitive Glass:** This requires development of types of glasses that are sensitive to electron beam/ LASER Beam and upon exposure to these change their optical density (OD) or transmittance. The development will be useful in the development of optical elements like sinusoidal calibration targets for optical payload calibration, gratings, Fresnel lenses etc. using grey scale electron beam or LASER lithography.	
D1.8	**Development of nano structured magnetostrictive thin films for Surface Acoustic Wave device applications:** Surface Acoustic Wave (SAW) devices are widely used in communications such as filters, delay line etc. Conventional SAW devices consist of metallic IDT on top of a piezoelectric film or substrates. Research involves the development of high quality thin films of giant magnetostrictive materials (e.g. Fe-Si) which exhibit high magnetostriction coefficient suitable for low insertion loss SAW devices.	
D 2	**Sub area**	**PCB wiring and assembly:**
D2.1	**Defects Analysis of solder joints in Electronics Fabrication for space use & algorithm development:** Fabrication data collection, compilation and methods can be developed to understand the cause of defect, quantification in various categories, impact of reviewed/reworked defects in solder joints under various environment conditions ,impact on life span long term space missions as well as on interplanetary missions, co-relation of that data in various orbits by preparing the samples, measuring relevant parameters. Subsequently, Algorithms development, Monitoring and improving PCB assembly quality by statistical optimization of processes and materials.	
D 3	**Sub area**	**Surface Treatment Process Technology**
D3.1	**Process development to realize Electroforming process for Aluminum components:** Electroforming is a technique used in fabrication of complex contoured components with high dimensional tolerances which are difficult to fabricate using conventional machining methodology. At present, electroforming process	

	of copper components on Aluminum mandrels has been successfully realized at SAC. Copper has disadvantage of high density of 8.9 grams/cc. Hence, efforts are invited to carry out in depth feasibility study to realize electroforming process of Aluminum components and develop detailed process & setup for the same. This process can be used for mm-wave components.	
D3.2	**Non-cyanide based Electroless Silver Plating process development:** Silver plated components are widely used in RF systems of satellites. With miniaturization of mechanical assemblies and usage of higher frequency bands like K-band & Ka-band, dimensions have decreased to around 4 mm & lower. Also long waveguides of the length of 1.2 meters are being used with twists and turns in various planes, making it extremely difficult to silver plate inside surface of the cavity using the conventional electrolytic silver plating methodology. Hence, proposals are invited in the area of non-cyanide based Electroless silver plating chemistry for plating aluminum 6061T6 alloy components with plating thickness of ≥2 microns of silver inside complex multi planar wave guides.	
D3.3	**Development of Electroless Gold Plating process:** Gold plating on aluminum 6061T6 boxes and Kovar carrier plates is being carried out for EMI/EMC requirements, corrosion protection, solder ability etc. Hence, proposals are invited in the area of Electro less gold plating process using either cyanide based or non-cyanide based chemistry for plating aluminum 6061T6 alloy components/Kovar substrates with plating thickness of ≥2 microns of gold. Once developed, this process will be used for all ISRO projects as per requirements.	
D 4	**Sub area**	**Environmental Test Technology**
D4.1	Development of compact, liquid nitrogen based, close loop controlled, highly energy efficient thermal systems for direct use with existing thermal vacuum chambers as well as climatic test chambers.	
D4.2	Development of non metallic, light weight, low loss cryogen transfer lines especially for efficient distribution of Liquid nitrogen.	
D4.3	Development of compact, low cost Pulse Tube cryo-coolers to facilitate testing tiny devices at low temperature as well as for low cooling requirement of IR/CCD detectors.	
D4.4	Development of acoustic coolers for small detector cooling application, handling high heat from the large heat sinks etc.	
D4.5	Development of thermoelectric cooling based compact climatic test chambers	

	and thermal vacuum chambers.	
D4.6	Development of mixed gas refrigeration based compact climatic test chambers and thermal vacuum chambers.	
D4.7	Study and analysis of various forms of contaminations like surface and airborne particulates, surface and airborne molecular contaminants in and around thermo-vacuum chambers. Carryout in-depth measurement of such contaminants using APC, PFO, RGA, TQCM and CQCM available and carry out detailed process study as well as make recommendations in this regard for implementation.	
E	**Area**	**Antenna (SAC)**
E 1	**Sub area**	-
E 1.1	**Development of algorithm and code for generation of meshing for 2D/ 3D geometries:** This work includes the development of algorithm and computer codes for mesh generation for arbitrary boundary of 3D geometry with details of data-structure for co-ordinates of each node with respect to local and global coordinate system. The algorithm should be capable of generation of adaptive meshing depending on the geometry and field values at different parts of the geometry depending on the electromagnetic boundary conditions.	
E1.2	**Analysis of Antennas of 3D structure using a Combined FEM/MoM:** The most popular and accurate method to solve 3D antenna problem is FEM. But there is drawback of FEM in incorporating Somerfield radiation condition. In order to incorporate radiation condition, it requires discretization to extend the computation region very far from the source region. Thus, the time and memory requirements for solving this problem are high. Method of Moments (MoM) on the other hand, incorporates Somerfield radiation condition through the use of appropriate Green's function. As a result, domain discretization can be kept to minimum. However, this method also has the disadvantage of being difficult to implement for complex penetrable structures. In order to get the advantages of FEM as well MoM, a combined FEM/MoM approach has been adopted to predict characteristics of antennas of 3D structure. As an example, the analysis of cavity backed aperture antennas using combined FEM/MoM technique is suitable for multi-layer microstrip antennas and slotted waveguide arrays.	
E1.3	**Time domain RF characterization of antennas:** RF Measurement of radiation characteristics of low gain antennas at lower frequency bands poses difficulties as there are multipath signal and noise in	

	the indoor and outdoor measurement ranges because of strong reflections from surrounding objects and the RF absorbers size at lower frequency band becomes larger and larger as the frequency is reduced and is difficult to install in indoor ranges because of real estate limitations. In order to mitigate various multipath signals, suitable algorithm based on various techniques may be studied and developed including the following topics: (i) The time or frequency response of the test range through time domain gating in antenna pattern measurements (ii) Channel modelling (iii) Spatial response of the test range.
E1.4	**Qusi-optical techniques for Millimeter-wave Antenna:** This type of antenna system are of paramount use in millimeter wave (30-300 GHz) and Sub-millimeter wave (>300GHz) frequency bands. This type of antenna system has a reflector-antenna that transforms the wide received signal-beams into beams of intermediate width (intermediate gain) that pass through a train of reflectors or lenses before being focused into the low-gain feed-horns of the receivers. The research problem includes the formulation using different techniques like long Fourier optics, Physical optics and Geometric theory of diffraction to design the train of the reflectors so as to optimize the overall gain of the antenna.
E1.5	**Antenna pattern characterization:** The research problem includes Algorithms and software development for near field correction techniques considering the various systematic errors of the planar near field test facility. This may also include data acquisition and processing software using standard instruments.
E1.6	**Fractal antennas:** Fullwave analysis and design of multiband antennas using printed antennas of fractal geometry for multi-frequency bands of operation.
E1.7	**Feed elements:** Analysis and design of high efficiency horn feed with OMT, polarizer, diplexer etc for multiple beam antenna, Trifurcated feed horn, Quasi integrated horn for high frequency application, horn with high power handling capability, Single aperture feed at C/Ku/Ka band for ground segment etc. The development of multi-channel rotary joints and beam waveguide systems can also be taken up.
E1.8	**Feed Array for reflector antennas:** Effect of mutual coupling between focal array feeds on the antenna performance can be studied. Beam shaping as well as the phase errors correction due to surface deformation may be accomplished by using cluster of feeds with proper beam forming network at the focal plane of the reflector. Investigation is needed to calculate the array excitation coefficients through the

	derivation of focal region fields for a shaped pattern or a reflector with deformed surface.
E1.9	**Electronic band-gap antenna:** Design and analysis of high efficiency/compact printed antenna array using photonic band gap structure, metamaterial etc may be taken up for wide angle scanning active phased array antenna.
E1.10	**Flexible coverage antenna:** Various reconfigurable antenna systems for flexible coverage on the antenna need to be studied and designed. Development of various beam-forming algorithms and its implementation required to be explored.
E1.11	**Design of Flat / Hyperbolic / Shaped Dichroic Sub reflectors:** There is a requirement to design surfaces that are dichroic i.e. r.f.-opaque for one frequency band and R.f.-transparent for another band. These may be flat or specified shape like hyperbolic or shaped. Investigators should be able to design the surface etch-pattern for the given two bands and the given set of incident angles when employed as a sub-dish. The research topic is the design and analysis of Frequency Selective Surfaces (diachroic surfaces) applicable to multi-frequency antenna system where quasi-optical de-multiplexing of various frequency bands are required to be carried out.
E1.12	**Common L1-L5-S-Band Ground Terminal Antenna for navigational satellite:** The navigational satellites will be radiating a composite signal covering the three bands simultaneously. There is a requirement to receive these three bands using a single compact ground terminal antenna. The RESPOND investigator should study and demonstrate an optimum design for these requirements.
E1.13	**Antennas based on Micro-machined / Wafer-borne Substrates:** At mm-wave frequency ranges, antennas may be realized on thin substrates and / or wafer-construction. The RESPOND investigators should study the various techniques and propose optimum fabrication methodology for such antenna systems for future linkage.
E1.14	**Medium- or High-Gain UHF Antennas for Satellites:** In recent times, the need for satellite-borne UHF antennas has emerged. Configurations for antennas with medium- or high-gain that may be mounted on satellites need to be studied and evolved. The RESPOND investigator should undertake this study and propose optimum antennas for this

	requirement. Prototype demonstration may be included in the scope.
E1.15	**Conformal Antennas for Omni-directional Coverage Patterns:** Due to upcoming space-science and inter-planetary missions, satellites need to carry antennas that are conformal to the cylindrical / arbitrarily-shaped satellite body. Also, pointing mechanisms may be expensive / unviable on such missions. Hence, investigators should develop antenna configurations that provide omni-coverage including the effect of the satellite body on the radiation pattern.
E1.16	**Ultra Wideband antenna at VHF band:** Design and development of suitable compact antenna element at 10-50MHz with 150-200% band-width with the constraints of mass & volume for interplanetary mission of ISRO may be taken up by the investigators.
E1.17	**Dual polarized wideband slotted waveguide array for higher antenna efficiency:** This investigation and design of slotted waveguide array intended at X & Ku band frequencies for band width around 14-15% with common antenna operating for dual linear polarization.
E1.18	**Soft computing techniques for shaped reflector antenna design:** Different evolutionary techniques may be developed for shaped parabolic hyperbolic and elliptical reflectors to generate required secondary pattern and scattered pattern of sub- reflector at both.
E1.19	**Analysis of Radomes on radar antenna performance:** The efficient operation of delicate microwave antennas in the presence of adverse weather conditions requires in many circumstances the covering of the antenna by a radome. Radome is a protective cover for the antenna and is used extensively on terrestrial, weather radar systems, air traffic control, telemetry, satellite communications, satcom uplink and receive-only terminals. Radome structure is a framework structure (metal or dielectric) of interconnected columns (beams/seams). Foam and honeycomb cores are often added between inner and outer skins of the radome to function as low dielectric constant spacer material (reduced reflections) providing structural strength and rigidity. Projects may be carried out for electromagnetic modelling of radome structure and the analysis to estimate the effects of radome on the antenna radiation characteristics may be carried out using suitable analysis techniques.

F	Area	System Reliability (SAC)
F1.1	Reliability related statistical techniques and advances	
F1.2	Reliability testing of components and systems	
F1.3	EMI / EMC Control techniques	
F1.4	Acceptance / long duration testing on units for MTBF analysis	
F1.5	Qualification & Screening of RF MEMs & HTS	
F1.6	Software Quality Assurance for on-board real time software development using RTOS	
F1.7	Software Reliability Growth Model for reliability assessment and improvement	
F1.8	Reliability analysis / FR estimation of mechanical parts.	
F1.9	**Study of Life / failure mechanisms in compound semiconductor photo-diodes:** The use of Opto-electronic devices such as LEDs, Photo-diode detectors and opto-isolators in Optical imaging payloads as well as in communication payloads is increasing. The device application in terms of functional requirements, sensitivity, speed, noise, signal isolation etc; are all affected by doping and device construction. Hence it is of great importance to study the various failure mechanisms associated with each type of device and the each effect of operating parameters on the life of such devices. Most photo detectors are operated at LOW TEMPERATURES, for reduced thermal noise and higher sensitivity. The focus of the study should be on identifying failure mechanisms in various photo detectors using InGaAs, InSb and Si-PIN technologies; identify the factors that accelerate performance degradation and develop models/ methods to estimate the life of such detectors.	
F1.10	**Reliability study on Piezo actuators for use in space:** For increased swath and improved resolution in Optical imaging systems on satellite platforms, there is a requirement to go in for large size reflective telescopes. With large size and increased mass, the precise focussing requirement requires mirror adjustments with micron/ sub-micron precision. Also, the resolution in large telescopes is affected by vibration, atmospheric turbulence or variations in satellite orbit. To compensate for the effects of gravity release, it is desirable to have capability for such precise adjustment, both on ground and on board the satellite. The current trend in large-aperture optics is to use piezo based tip/tilt systems or Hexapod 6-axis micro-	

	positioning systems for active Vibration damping and compensate for the effects of gravity release, thereby improving the effective resolution. These may be used for periodic re-adjustment or real time compensation of vibration/ orbital perturbations, during longer exposures. Another requirement is for the alignment and focussing of large area Segmented Mirror assemblies, using Linear Actuators. The essential Characteristics of piezo based actuators, include • High Stiffness • High Pushing Forces ~ thousands of N • Pulling Forces ~ hundreds of N • Travel Ranges to ~ 100 µm to 1 mm • Nanometer resolution • Micro-second response times • Operation in Vacuum over a very wide temperature range (-50 to 100 ºC) • Very High Reliability ~ billions of operating cycles, with high-duty-cycle In order to evaluate the reliability of this technology, extensive characterization of the mechanical performance and reliability is to be conducted over temperature, thereby paving the way for their un-restricted use in future payloads. A parallel activity would have to be undertaken for the development of compact control electronics.	
G	**Area**	**Mission Development Area (ISAC)**
G 1	**Sub Area**	**Mission (ISAC)**
G 1.2	New tools and techniques for automation of multi satellite operations	
G 2	**Sub Area**	**Navigation (ISAC)**
G 2.2	Design of data structure for minimizing time to first fix	
G 2.3	Best data encryption algorithm design for hack free / secured data transfer	
G 2.4	**Broadcast signal Anti-Spoofing techniques** - Design of Long PRN code (like GPS P(Y)) for secured application - Design of different types of PRN codes for GNSS signals (Gold code, kasami) - Message Authentication	
G 2.8	Design of better transmitted data integrity like Forward Error Correction (FEC), Interleaving	
G 2.9	Algorithm development of inter satellite ranging and onboard orbit estimation	

G 2.10	**Determination of Spacecraft orbit for Inter – Planetary Mission through Optical Navigation (LEOS)** The Spacecraft will navigate autonomously by using optical data taken by on-board camera to determine its orbit and use this information to predict its future trajectory and make necessary corrections. The objective of the study is to develop a methodology to determine the spacecraft's position and velocity for intermediate cruise and target encounter phase. Intermediate cruise phase navigation is based on image celestial bodies (called beacons) through Line of Sight (LOS) measurements in the background of stars whose Helios Centric Positions are known in order to estimate the Spacecraft Position and Velocity. Target encounter phase where the object (beacon) LOS measurements are made through image processing techniques either by computing Center of Mass (COM) for known image types, Centre of Brightness (COB) for unknown image types and limb measurement for the images than do not fit fully in FOV and estimate the Spacecraft Position and Velocity. The study involves systems design, Framing Camera Specifications, Image Processing, Navigation and Guidance and Software implementation.	
G 3	**Sub Area**	**Flight Dynamics (ISAC)**
G 3.1	**Orbit determination:** Parameter estimation methods, including least squares and Kalman filtering. Attention should be paid to statistical aspects and data processing	
H	**Area**	**Communication and Power (ISAC)**
H 1	**Sub Area**	**Communication**
H 1.1	PN Ranging Receivers	
H 1.2	MMIC based TTC Transponders	
H 1.3	Optical data communication	
H 1.4	RF switches development for spacecraft application	
H 2	**Sub Area**	**Power**
H 2.1	Regenerative fuel cell technology development with an energy density of 420Wh/Kg. These are also called Reversible proton exchange membrane fuel cells where each cell is capable of operating both as a fuel and as electrolyser.	
H 2.2	Radio isotope thermo-electric generator. These are static in operation providing very high reliability and long life.	

H 2.3	Development of Gallium Nitride Solar Cell development	
I	**Area**	**Integration and Checkout (ISAC)**
I 1	**Sub Area**	**Integration**
I 1.1	Development of highly accurate (better than 0.05mm) 3D measurement System (Photogrammetry based)	
I 1.2	Development of system capable of measuring the 3D co-ordinates of markers / 3D objects. The system should be capable of measuring the 3D co-ordinates of the markers on the object to be measured	
J	**Area**	**Mechanical Systems (ISAC)**
J 1	**Sub Area**	**Thermal**
J 1.1	Novel thermal bus systems which can collect transport and provide heat for components	
J 1.2	Phase change materials / studies	
J 1.3	Thermo electric devices	
J 1.4	Variable emissivity coatings. Near unity emissivity with the ability to reduce emissivity by at least a factor of ten.	
J 1.5	Thermal control of microelectronics (at board and chip level): - Micro channels (single and two phase) - Micro heat pipes and loop heat pipes (transport capacities can be in the range 1W to 100W)	
J 1.6	Process development for porous metal wicks (used in loop heat pipes) with complex shapes and their fluid / mechanical characterization.	
J 1.7	Computationally efficient algorithms / codes for view factor calculation including shadowing effects and directional / spectral surface properties.	
J 1.8	Radiative / flow / combustion model for prediction of heat flux on spacecraft surfaces from thruster plumes.	
J 1.9	Development of an advanced solver for coupled fluid flow and heat transfer with conduction, radiation (participative and non-participative) and convection.	
J1.10	Contamination of optical surfaces due to material migration and deposition in a space environment.	

J1.11	Degradation of spacecraft thermal properties (including contamination films) by high energy particles, atomic oxygen and UV.	
J1.12	Development of flash techniques for thermal diffusivity measurement.	
J1.13	Development of light weight stirling / Brayton engines for spacecraft application to generate power using waste heat.	
J1.14	Enhancement of heat transfer in fluids using electric / magnetic fields.	
J 2	**Sub area**	**Structures**
J 2.1	Advanced composite materials having higher stiffness, higher strength and better hygroscopic properties	
J 2.2	SMART materials like piezo elastic, electrostrictive and magnetostrictive materials.	
J 2.3	Shape memory alloys to actively control vibrations and shape control.	
J 3	**Sub area**	**Mechanisms**
J 3.1	Humanoid mechanism development: The compact mechanism / actuation required for a humanoid (2 legged system) to accomplish movements in a stable manner is to be developed.	
J 3.2	Gripper for end reflector: Grippers for micro Robots to handle problem related to handling / operating different tools etc. to be developed.	
J 3.3	Analysis of large deployable membrane structure: This involves non-linear FEM methods and required for large unfurlable / inflatable antennas which are mass efficient.	
K	**Area**	**Controls and Digital (ISAC)**
K 1	**Sub area**	**Control Dynamics**
K 1.1	Control algorithms for high pointing and stability for advanced remote sensing satellites	
K 2	**Sub area**	**Control Electronics**
K 2.1	64 bit processor development	
K 2.2	Advanced control systems for high resolution imaging satellites	

K 2.3	System on chip and mixed signal processing	
K 3	**Sub area**	**Digital Systems**
K 3.1	Research and development of an efficient image compression algorithm for space application / Advanced Audio / Video coding	
L	**Area**	**Reliability and Components (ISAC)**
L 1	**Sub area**	**Indigenization and Components Group**
L 1.1	System-In package (SIP): Enabling Technologies viz. Multichip module with chip level stacking & embedded passives and MMIC based RF / Microwave modules to bring the SIP to a more complete functional system	
L 2	**Sub area**	**Reliability**
L 2.1	Contamination modelling and kinetics studies: To establish computer model for estimation of in-orbit contamination by taking into account the orbit parameters	
M	**Area**	**Systems Production (ISAC)**
M 1	**Sub area**	**Systems Engineering**
M 1.1	Automation test systems for various space conditions. Spacecraft electronic packages (simulation, Analysis) and data logging.	
M 2	**Sub area**	**PCB Design & Fabrication**
M 2.1	Advanced Chemical / materials development for fine hole plating and fine line etching in PCB application	
M 2.2	Development of advanced photo lithography for high density interconnects (HDI)	
N	**Area**	**VLSI Design (SCL)**
N 1	**Sub area**	**Specific R&D problem/issue for fabrication in 0.18µm CMOS process**
N 1.1	Charge pump PLL frequency synthesizer design Description: Design of low phase noise differential CMOS VCO Differential change pump with CMFB(Common Mode Feed Back) Basic specs: 5MHz to 65MHz PLL output frequency required: input frequency*(28)	

N 1.2	Design of instrumentation amplifier The brief specifications are: Low noise:0.3μV p-p at 0.1 Hz to 10 Hz Low nonlinearity 0.003%(G-1) High CMRR: 120dB (G=1000) Low offset voltage: 50μV Low offset voltage drift: 0.5μV/OC GBW product: 25 MHz	
N 1.3	Design of a current feedback amplifier The brief specifications are: High speed: 1650 Mhz(G = +1) Low voltage offset : 0.7 mV Low input bias current : 7μA High O/p drive : 100 mA	
N 1.4	Design of low Noise amplifier The brief specifications are; To operate from 1.8V power supply To give flat gain from 3 to 5 GHz To deliver 21 dB power gain with only -15dB variation Average noise figure to be 5.4 dB Input and output reflection coefficients to be -13.3 and -19.5 dB	
O	**Area**	**CMOS Process Technology (SCL)**
O 1.1	Development of 1.8/5V 1/0 circuits (Analog and Digital Pad Circuits with ESD) in 180 nm CMOS process is required. This work will be done subsequent to process integration for 5V-MOSFETs in the baseline process	
O 1.2	The minimum-channel length MOSFETs SCL process (180nm CMOS technology) has Unity Current Gain frequency, Ft ~55 GHz. The existing device models supported by the technology are however valid up to baseband frequencies (one tenth of Ft of transistors) only. Development of accurate frequency dependant SPICE models for both active transistors and passive elements (Inductors & capacitors) in gigahertz range is required for rf-circuit designs capability in the existing process	
P	**Area**	**Development and Educational Communication (SAC)**
P 1.1	Mapping Information and Communication Practices in the Tribal Areas specially focus to Rajasthan, Madhya Pradesh, Gujarat and Maharashtra states	

P 1.2	A comparative study on Media Habits between Rural and Urban India
P 1.3	Community's Felt and perceived information needs in the agriculture sector
P 1.4	Community's Felt and perceived information needs in the health sector of Rural India
P 1.5	Impact Assessment of Edusat Network as supportive role in the field of formal education & teachers' training

4.0 Earth Observations Programme

A	**Area**	**Mission Development and Remote Sensing-Sensor Technology**
A1	**Sub area**	**Electro-Optical Sensors (SAC)**
A1.1	Ultra-low power, High-speed analog front-end devices for processing of detector signals and interfacing devices	
A1.2	Miniaturization of electronics in the form of low power ASICS and Read Out Integrated Circuits (ROIC)	
A1.3	On board data processing, loss-less data compression and generating theme based data output using radiometric, spatial and spectral compression techniques	
A1.4	Analog, mixed signal and digital ASIC design, simulation, verification	
A1.5	Advanced PCB technology for miniaturization of high speed and high power front-end electronics including its thermal management	
A1.6	Onboard high speed data transfer, interfacing and networking	
A1.7	Extraction of very low signal from noise – Techniques	
AI.8	High power capacitance/inductance drivers with multilevel voltages	
A1.9	Modelling of special devices – Techniques	
A1.10	Modelling of devices for Cryogenic temperature operation	
A1.11	Mitigation techniques for radiation environment in space (TID/SEL/SEU etc) - Device level, System level	
A1.12	Topologies for High Speed design and digitization	
A1.13	Design of >30 bit Digitizer	
A1.14	Chip on board technology for space hardware	
A1.15	EMI susceptibility analysis for co-existence of low noise, high speed, high power analog/digital circuits	
A1.16	DSP based real /near real time data processing for signal analysis and image processing with emphasis on frequency and spatial domain.	

	Tentative applications are • Hardware and/or software with Image Based attitude determination electronics. • Spacecraft docking system electronics • Real Time decision making for Landing System	
A1.17	Onboard computer electronic system (including volatile, nonvolatile mass memories, processors, standard interfaces, RTOS etc.) for space environment supporting soft computing of complex algorithms and real time applications	
A1.18	Development of high power (100W) high efficiency (>90%) power amplifier working over unregulated raw bus for driving low impedance load (< 4 Ω)	
A1.19	Algorithm to minimize jitter at cold tip of pulse tube cooler or sterling cycle cooler using close loop active vibration control	
A1.20	Development of algorithm or MATLAB model to estimate/optimize PID coefficient for optimum response based on overall close loop transfer function or any industry defined PID tuning method. Also, development of cooler transfer function based on empirical data or close loop response measurement.	
A1.21	Very Low noise (≤1mV), Low power (<10W), highly efficient (>90%) space grade miniaturized (12W/in3) isolated power supply /module including advance features for protection and output control.	
A2	**Sub area**	**Optics (SAC)**
A2.1	Compact optical systems	
A2.2	Studies and solution for gravity effect on large diameter light weight optics	
A2.3	Adaptive optical elements	
A2.4	Development of extremely thin and deformable mirrors	
A2.5	Metal mirror optics for VIS / NIR imaging	
A2.6	Interferometric sensing system	
A2.7	Optical butting to increase swath at higher resolution	
A2.8	On-board focusing	
A2.9	Development of wedge/ strip filters	

A2.10	Athermalization of optics using phase plate	
A2.11	Studies on super resolution techniques	
A2.12	Image quality analysis of catadioptric (Reflective and Refractive) systems	
A2.13	Origami lenses	
A2.14	Diffractive Optical Elements (DOEs) and development of hybrid lenses (diffractive + refractive)/Binary Optics	
A2.15	Super Lenses (using meta-materials)	
A2.16	Foveated Optics	
A3	**Sub area**	**Detectors (SAC)**
A3.1	Modelling of CCD based imaging sensor charge transfer scheme.	
A3.2	Minimization of Charge of transfer efficiency degradation when irradiated with high energy radiation	
A3.3	Mathematical simulation of Quantum Dot Infrared detector performance	
A3.4	Development of Si photodiodes with high responsivity in blue and NIR spectral regions.	
A3.5	Surface treatment approaches for photodiode Quantum Efficiency improvement (NIR to Blue and/ or selected wavelength regions). Graded antireflection coating for minimization of reflection as a function of wavelength, in area array Si CCD	
A3.6	Surface treatment for dark current minimization	
A3.7	APD development (Si and InGaAs)	
A3.8	Development of MCT based PV detector sensitive in the spectral region SWIR-LWIR regions	
A3.9	Multiband (SWIR/MIR, MIR/SWIR - detector Infrared detector Development (including Quantum/ Type-II Strained layer type detectors)	
A3.10	Development of Multi-band high quantum efficiency detector arrays.	
A3.11	Hemi sphere/ flexible Focal plane arrays	
A3.12	High speed high performance APS arrays	

A3.13	Miniature gas sensors for CO, CO2, CH4, NH3, O2, N2O, SO2and other Greenhouse gases.	
A3.14	Optical Fiber based gas sensor	
A4	**Sub area**	**Electro-Optical Systems (SAC)**
A4.1	Fourier transform spectrometers for space	
A4.2	Imaging spectrometer- VNIR and TIR	
A4.3	Compressive sensing techniques	
A4.4	Tera-Hertz imagers	
A4.5	Compact optical systems	
A4.6	Formation Flying EO systems	
A4.7	Imaging Science – Modelling of complete imaging chain – simulation and advancements	
A4.8	Miniaturization of EO sensors/imagers through use of MOEMS	
A4.9	Space LIDAR/LADAR	
A4.10	Precision calibration sources for ground and onboard use	
A4.11	Precision scene simulators	
A4.12	Fibre Optic based image relay system	
A4.13	Studies on 360º imaging optical systems relevant to space based remote sensors.	
A4.14	Micro Mirror based scanners and imagers.	
A4.15	Inter-calibration of hyper-spectral sensors having different spectral response.	
A4.16	Development of models for radiometric and background radiation performance evaluation of Payloads	
A4.17	Identification of trace gases using mass spectrometry data	
A4.18	Development of diffractive/binary/hybrid optics	

A4.19	Interferometric telescopes	
A4.20	Wave front sensing and coding	
A5	**Sub area**	**Micro Fabrication for Optics (LEOS)**
A5.1	**Deformable mirror by micro fabrication for phase correction in adaptive optics** Deformable Mirror (DM) is an important sub system of adaptive optical instrumentation which helps in improving the optical performance of an imaging system by actively correcting the measured wave font errors. The surface figure of a deformable mirror is actively controlled and modified such that it cancels out the measured surface error of system. It is made up a flexible Si wafer with thin film piezoelectric actuators fabricated on the back side using micro lithography techniques. This technology has multiple applications in improving imaging performance, optical communicated and ophthalmology.	
A5.2	**Micro mirror array for wave front phase sensor** Micro mirror array is an important optical device with multiple applications. Realizing the fabrication technology of this device will be a significant step in the development of more complex instruments such as Shack Hartman Sensor etc.	
A6	**Sub area**	**Spectroscopy instrumentation and application (LEOS)**
A6.1	**Optical design and development of compact spectrograph for spectroscopy** Aberration corrected spherical surface gratings for specific spectroscopy application can be designed and the groove pattern can be realized using direct-write electron beam lithography. It is possible to fabricated analog depth diffractive optics in thin films of polymethyl methacrylate (PMMA). Diffractive optic fabrication on non-flat (to date convex spherical) substrates can be fabricated utilizing the large depth of filed inherent in E-beam lithography. Realization of this technology will help in realizing compact, high performance spectrograph with minimum number of optical components.	
A6.2	**Raman spectroscopy based studies on optical materials and minerals:** It is now well established that most of the covalently bonded optical materials and minerals have their characteristic Raman spectrum which can be used to identify the compound. Proposal to do mineralogical study	

	using Raman spectroscopy are useful to collect sufficient data and develop techniques to analyze and identify mineral compositions of any unknown minerals. These results and experience will help in future moon / mars mineralogy using Raman instrument.	
A6.3	**Raman spectroscopy application in earth and planetary atmosphere studies :** The gaseous composition of earth and planetary atmospheres are required to be studied and analyzed on a regular basis to understand the climatic changes that are happening. LIDAR instrument based on Raman spectroscopy can give us valuable information on gaseous distribution along the attitude. Laboratory simulated atmosphere studies of gaseous planets and also experimental Raman LIDAR spectroscopy studies of earth atmosphere are of interest.	
A7	**Sub area**	**Electro- Ground Checkout Systems – (SAC)**
A7.1	Embedded firmware for Real time Data processing, continuous data acquisition (data rate of up to 2 Gbps), Real time video streaming (@ 15fps of frame size 2560x2160) and real time Image display.	
A7.2	Drivers for multi-core DSP system, with RTOS and algorithms for real- time object identification as well as tracking.	
A7.3	General purpose graphics processing based systems for high speed real time image display.	
A7.4	Very high speed Data acquisition of the order of 40Gbps sustained for about 2 TB volume.	
A7.5	3-axis precisely controlled mounts for distortion free imaging.	
A7.6	Extraction of finer spectral resolution information from Hyper-spectral Imagery, given a large number of relatively coarser resolution images with overlapping spectrums.	
A7.7	Algorithm/software to create a super straddle of workstations towards effective utilization of computing resources for electro-optical payload development environment.	
A7.8	Development of algorithms/software to generate 3D images using DMD based scanning of targets.	
A7.9	Development of Mathematical Models for an Electro-Optical System and	

A7.10	Software to simulate the final image, with sensitivity to design parameter/system environment/onboard processing/viewing geometry.	
A7.11	Firmware for Baseband Reception of high speed serial data and real time extraction and dissemination of raw data from FEC coded/CCSDS formatted/Compressed/Encrypted data stream.	
A8	**Sub area**	**Integration and Testing (SAC)**
A8.1	Space-borne electro-optical performance estimation models	
A8.2	Automation of imaging system test setup	
A8.3	Precision test setups	
A8.4	Development of innovative techniques/methodologies for integration and testing	
A8.5	Development of imaging system performance optimization and characterization techniques	
A8.6	Development of In-orbit performance prediction models and performance evaluation techniques	
A6.7	Development of methodologies and fast algorithms for analysis of large amount of test data	
A8.8	Development of highly accurate (better than 0.05mm) 3D measurement System (Photogrammetry based) **(ISAC)**	
A8.9	Development of system capable of measuring the 3D co-ordinates of markers /3D objects. The system should be capable of measuring the 3D co-ordinates of the markers on the object to be measured **(ISAC)**	
A9	**Sub area**	**Sensor Electronics (SAC)**
A9.1	Onboard intelligence	
A9.2	Ultra-low power ASIC, mixed-signal ASIC	
A9.3	Design of High speed FPGA	
A9.4	DSP and embedded design	
A9.5	Mixed-signal component characterization	

A9.6	Miniaturized power supply	
A9.7	HMC-based switching regulator	
A9.8	UAV-compatible hardware	
A9.9	High speed data acquisition and processing	
A9.10	UAV-compatible hardware	
A9.11	Space radiation modelling	
A9.12	EMI/EMC analysis	
A9.13	GP/GPU based software	
A9.14	Miniature sensors for in-situ measurements	
A9.15	Biochemical sensors	
A9.16	**On Orbit mounting estimation of star sensor (LEOS)** Star Sensor Mounting Estimation using on orbit / in-situ measurements The star sensor provides attitude accurate to 10'' in measurement axes and 40" in bore-sight axis, leading the spacecraft pointing and control of 36" in body frame at about 4/8Hz update rate. The mounting / mechanical stability contributes to about 4-6'' uncertainty. Also due to various factors like thermal, effects of structural stability etc., the SS mounting varies by small amount cyclically in orbit/season. Towards providing further improved attitude accuracy of about 10" (in all three axes in body frame), it is proposed for research studies the problem of estimating the star sensor mounting on orbit/in-situ, using star sensor measurements, so that mounting updated at every attitude solution cycle, can be delivered along with estimated attitude solution to AOCS for significantly improving the pointing control accuracies of spacecraft & location accuracies of imageries.	
A9.17	On board star catalog generation for a small field of view (FOV) star sensor. The database should contain inertial coordinates of selected stars. Star separation table in the form of indices of star **(LEOS).**	
A10	**Sub area**	**Microwave Sensors (SAC)**
A10.1	**System Design and Configuration:** MTI from space borne platforms, SAR Polarimetry and Polarimetric Interferometry, new algorithms for Polarimetric Decomposition using hybrid	

	polarimetry, Tandem Bistatic SAR, Sweep SAR & Digital Beam Former based SAR system configurations. Non-linear modulation techniques, Active Radar Calibrators, Stepped Chirp / CW-LFM based Ultra wideband Ground-Penetration Radars, millimeter wave atmospheric temperature and humidity sounding, Altimetry & nano SAR at RF & mm-wave.
A10.2	**Transmit-Receive Technology:** Wideband, high power TR Modules in L, S,C & X-bands, High Power Pulsed TWTA, compact Microwave Power Modules (c-MPM), High Efficiency Pulsed & CW Power Amplifier techniques & technologies (MOS/GaAs FET, GaN HEMT/HBT) with associated thermal & power management, High power & low loss Ferrite Switch assemblies, ultra low noise & ultra high frequency (mm & sub-mm freq. range) technologies employing mHEMT/pHEMT/Schottky/RF-CMOS for linear(LNAs/Gain Blocks), non-linear (mixers/multipliers/VCO) & control circuits (Phase shifters/Attenuators/Switches), Multi Chip Module technologies employing multi-layer soft substrates/LTCC/HTCC, Compact, high stability, coherent Phase Locked (VCOs/DROs based) Frequency Generators, metamaterial structures.
A10.3	**Power Supply Technology:** Miniaturized, high efficiency, pulsed power supplies with higher current capabilities for Microwave sensors, Point Of Load (POL) Hybrid/ASIC, soft switching DC-DC converters, Reconfigurable (FPGA based) PWM Converter.
A10.4	**Digital and Mixed Signal Technology:** Digital signal processor (10 GFLOPS), Digital data compression and de-compression (factor>4), ASIC / SoC Design and Development, Fault tolerant Reconfigurable 32/64-bit Processors/SoC, High speed & High Capacity (>500 Gbits) Scalable Solid state mass storage, Wideband waveform synthesizer (500 MHz or Higher bandwidth), Mixed Signal ASIC Design & Development, Ultra-High Speed Serial / Parallel (>1 Gbps) SERDES/Opto-electronics devices & Interfaces (wired/wireless), Ultra High Speed (>1 GSPS) and Ultra-High Precision Data Acquisition Electronics (16 bits & Higher), Design of Radiation Hardened Cell libraries for standard CMOS process ASIC's, Radiation Tolerant/Hardened Package design.
A10.5	**Onboard Payload Data processing Technology:** Onboard SAR Signal Processing system, Onboard Multi-channel Complex Correlator for Synthetic Aperture Radiometer, Onboard signal processing for Altimeter Sensor, Geometric and Radiometric calibration

	of microwave sensors.	
A10.6	**Signal and Image processing Algorithms:** Signal Processing and Tracker algorithms for Altimeter Sensor, Complex Correlation Algorithm for Synthetic Aperture Radiometer & Complex Correlator Performance Analysis, Onboard SAR Processor, Polarimetric Data Processing and Analysis, Super Resolution Image Processing Algorithms, Feature Extraction Algorithms for Microwave Data, Extraction of Subsurface Dielectric properties for Ground Penetration Radar.	
A11	**Sub area**	**Mission (ISAC)**
A11.1	New tools and techniques for automation of multi satellite operations	
A12	**Sub area**	**Flight Dynamics (ISAC)**
A12.1	Orbit determination: Parameter estimation methods, including least squares and Kalman filtering. Attention should be paid to statistical aspects and data processing	
A13	**Sub area**	**Power (ISAC)**
A13.1	Regenerative fuel cell technology development with an energy density of 420Wh/Kg. These are also called Reversible proton exchange membrane fuel cells where each cell is capable of operating both as a fuel and as electrolyser.	
A13.2	Radio isotope thermo-electric generator. These are static in operation providing very high reliability and long life.	
A13.3	Development of Gallium Nitride Solar Cell development	
A14	**Sub area**	**Mechanical Systems – Thermal (ISAC)**
A14.1	Novel thermal bus systems which can collect transport and provide heat for components	
A14.2	Phase change materials / studies	
A14.3	Thermo electric devices	
A14.4	Variable emissivity coatings. Near unity emissivity with the ability to reduce emissivity by at least a factor of ten.	
A14.5	Thermal control of microelectronics (at board and chip level):	

	- Micro channels (single and two phase) - Micro heat pipes and loop heat pipes (transport capacities can be in the range 1W to 100W)	
A14.6	Process development for porous metal wicks (used in loop heat pipes) with complex shapes and their fluid / mechanical characterization.	
A14.7	Computationally efficient algorithms / codes for view factor calculation including shadowing effects and directional / spectral surface properties.	
A14.8	Radiative / flow / combustion model for prediction of heat flux on spacecraft surfaces from thruster plumes.	
A14.9	Development of an advanced solver for coupled fluid flow and heat transfer with conduction, radiation (participative and non-participative) and convection.	
A14.10	Contamination of optical surfaces due to material migration and deposition in a space environment.	
A14.11	Degradation of spacecraft thermal properties (including contamination films) by high energy particles, atomic oxygen and UV.	
A14.12	Development of flash techniques for thermal diffusivity measurement.	
A14.13	Development of light weight stirling / Brayton engines for spacecraft application to generate power using waste heat.	
A14.14	Enhancement of heat transfer in fluids using electric / magnetic fields.	
A15	**Sub area**	**Mechanical Systems – Structures (ISAC)**
A15.1	Advanced composite materials having higher stiffness, higher strength and better hygroscopic properties	
A15.2	SMART materials like piezo elastic, electrostrictive and magnetostrictive materials.	
A15.3	Shape memory alloys to actively control vibrations and shape control.	
A16	**Sub area**	**Mechanisms (ISAC)**
A16.1	Humanoid mechanism development: The compact mechanism / actuation required for a humanoid (2 legged system) to accomplish movements in a stable manner is to be developed.	

A16.2	Gripper for end reflector: Grippers for micro Robots to handle problem related to handling / operating different tools etc. to be developed.	
A16.3	Analysis of large deployable membrane structure: This involves non-linear FEM methods and required for large unfurlable / inflatable antennas which are mass efficient.	
A17	**Sub area**	**Control Dynamics (ISAC)**
A17.1	Control algorithms for high pointing and stability for advanced remote sensing satellites	
A18	**Sub area**	**Control Electronics (ISAC)**
A18.1	64 bit processor development	
A18.2	Advanced control systems for high resolution imaging satellites	
A18.3	System on chip and mixed signal processing	
A19	**Sub area**	**Digital Systems (ISAC)**
A19.1	Research and development of an efficient image compression algorithm for space application / Advanced Audio / Video coding	
A20	**Sub area**	**Reliability and Components – Indigenization (ISAC)**
A20.1	System-In package (SIP): Enabling Technologies viz. Multichip module with chip level stacking & embedded passives and MMIC based RF / Microwave modules to bring the SIP to a more complete functional system	
A21	**Sub area**	**Reliability (ISAC)**
A21.1	Contamination modelling and kinetics studies: To establish computer model for estimation of in-orbit contamination by taking into account the orbit parameters	
A22	**Sub area**	**Systems Engineering (ISAC)**
A22.1	Automation test systems for various space conditions. Spacecraft electronic packages (simulation, Analysis) and data logging.	
A23	**Sub area**	**PCB Design & Fabrication (ISAC)**
A23.1	Advanced Chemical / materials development for fine hole plating and fine line etching in PCB application	

A23.2	Development of advanced photo lithography for high density interconnects (HDI)	
A24	**Sub area**	**Space Astronomy - X-Ray/Thin films (ISAC)**
A24.1	Development of thin X-ray windows (pin hole free, few micron thick, made of low Z materials) (Energy of interest 200 eV to 2000 eV) for x-ray detector applications.	
A24.2	Development of thin film windows for the transmission of charged particles, especially particles of higher charge.	
A24.3	Laboratory characterization of poly capillary x-ray optics.	
A25	**Sub area**	**Optical Thin Films (LEOS)**
A25.1	**Studies on transition metal oxide thin film coatings**: Transition metal oxide coatings are potential candidates for their applications as infrared detector sensing elements, switching devices, radio-frequency transparent thermal control coatings, etc. Studies on optical, electrical and thermal properties of the thin films will lead to development of devices for space applications.	
A25.2	**Laser damage threshold studies on optical thin film coatings:** The optical coatings such reflector coatings, antireflection coatings, interference filter coatings, etc have their applications in laser based instruments for ground as well as space applications. Based on the energy of the laser the coatings may be damaged. The studies on laser damage threshold of optical coatings give an insight into the durability aspects of the coatings for laser applications.	
A25.3	**Studies on hydrophobic/ dust repellent coatings:** Optical thin film coatings are essential for space based reflective/ refractive electro-optics systems. The front optical elements being exposed to space environment, they need to be protected from dust and condensable vapours which seldom detrimental to the performance of payloads. These coatings will also be useful in interplanetary missions during landing the instrument over the surface of the planet. Hence the study of hydrophobic/ dust repellent coatings find space applications	
A25.4	**Infrared optical coating technologies for filters, Anti reflectance coatings etc for IR optics:** Space qualified optical coating technologies to produce filters and ARCs in	

	different spectral bands in the near IR, SWIR and far IR for the imaging and spectroscopy instruments that are being envisaged in the future space programs are required to be developed.
A25.5	**Thin film solar cells and thin film batteries for satellite power requirement** It is already recognized that Thin film solar cells based Cu-In-Ga-S (CIGS) materials coatings are highly advantageous for space power application as these panels have high specific power (Watts / Kg) and are highly radiation resistant. Development of this technology for space usage will help in significantly reducing the weight contribution due to solar power requirements.
A25.6	**Nano technology based optical / gas sensors :** Nano technology based rechargeable Thin film batteries which can be charged and store the power generated by solar cells are under development for space application. With this combination failures due to lack of power can be significantly reduced.
A25.7	**Optical material, coatings and components for NIR or Visible LASER development :** Indigenous development of LASER for space application in an ongoing process at LEOS which requires lasing materials, damage resistant coatings and Thin film based laser diodes etc., research and development in realizing these technologies can be very useful.
A25.8	**Ultra narrow band pass and notch filters for a single wavelength of a laser line :** These filters are required for Raman Spectroscopy Instrumentation where the incoming laser should be spectrally stable with a very narrow band width and without any side lobes. This can be possible only with a very narrow band pass filters placed in front of the laser. Similarly the Rayleigh scattered radiation from a laser illuminated sample has the same wavelength as the laser. In order to observe the Raman Spectrum, this component needs to be filtered out completely using a very narrow band notch filter centered at the laser wavelength. Development of these filters will help in indigenous realization of Raman instrument for space application.
A25.9	**Glancing Angle Deposited optical films with unique optical properties and their applications :** Porous nano-engineered thin films fabricated using GLAD have a wide variety of optical applications. Helical films exhibit intriguing chiral optical

	properties, including circular Bragg effects and optical activity. GLAD films with grade index can be used for wide-band antireflection coatings exhibiting transmittance in excess of 99.7% over a 460 nm wavelength range, rugate filters with wide stopbands, spectral hole filters with narrow passbands, and even optical humidity sensors with superior performance response time and sensitivity to many commercial available sensors. The square spiral chiral film can be used to produce photonic crystals with a complete, three dimensional bandgap.	
A26	**Sub area**	**Gravity gradiometer - Atom Interferometry (IISU)**
A26.1	Design and Development of Gravity Gradiometer using atom interferometry techniques in a double MOT set up with laser cooled Rb atoms.	
A27	**Sub area**	**Ultrasonic - Motor, manipulator excitation electronics (IISU)**
A27.1	Design of compact ultrasonic motor for micro actuators	
A27.2	Design of a micro manipulator which uses the ultrasonic motor	
A27.3	Development of an ultrasonic motor including fabrication techniques, manufacturing, development of excitation electronics.	
A27.4	Assembly of the motor with the manipulator and demonstration of the same.	
A28	**Sub area**	**Smart PCBs - Stress strain sensitive films (IISU)**
A28.1	Design of multilayer PCB with integral stress/strain sensitive films	
A28.2	Development of the strain/stress sensitive film embedded PCB	
A28.3	Demonstration of the insitu stress measurement during vibration of the randomly populated SMART PCB, in the vibration shaker.	
A29	**Sub area**	**Accelerometer - Micro cavity resonator and microwave electronics (IISU)**
A29.1	Design of compact microwave cavity resonator	
A29.2	Design of compact microwave cavity resonator with One of the sides (wall) movable.	
A29.3	Design of the movable wall which is sensitive only to Acceleration. Acceleration induced changes in the dimension of the cavity alters the	

	resonance frequency.	
A29.4	Design of microwave excitation and detection schemes for the resonator.	
A29.5	Development of cavity resonator and microwave electronics	
A29.6	Development of fabrication technology for realizing the microwave cavity resonator	
A29.7	Development of compact electronics including microwave generator, and detector.	
A29.8	Assembly of microwave cavity resonator with the electronics.	
A29.9	Demonstration of accelerometer principle	
A30	**Sub area**	**Fusion Algorithm for computation of Spacecraft Attitude with Multiple – Head Star Trackers (LEOS)**
A30.1	**Development of optimized fusion algorithms and techniques to combine the images obtained from multiple heads, compensate for thermo-elastic distortions between heads and compute spacecraft attitude** Higher attitude measurement accuracy is obtained by using the star image captured from multiple star tracker heads that are mounted with different relative orientations. The accuracy is improved with the availability of more number of stars from multiple heads and different orientations of star tracker heads that offset bore-sight errors. The difficulty is multiple heads configuration is the results may be affected by thermo –elastic distortions between the heads	
A31	**Sub area**	**Micro Aircraft for Mars-2 (LEOS)**
A31.1	**Development of Unmanned Arial Vehicle (UAV) which can fly using solar power.** • It will have imaging payload and an RF link with the orbiter spacecraft. • It should have adjustable propellers to fly forward as well as for hovering. • It should be built with non-corrosive and light weight material. The Mars is having lot of attention from the researchers for its exploration, related to existence of life. Typically the exploration is carried out in two phases. • A spacecraft orbiting over Mars and taking images with very high	

	resolution images, which are bulky to fine the area of interest. But this has limitations. The dust and clouds make a thick layer and make the visibility poorer for the attitude of a spacecraft. • After finding the region of interest a rower is made to land on the surface and the rower does the soil study in very limited area. • There can be one intermediate stage to find out area of interest on Mars surface by a low attitude Arial survey. Since Mars is having atmosphere an Aeroplane can fly over here. This plane should be solar powered, built with light weight non corrosive materials and carries small camera for surveillance and RF link with the satellite should have Mars upto 3 kg. It's propellers should be adjustable to front direction fly as well as for hovering. The Aero plane is deployed from the satellite into the Mars atmosphere and the plane performs high resolution survey on a wide area with miniature cameras. In case the area is found to be unsuitable the plane can be made to hover at a different area. This makes the search very economical for the desired landing spot for a rover, since the higher resolution images can be obtained with a much smaller payload when a low attitude survey is carried out.	
B	**Area**	**Remote Sensing Image Processing and Software Development**
B1	**Sub area**	**Image Processing (SAC)**
B1.1	**Advanced technique and algorithm development for in-flight Geometrical Calibration and its Standardization for Optical Remote Sensing payloads:** In-flight geometric calibration exercises are carried out usually during initial phase of the mission and necessary algorithms and corresponding s/w are developed for each mission separately. Special efforts are put for conducting a large number of exercises and analysis of results. This makes the in-flight experiments purely mission dependent calling for s/w changes for any new mission. Further, different modelling approaches are available with the DP team. So a need for generalized s/w is felt based on the current experiences while giving scope for flexibility to extend the approach for new sensors like TDI and other high-resolution imaging modes. A scheme for standardization/generalisation of this activity is being evolved in terms of the following viz. • Establishing necessary set of pre-identified test bed areas where adequate number of accurate control points are available, for use by any mission • Development of mission independent techniques/algorithms and	

	necessary s/w to work with or without control. • Provision to incorporate new techniques, various modelling options to work with/without control points, options for single sensor, stereo sensors, triple sensors, multi-strips, multi-bands, TDI sensor, imaging modes etc. • Identifying a set of common in-flight geometric parameters for adjustment for any mission as well as mission specific features. • Approach should be able to characterize interior and exterior orientation of the sensors. • Standardization of definition, convention for in-flight geometric parameters and their use • Estimation and separation of attitude biases from spacecraft alignment and payload alignment angles etc. • Standardization of Input /Output file formats and contents • Scope for adding any additional, new features pertaining to in-flight procedures. This research aims at development of new procedures (both technology development as well as R&D work for development of algorithms and s/w) and standardization/generalization of the approaches for in-flight geometric calibration of the sensors onboard remote sensing satellites, which will result in high accurate data product realization at system level, apart from improving registration and mosaicking accuracies across missions for handling heterogeneous data sets. This can also give a future direction to the calibration procedures in terms of the requirements of some of the hardware onboard so that they can be useful in the future remote sensors (Cartosat-2C/2D, Cartosat-3, Cartosat-1A/1B, Chandrayaan-2 etc) of different configuration.
B1.2	**Modelling for Multiple Satellite/Sensor/Strip/View data in block adjustment sense:** The aim of this research is to develop approaches/techniques (both parametric and non-parametric) to model simultaneously data from multiple satellite/sensor/strips/Views from Cartosat-1/2/2A/2B and future missions to generate terrain corrected products with high accuracy. The scope of the proposal includes development of techniques for generation of Digital Elevation Models and Orthoimages without using the control points so that it can meet the Global requirements. This can be achieved by increasing the redundancy in the datasets. Both Physical and RPC models will be built in block adjustment such a way, it can be easily adopted for planetary

	missions Chandrayaan-1 and Chandrayaan-2. It is planned to make use of this approach with global missions like Quickbird, IKONOS, Worldview for available data sets. The proposed research will be able to handle and model full pass duration with limited control or no control and pave way for realizing highly accurate DEMs and good quality data products especially for future HR missions like Cartosat-2C/2D, Cartosat-3, Cartosat-1A/1B etc.	
B1.3	Relative Radiometric Normalization Techniques	
B1.4	Advanced image Registration models/frameworks/software/libraries	
B1.5	Image classification and intelligence	
B1.6	Kernel based Learning/Machine Learning for Change detection analysis	
B1.7	Super resolution Approaches for Remote Sensing Images	
B1.8	Automatic Feature Extraction and Labelling Techniques	
B1.9	Noise Modelling, Blur removal	
B1.10	Image Representation	
B1.11	Image Based Modelling and 3D re-construction	
B1.12	Automatic extraction of 3D city models using LIDAR/ Satellite data - **(IIRS)**	
B2	**Sub area**	**Earth Observation Data Processing (SAC/ NRSC/IIRS)**
B2.1	Advanced sensor models for optical & Microwave data Geo-referencing **(SAC/ NRSC/IIRS)**	
B2.2	Techniques for Geospatial Data Analysis **(SAC/ NRSC/IIRS)**	
B2.3	Atmospheric correction procedures implementation for Visible &NIR **(SAC/ NRSC/IIRS)**	
B2.4	**Data Processing for Smart Satellites (SAC)** Technology demonstration of complete Data processing on-board and disseminating products/Information.	
B2.5	**Cloud Avoidance Scheduling (NRSC)** Payload programming makes the optimum use of satellite resources to satisfy User requirements. The various capabilities of the IRS satellites and its resources call for a meticulous planning. Payload programming is	

	successful only when it results in acquisition which cater to user requirements in terms of data quality, correct area of coverage (targeting accuracy), timeliness (within the period of interest) and cloud free acquisition. Cloud cover is one of the major problems in the acquisition of optical satellite remote sensing data and has a negative impact on the efficiency of data scheduling. The necessary global cloud information (on a daily / hourly basis) derived from meteorological satellites has to be incorporated in the planning system to improve the planning efficiency.
B2.6	**Time Series Data Processing (SAC)** Re-Processing all IRS, land and ocean data for generation of Atmospherically corrected ortho-rectified (water leaving radiance and ground reflectance) products, which can be used for Time Series analysis and generation of climate quality products
B2.7	A private cloud infrastructure for Image processing and highly compute intensive applications so as enable designers/developers to dynamically use computing and storage resources in HPC environment **(SAC)**
B2.8	GRID enabled Global Data Processing Model **(SAC)**
B2.9	Parallel Processing approaches for real time data processing and re-processing in HPC environ **(SAC)**
B2.10	**LIDAR Data Processing (SAC)** Space Based, Ground Based and Aerial LIDARS
B2.11	Data Processing for Atmospheric studies using space borne platforms **(SAC)**
B2.12	INSAT-3D, Resourcesat-2R, GISAT Improved Processing algorithms and techniques to support real time users requirements and generation of Atmospherically corrected Land Products **(SAC)**
B2.13	Generalized Data Processing Software for Air-borne HySI Optical sensors **(SAC)**
B2.14	Development of Advanced SAR Image Formation techniques, Polarimetric techniques for air-borne & space-borne payloads **(SAC)**
B2.15	Hybrid polarimetric modelling for scattering information retrieval from man-made and natural features **(IIRS)**

B2.16	Snow depth and Snow Water Equivalent (SWE) estimation using SAR and ground based measurements in Himalayas **(IIRS)**	
B2.17	Semi-empirical modelling for forest biophysical characterization using PolSAR data **(IIRS)**	
B2.18	SAR calibration and attenuation measurement using triangular trihedral corner reflectors for RISAT-1 data **(IIRS)**	
B2.19	Characterization of opencast mining areas using various polarimetric decomposition techniques **(IIRS)**	
B2.20	Urban Feature/metallic extraction using fully polarimetric data **(IIRS)**	
B2.21	PolInSAR based semi-empirical modelling for forest aboveground biomass estimation **(IIRS)**	
B2.22	Space-borne three dimensional SAR tomography **(IIRS)**	
B2.23	Estimation and Correction of Tropospheric and Ionospheric Effects on Differential SAR Interferograms **(IIRS)**	
B2.24	Calibrated Climate Quality Products generation and global dissemination from Scatterometer & Altimeter type of Payloads **(SAC)**	
B2.25	Augmentation of analysis and applications packages for microwave Sensors **(SAC)**	
B2.26	New retrieval Algorithms – FSI (Full Spectrum Inversion) of ROSA data Processing **(SAC)**	
B3	**Sub area**	**Data Simulation (SAC)**
B3.1	**High resolution data simulation for future Cartosat series:** There is a need of data simulation towards understanding the TDI devices in terms optical butting (used to make swath larger), high bit depth (radiometric resolution) and spatial resolution (0.5 m or higher). Therefore TDI sensor data simulation will be taken up in near future by using the other TDI devices data already flown globally like IKONOS/Quick Bird etc. This simulation will help in calibration, and testing the data processing and data compression s/w of Cartosat-2C and 3.	
B3.2	Developing Advance Techniques for Simulations of EO data, Simulations of Sensor Data for pre-flight software testing	

B3.3	Development of simulator for altimeter data generation and processing.	
B4	**Sub area**	**Data Visualisation, Cloud Computing & Software Architecture (SAC)**
B4.1	**An immersive satellite image navigator with human gesture recognition** This research may brandish a complete suite to visualize the image data with gesture recognition features. This kind of navigation will enable swift display and browsing of satellite image data with the help of no contact, gesture driven device. Also, it can be used in discussion panels, exhibitions and presentations which intend to use this type of visualization as an approach for technology demonstration.	
B4.2	**Development of Image fusion techniques for Catosat-2C between MX & PAN** This research is aimed towards development of image fusion techniques by spatial and frequency domain methods for merging HR PAN & MX data. The scope includes • Development of Image fusion method to generate merged product of Cartosat-2C. • Study & implementation of suitable algorithm and in-house software development from the existing approaches for HR data and • Initially testing can be done by existing Cartosat-1 & IRS-P6 data sets towards the realization of Catosat-2C.	
B4.3	**Full Pass/Strip satellite attitude rectification using dynamically generated control points** Satellite attitude rectification normally relies on the use of manually identified GCPs or Ground Control points. The cost of acquiring them is often prohibitively expensive. Terrain, relief corrected and geo-registered Orthoimages made available by DEM projects such as CartoDEM can be used to dynamically generate large number of feature based control points. These control points can then be used in the physical model to rectify the satellite attitude over whole satellite pass and improve the location accuracy of products. The modelling would be done using the quaternions in the resection equations rather than the using the roll, pitch and yaw as attitude.	
B4.4	**Image Matching for DEM generation** One of the most important components of DEM generation from stereo/	

	multi-view imagery is the generation of high density match points and their structuring. Current version of CartoDEM based on Cartosat-1 stereo pair is based on advances in template matching to produce high density match points and structuring by TIN. Further research areas taken up in this include feature-based matching, better shadow and outlier detection, and improved DEM regularization/ conditioning for end-use. Another area of research in this field is development of robust algorithm for triplet matching, which will be enhancing the current version of Lunar DEM generated from Chandrayaan-1 TMC as well as for future Chandrayaan-2 TMC.
B4.5	**Image Quality Improvement** The image component of Data products are a result of correction for systematic errors/ variations in Radiometry and Geometry. Development of techniques for restoration (MTF correction) of high spatial resolution imagery (e.g. Carto-2 series), de-striping of narrow-band sensors like OCM, and spectral de-convolution of Hyper-spectral imagery are areas of research in this category. Currently operational MTF restoration for Cartosat series are based on techniques developed here.
B4.6	**Post-launch Calibration of space-borne sensors** This is carried out for medium resolution optical land-imaging sensors' radiometry based on natural calibration sites, for narrow-band Ocean Colour sensors based on Moon-imaging, for high resolution sensor MTF based on artificial targets, and for SAR sensor geometry using corner reflectors and radiometry from natural sites. Development of suitable models for ground radiometry assimilation, Top-of-Atmosphere radiance generation, Moon-image irradiance modelling, target design and modelling for MTF evaluation, and for modelling of calibration parameter determination for SAR targets are areas of research in this category. In each aspect operational methods are based on R&D carried out here.
B4.7	**Quality Indices for quantifying Data Quality** There is a need for continuous R&D for identifying suitable quality parameters for each IRS sensors, development of algorithms for evaluating the parameters from data, and quantifying uncertainties in the process.
B4.8	**Sensor Web Enablement (IIRS)** Open Geospatial Consortium (OGC) has taken a major initiative towards the development of OGC SWE specification. The OGC's Sensor Web Enablement (SWE) standards enable developers to make all types of sensors, transducers and sensor data repositories discoverable, accessible and useable via the Web. Some of the key areas of SWE research are on Sensor Web Data Visualization, Sensor Web Data Uncertainty

	Management, Sensor Web Data Management (e.g., Indexing, Caching, Query & Processing), Sensor Web Data Discovery and Search and SWE Deployment for Real-world Applications. Also few areas like Convergence of GeoWeb, Sensor Web and Social Web and Interoperable Middleware Architectures for heterogeneous Sensor Networks/Sensor Web are in developmental stages.	
B 5	**Sub Area**	**Satellite image data compression & decompression (NRSC)**
B5.1	**Development of high speed CCSDS image compression/decompression technique**: The CCSDS has established a recommended standard for a data compression/decompression algorithm applied to two-dimensional digital spatial image data from payload instruments and to specify how this compressed data shall be formatted into segments to enable decompression at the receiving end. The steps followed can be briefed as: performing an image de-correlating operation (DWT) and then encoding the coefficients in various stages in order to obtain the compressed image. The compressed image has to be decoded with the knowledge of the segment header. Rate regulation needs to be done in order to adjust the compression rate. The decoded coefficients are correlated back (inverse DWT) to get the reconstructed satellite image All the future Cartosat missions follow the CCSDS image compression/decompression technique and there is a need for the high speed implementation of the same. The requirement is the implementation of all the compression and decompression steps using General Purpose Graphics Processing Unit (GPGPU) and CUDA software.	
B6	**Sub area**	**Error Correction Coding (NRSC)**
B6.1	**Reed Solomon decoding software development for satellite data:** • Satellite communication channels are subject to channel noise, and thus errors may be introduced during transmission from the source to a receiver. Error detection techniques allow detecting such errors, while error correction enables reconstruction of the original data. Reed Solomon decoding algorithm is one of the error correcting algorithms to correct the received data with errors. Different formats of RS decoding standard algorithms are available like (247,255), (223,255). These things work in two modes one in CCSDS format	

	and the other in traditional standard mode. • Because of huge volume of satellite data and large mathematical computation it is time consuming to decode the data by using the traditional methods of Reed Solomon decoding algorithm. Hence there is a need for the high speed implementation of the same. The requirement is the parallelism of the Reed Solomon algorithm in General Purpose Graphics Processing Unit (GPGPU) and by parallel approach in Central Processing Unit (CPU).	
B7	**Sub area**	**Distributed Workflow Management (NRSC)**
B7.1	**Autonomous Multi agent Job Scheduling Algorithms for distributed systems:** Large scale processing and knowledge extraction from data requires execution of complex workflows in a distributed environment. A generic framework needs to be evolved for collaborative computing among the resources to obtain maximum throughputs from the systems Development of (i) multi-agent system architecture for processing data in a distributed network environment (ii) models for a multi agent communication (iii) schemes for automatic configuration of agents based on the dynamics of the real time job scheduling and (iv) Resource optimization algorithms to improve the processing timelines	
B8	**Sub area**	**Data Mining (NRSC/SAC)**
B8.1	**Parallel Algorithms for Knowledge Extraction from Big Data:** Large volumes of data that cannot be stored in normal relational databases are being generated every day from the remote sensing satellites. Many software elements extract information from the raw data generating information in unstructured form such as images, log files, user orders in pdf, word etc. There is a need for developing efficient data mining algorithms to tag the data sets for facilitating efficient build up of archival and retrieval. • In general data mining algorithms work on data sets that are of reasonable size and cannot handle BIG data. • Develop Parallel Algorithms for mining the classification rules to facilitate data archival in an optimal manner • Develop mining algorithms that are Incremental and can learn and unlearn from the continuous satellite data acquisitions • Develop algorithms for extracting meaningful trends in the customer ordering, build customer satisfaction index, predict the future sales	

	or potential sensors or popular products etc.,	
B9	**Sub Area**	**Software Engineering (NRSC)**
B9.1	**Software Reliability Modelling and Metrics:** There is a need to develop automated tools to extract different metrics from various software packages developed by ISRO to estimate their reliability and predict if possible the failure rates from the version history. • Develop customized metrics for different types of software packages including real time, near real time, post processing, workflow software and distributed software • Develop algorithms for estimating the software reliability numbers and predictive models for forecasting the failure conditions	
C	**Area**	**Earth, Ocean and Atmospheric Sciences Applications**
C1	**Sub area**	**Atmospheric / Oceanic sciences and climate (SAC/NRSC/IIRS)**
C 1.1	**Retrieval of geophysical parameters from satellite data (SAC)** ISRO has planned for launching a number of meteorological and oceanographic satellites in near future. It has already INSAT-3A, KALPANA, Megha-Tropiques, SARAL and Oceansat-2 satellites in the orbit. In near future it has plan to launch INSAT-3D and GISAT. It is a challenging work to retrieve geophysical parameters from the sensor data of these satellites. This involves Radiative Transfer modelling and the Inverse modelling techniques.	
C 1.2	**Assimilation of satellite data in numerical weather and ocean prediction models (SAC)** Advance research is being carried out for assimilation of satellite derived parameters in numerical weather and ocean prediction models. This involves development of various assimilation techniques for improving the initial condition in the models. Recently special emphasis is on direct assimilation of satellite measured radiance into the input. This involves Radiative Transfer modelling and optimization techniques.	
C 1.3	Retrieval of IPAR & PAR flam OCM-2 irregular basis and validation with measurements for different regions of tropical, sub tropical and Polar areas **(NRSC)**	
C 1.4	Retrieval of sea surface salinity from satellite data and validation **(NRSC)**	

C 1.5	Ocean surface characterization using SARAL Altika Data **(NRSC)**
C 1.6	Meso-scale ocean eddy scale analysis **(NRSC)**
C 1.7	Ocean wind, wave and current assessment in coastal waters **(NRSC)**
C 1.8	Satellite altimeter waveform analysis to improve geophysical parameters retrieval **(NRSC)**
C 1.9	Satellite altimeter Data assimilation in ocean models **(NRSC)**
C 1.10	Derivation of Ocean surface currents utilizing data from SARAL AltiKa and OSCAT. Combining geostrophic currents from SSHA (from Altimeters) and wind driven currents from wind velocities (from Scatterometer), the ocean surface currents can be obtained **(NRSC)**
C 1.11	Ocean modelling: Investigation of the thermal inertia of the Indian Ocean. Ocean models can be used to investigate the thermodynamics of the oceans with emphasis on long term thermal evolution in the oceans. This would help in estimating the thermal inertia of the ocean, an indicator of effects on climate change. **(NRSC)**
C 1.12	**Numerical weather prediction with general circulation models (SAC)** Real time weather forecast is an essential component during satellite launches from the launch pad as the launch vehicle is exposed to weather 2-3 days before the launch. Short range weather prediction is made using numerical weather prediction model and assimilation of satellite data. The same technique is also used for All India weather forecast in 5 km resolution. This involves dynamic modelling, physical parameterization and assimilation of satellite data.
C 1.13	**Ocean state forecast with global and regional numerical dynamic models(SAC)** Ocean state forecast is being done by using Ocean general circulation model and wave models. As there are only a few observations are available over the ocean, there is large uncertainty in the initial condition. Assimilation of satellite data is an important component to generate the initial condition and the forcing field. This involves advance assimilation technique for ocean data assimilation.
C1.14	**Air sea interaction studies (SAC)** To understand some of the atmospheric and oceanic processes near ocean surface, air sea interaction study is very important. Because of scarcity of observed data over the ocean, it is important to understand

	these processes with the help of satellite data. This involves diagnostic studies of the processes with satellite data.
C1.15	**Diagnostic studies for Monsoon (SAC)** For better prediction of Indian Monsoon, it is necessary to understand the physical mechanism of convective processes. For this purpose, a lot of diagnostic studies are being carried out using satellite data like vertical profiles of atmospheric temperature and humidity. These profiles help to understand the stability of the atmosphere.
C1.16	**Cyclone track and intensity prediction using satellite data and numerical models (SAC)** Cyclone track and intensity prediction is very important activity as there is huge damage occurred due to cyclones. Improvement of cyclone track is being done by using numerical models and satellite data. Satellite data is used to determine the present location of the cyclone when it is over the ocean and away from the coast. The exact determination of the current and past location is useful for prediction of its future movement and intensity prediction. This involves both empirical and dynamic modelling and assimilation techniques.
C1.17	**Polar ice dynamics studies (SAC)** To study the impact of climate change on polar ice cover, satellite data are used for monitoring the ice cover over the Polar Regions. Research is being done for identifying different type of ice cover using various satellite measured parameters.
C1.18	**Climate prediction with coupled Atmosphere-Ocean-Land-Ice models (SAC)** For long term prediction of climate, Coupled model of Atmosphere, Ocean, Land and Ice is very important component. In these models, coupling is an important area of research as different components have different spatial and temporal variability. This involves balancing the fluxes at the interface boundaries of each component of the model.
C1.19	**Climate Change Impact assessment** – Anticipated/Ensuing climate change is expected to alter the water resources availability, demand and use patterns. Many uncertainties remain about the extent of these climatic changes, as well as about their societal implications. Assessment of vulnerability and resulting risk to water resources due to climate-change impacts is necessary to work out appropriate adaptation and mitigation strategies **(NRSC)**

C1.20	**Impact of climate change on Himalayan snow and glaciers (SAC)**
C1.21	**Advanced system study for new sensor definition (SAC)** For new measurements of atmospheric and Oceanic parameters, new advance sensors have to be defined for future satellites. System study is being done with the help of Radiative transfer models to define the appropriate frequency and bandwidth of new sensors.
C1.22	**Development of coastal algorithm for ocean colour remote sensing (SAC)** Development of Case-2 geophysical algorithms for Indian coastal waters, Atmospheric correction models for turbid waters, Development of CDOM and TSS algorithms and Bathymetry estimation in optically shallow waters.
C1.23	**Coastal Carbon Dynamics in Oceans(SAC)** Bio-geo-chemistry of the coastal oceans, Study of various components of the carbon cycle, Nitrogen cycle and phytoplankton blooms, Fish stock assessment, Primary and New production modelling.
C1.24	**Development of bio-optical algorithms in CASE-2 waters (NRSC)** With the availability of OCM-1 and 2 and for the future OCM-3 with more spectral bands a programme has been planned for reprocessing of ocean colour data sets for the development of ECV like chlorophyll-a, PAR and diffusive attenuation coefficient in coastal waters. Using large sets of in-situ underwater radiation measurements and associated bio-physical measurements coastal bio-optical algorithms has to be developed. Using this algorithm reprocessing of OCM data is to be planned.
C1.25	Coastal vulnerability models and risk assessment **(SAC)**
C1.26	Response of Coastal system due to climatic change and its long and short term implications **(NRSC)**
C1.27	Satellite based retrieval of geo-physical parameters for coastal processes assessment **(NRSC)**
C1.28	Eco-system change direction and responses due to coastal change using high resolution IRS-data sets **(NRSC)**
C1.29	**Atmospheric Aerosol Research (SAC)** Algorithms for atmospheric aerosols using satellite over land and oceans, Aerosol transportation and climate studies.

C1.30	Urban heat fluxes (quantification of surface energy processes, urban weather, urban heat distribution and heat fluxes) **(IIRS)**
C1.31	Atmospheric Modelling: Pixel based AOD estimation by radiative transfer modelling using TOA radiance and validation with field instruments **(IIRS)**
C1.32	Atmospheric modelling: Development of image based aerosol retrieval techniques over satellite imagery **(IIRS)**
C1.33	**Green House Gases Estimation (SAC)** One of the recent trends in remote sensing understands the climate change trough space measurements. Atmospheric Green house gases concentration and measurements of flux are important research Area. India has plans to launch such mission (ENVSAT Series) in future with other countries (OCO of USA, GOSAT-2 of Japan). There is need to develop radiative transfer scheme to model and retrieve the gases concentration. There is need to in situ measurement of CO2, CH4, N2O etc fluxes for validation of satellite products.
C1.33	Regional monitoring of Trace and Green house gases **(NRSC)**
C1.34	Retrieval of green house gases using satellite data **(NRSC)**
C1.35	Transport of chemical constituents of atmosphere using WRF chemical transfer modelling **(NRSC)**
C1.36	Aerosol Optical Thickness and Atmospheric Correction over Land: **(SAC/IIRS)** Calibration and radiometric normalization is the key issue in future remote sensing activities related with biophysical parameter retrieval and climate change. Atmospheric correction of the satellite data is a challenge. Most important input for atmospheric correction involved estimation of Aerosol optical thickness (AOT) either from network of ground observations or satellite data. Retrieval of AOT sensors like Resourcesat series is a challenge. There is need to develop simplified correction approach including AOR inputs using dark dense vegetation approach. There is further need to develop instrumentation with capability of polarized measurements and LIDAR sensing.
C1.37	Study of Boundary Layer dynamics **(NRSC)**
C1.38	Aerosol characterization and its impact on solar radiation **(NRSC)**
C1.39	Surface energy budgeting using remote sensing **(NRSC)**

C1.40	Impact of aerosol on agricultural productivity **(NRSC)**	
C1.41	Retrieving vertical profile of temperature and humidity using Radio Occultation (RO) data **(NRSC)**	
C1.42	Atmospheric Transport (role in determining the distributions of chemical species in the atmosphere, understanding process, circulation, vertical transport, atmospheric stability, turbulence etc) **(IIRS)**	
C1.43	Particulate matter monitoring (understanding air quality standards, classification of particulate matter, evolution, transportation, processes, measurements analysis and modelling) **(IIRS)**	
C1.44	Trace gases measurement and monitoring (understanding trace gases, evolution, transportation, processes, measurements analysis and modelling) **(IIRS)**	
C1.45	Atmospheric sounding (measurement and understanding of vertical distribution of physical properties of the atmospheric column such as pressure, temperature, wind speed and wind direction, pollution and other properties using remote sensing and in situ observation) –(IIRS)	
C2	**Sub area**	**Geosciences (SAC/ NRSC/ IIRS)**
C2.1	**Himalayan Cryosphere (SAC)**	
	Modelling snow and glacier depth	
	Development of algorithms for auto extraction of glacier features from multi-sensor satellite data with particular reference to Hyperspectral and thermal data	
	Snow and glacier hazards including avalanche forecasting, crevices detection and modelling burst of moraine dam lakes	
	Microwave remote sensing for snow & glaciers including interferometry techniques	
C2.2	**Marine Geosciences (SAC)**	
	Development of techniques to retrieve gravity/geoid using satellite altimetry over oceans	
	Modelling marine lithosphere using gravity and other geophysical data	
	Understanding subsurface tectonics and associated processes	

	Study of water quality parameters such as turbidity, Ph, etc using hyper spectral remote sensing data; Calibration of the remote sensing data using the field observations **(NRSC/ IIRS)**	
C2.3	**Geo-Archaeology (SAC)**	
	Developing approach to analyze multisensor satellite data (Radar and high resolution multispectral data in particular) for identifying hitherto unknown surface/buried archaeological sites	
	Validation using geophysical techniques such as GPR, pitting and trenching.	
C2.4	**Geology, Structure and Geomorphology (NRSC/ IIRS)**	
	Hyper spectral response characterization of intimately mixed geological samples occurring in complex geological terrain **(NRSC)**	
	Spectral library generation of rocks & archiving from various geological terrain in visible and thermal region **(NRSC/IIRS)**	
	Sub-surface geo / archaeological features using GPR data sets**(NRSC)**	
	Geophysical data collection and analysis for understanding the subsurface in some of the important geological province **(NRSC)**	
	Active faults mapping using high resolution satellite data **(NRSC/IIRS)**	
	Development of an automatic technique using satellite data and DEM for identification of landforms in different geomorphic provinces of India **(NRSC)**	
	Numerical modelling for crustal deformation using GPS vectors **(NRSC/IIRS)**	
	Mapping/ Updation of major Tectonics Grains in N. India using RISAT-1 Data **(IIRS)**	
	Analysis of Geomorphic Indicators for studying Active /Current Tectonics **(IIRS)**	
	Space borne geodetic techniques like gravity data processing & analysis, DINSAR and related Techniques **(IIRS)**	
C3	**Sub area**	**Soil Resource Characterization, Land Use Planning and Watershed Management (IIRS)**

C3.1	Terrain Characterization in Hydrological properties of soils	
C3.2	Spatial prediction of soil properties	
C3.3	Expert knowledge & fuzzy logic in characterization of soil properties	
C3.4	Soil & Nutrient Loss modelling at watershed scale	
C3.5	Climate change Impact of soil erosion and soil quality	
C3.6	Soil Quality Assessment and Monitoring using hyper spectral data	
C3.7	Soil Nutrient Management for Precision Agriculture using hyper spectral data	
C3.8	Soil Clay Mineral Identification and Mapping using hyper spectral data	
C3.9	Microwave RS in Characterization of salt-affected soils and waterlogged area	
C3.10	Soil carbon sequestration	
C3.11	Impact of climate change on soil processes	
C3.12	Satellite based Evapo-transpiration Estimation	
C3.13	Land surface parameter estimation: Estimation of land surface albedo using radiative transfer principles	
C4	**Sub area**	**Agriculture and agro-ecosystem (SAC/IIRS)**
C4.1	Development of mathematical/matching algorithm in spectral library development using hyper spectral data **(SAC)**	
C4.2	Integrated approach (including remote sensing inputs) for multi-crop assessment in sparse cropped regions **(SAC)**	
C4.3	Ingestion of RS inputs/products in Climate change analysis/modelling of agro-ecosystems **(SAC)**	
C4.4	Development of GHG models for agro-ecosystems under different conditions **(SAC)**	
C4.5	Algorithm development for agro-ecosystems product generation from geostationary platform **(SAC)**	
C4.6	Climate change impact on Crop Productivity **(IIRS)**	

C4.7	Energy Flux and carbon flux measurement and modelling in Agro-ecosystem **(IIRS)**	
C4.8	Carbon fluxes measurement and monitoring in Agro-ecosystem **(IIRS)**	
C4.9	Satellite based estimation of land surface energy **(IIRS)**	
C4.10	Satellite Derived Land Surface Parameters and Meteorological Variables **(IIRS)**	
C5	**Sub area**	**Forest and Environment (SAC/NRSC/ IIRS)**
C5.1	**Sensor System Studies for Environmental studies** Sensor system studies involve feasibly experiments and radiative modelling activities to arrive at suitable sensor parameters for monitoring earth and planetary objects. Development of spectral library, ground based experimentation in field of agriculture, forest and other ecosystem are required to propose suitable spatial, spectral and radiometric resolution of satellites. Modelling codes such 6S code, MODTRAN etc are used to study the sensitivity of surfaced and atmospheric parameters. It is needed to carry out simulation experiments to propose optimum sensor parameters and develop retrieval algorithms for geophysical parameters from future Resourcesat series, NEMO-AM, ENVSAT Series and GISAT satellites for environmental applications.	
C5.2	**Forestry and Ecology- Biophysical parameters (NRSC)**	
	Sub pixel tree cover estimates using multi sensor IRS imagery	
	Observations on ecophysiological factors for tropical forests and parameterization of biome models for Indian forests	
	Feature recognition of tree and canopy objects in IRS pan and multi spectral imagery	
	Automated methods for estimation of tree allometry fine scale biomass and stand structure using laser measurements **(SAC/ IIRS)**	
C5.3	**Forest Meteorology and Ecosystem Modelling (SAC)** Quantification of energy fluxes helps in modelling regional climate. SAC is involved in development of 24 Micrometeorological station networks in India which are taking continuous measurements in agriculture and natural vegetation system. There is need to develop land surface process models to quantify the fluxes with reference to surface and atmospheric forcing. Most of the biogeochemical modelling depends on phenological	

	understanding of different vegetation types. There is need to carry out ground experimentation as well as satellite modelling to estimate the phenological matrices of different vegetation types. Such efforts would lead to develop the forest growth simulation models. Modelling NPP using satellite measurements such as INSAT-CCD is an important future thrust area. There is need to develop process based model to quantify the net primary productivity and ecosystem level productivity. Network of annual biomass measurements are needed to validate the NPP products. It is known that biomass modelling is limited with optical measurements due to saturation of optical light in denser canopy. Radar based approaches provide improved assessment. It is proposed to develop LIDAR based modelling to account the height of the forest in the estimation of forest biomass. Detection of forest fire and development of fire alarm system based on bioclimatic indices is an important research area which will be carried out using INSAT-3D satellite data.	
C6	**Sub area**	**Water Resources (IIRS)**
C6.1	Future climate data downscaling using statistical methods and subsequent hydrological modelling	
C6.2	Precipitation estimation(for better understanding of the spatial and temporal distribution of precipitation which is critical to climatic, hydrologic, and ecological applications)	
D	**Area**	**Aerial Remote Sensing (NRSC)**
D1	**Sub Area**	**Automatic feature extraction from aerial images**
D1.1	The objective of this study would be to explore the possibilities of automatic feature extraction through the fusion of high resolution aerial digital camera images and DSM either from Lidar technology or from photogrammetry. As per the literature, the fusion of DSM from Lidar scanners and image data from digital cameras showed promising results. The data from these two sources is complimentary to each other and hence make a great combination	
D2	**Sub area**	**Segmentation of Aerial / satellite data**
D2.1	Segmentation becomes more important with increasing spatial resolution of imagery. Texture in high-resolution aerial and high resolution satellite images requires substantial amendment in the conventional segmentation	

	algorithms. The potential applications of this segmentation process are (1) Automatic 3D model generation (2) automatic DEM generation from DSM (3) Automation in Quality Checking of vector maps and many more.	
D3	**Sub area**	**Aerial Data Compression**
D3.1	Development and incorporation of lossless compression algorithm(s)/ technique(s) for better handling, archival, effective usage and time critical data processing of aerial analog and digital data. The compression algorithm must meet the requirement of aerial compression system for storage and operation time. The compression techniques must reduce operation memory, and accelerate the processing speed without any data loss.	
D4	**Sub area**	**Radiometric Calibration LiDAR Waveform**
D4.1	Radiometric calibration refers to the statistical process of deriving physically well-defined radiometric quantities from the sensor's raw measurements. Waveform LiDAR system provides detail information about the backscattering properties of the observed targets by recording complete return signal. Even though waveform measurements have high content of information, data acquired during different flight campaigns cannot be directly compared without a proper radiometric calibration. Model waveform Radiometric calibration requires formulation of LiDAR equation. This model may be useful for the retrieval of higher level data products.	
E	**Area**	**Planetary Sciences (SAC)**
E1	**Sub area**	**Planetary Data Processing**
E1.1	Geometric Models for Data Processing of Astronomical objects	
E1.2	Data Processing for Indian Mars Mission which includes new algorithm for registration and calibration of Thermal Imaging system & Processing of MARS Colour camera	
E1.3	Autonomous Navigation of Planetary Rovers, with Soft-computing approach for autonomous navigation of rovers	
E2	**Sub area**	**Planetary Sciences and Marine Biology related activities – (SAC)**
E2.1	**Lunar Surface Sciences:** The main research themes for research includes Lunar Surface composition, Lunar morphology, Hyperspectral data analysis for Lunar	

	Surface, Thermal Remote Sensing of the Moon, Spectral characterization of Lunar analogues, Lunar surface dating and lunar volcanism.	
E2.2	Polarimetric modelling of Lunar surface characterization **– (IIRS)**	
E2.3	**Lunar Gravity and Crustal thickness studies: (SAC)** Using the surface elevation and satellite tracking data lunar gravity can be deduced and this gravity data can be further modeled using gravity reduction methods to find out the lunar crustal thickness, which provide information about the lunar interior processes. The main research themes include Lunar gravity modelling, inversion modelling for crustal thickness and lunar interior.	
E2.4	**Studies related to Martian surface and Polar Ice (SAC/NRSC)** Major research themes are Characterization of Martian analogues rocks in India, Hyperspectral analysis of Mars data, Thermal remote sensing of Mars, Martian Atmosphere.	
E2.5	**Simulation of Methane distribution and visualization in MARS Atmosphere (SAC/NRSC)** Indian MARS mission will be carrying MSM (Methane Sensor for MARS) to map the methane sources and deriving concentration in MARS atmosphere by ppb accuracy. Simulations are planned using other MARS orbiter data like MGS etc. considering the specification of Indian MSM for visualization and understanding the data. This simulation is to be carried jointly with the help of Principal Investigator of MSM.	
E2.6	**Developing Advance Techniques for Planetary Data Visualization (SAC)** • Real Time Visualization of robots • Visualization of astronauts space walks • Identification of landing sites on other planets	
E2.7	Establishment of a Virtual reality and data/ Information visualization facility for planetary missions **(SAC)**	
F	**Area**	**Disaster Management**
F1	**Sub area**	**Geo-hazards (SAC/NRSC/IIRS)**
F1.1	Earthquake Precursor Analysis for moderate to high magnitude earthquakes in India for understanding the spatio-temporal likelihood of earthquakes **(SCA/NRSC/IIRS)**	

F1.2	Modelling geodynamics **(SAC/ NRSC)**
F1.3	Early warning of landslides **(SAC/NRSC)**
F1.4	Logistic regression based method for landslide hazard zonation **(IIRS)**
F1.5	2D Flood Inundation Modelling - Simulation of flood inundated areas for a given discharge using DEM and other inputs from satellite data **(NRSC)**
F1.6	Integration of satellite based inputs along with DEM for forecasting a flood discharge and to provide early warning. **(NRSC)**
F1.7	Simulation of inundation in urban environment using hydrologic and hydraulic models **(NRSC)**
F1.8	Assessing the possibility of cloudburst using INSAT images **(NRSC)**
F1.9	Automated detection of landslide using AWIFS and Cartosat-1 derived DEM **(IIRS)**
F1.10	Debris flow modelling and risk assessment **(IIRS)**
F1.11	Tsunami modelling **(NRSC)**

5.0 Space Sciences Programme

A	**Area**	**Investigation on Near Earth Environment (PRL)**
A 1	**Sub area**	**Thermosphere – Ionosphere System:** Thermosphere and ionosphere are mutually coupled System with neutral and plasma affecting each other with different time scales. In addition, this part of atmosphere/ionosphere also gets affected from the forcing above by sources of solar origin and also from lower atmosphere. Thus comprehensive studies using various techniques are needed.
A 1.1	Thermospheric Airglow and their processes.	
A 1.2	Plasma and neutral dynamics in Thermosphere-Ionosphere system.	
A 1.3	Coupling of High-low latitude Thermosphere-Ionosphere system.	
A 1.4	Effects of solar eclipse, earthquake on ionosphere.	
A 1.5	Waves and instabilities in ionosphere.	
A 1.6	Geomagnetism: Ionospheric, magnetospheric and solar wind induced Variable and transient (pulsations) phenomena.	
A 1.7	Ionospheric modification.	
A1.8	Study of height profiles of electron density, electric field, and neutral wind in the equatorial F region	
A1.9	Linking the thunderstorm related dynamical forcing on the upper atmosphere	
A1.10	Measurements of upper mesospheric temperature and winds	
A1.11	Whole atmosphere coupling through wave forcing through observations and modelling	
A1.12	Three dimensional simulation of Rayleigh Taylor instability	
A1.13	Modelling of equatorial electrojet	
A 2	**Sub Area**	**Study of low latitude ionosphere Satellite Based Communication and Navigation systems**
A2.1	Study of low latitude ionosphere applied to satellite based communication and navigation systems	

A 2.2	Ionospheric Phenomena using TEC by GPS and other parameters.	
A2.3	GNSS based ionospheric retrieval under Equatorial Spread F events	
A2.4	GNSS observations and ionospheric forecasting for Quiet geomagnetic conditions	
A2.5	Study of space weather events and geomagnetic storms in nearly same longitude zone to evaluate the latitudinal ionospheric response in the same local time zone. Similarly, study of longitudinal differences in such response	
A2.6	Study of Electro-dynamical and thermospheric processes leading to positive and negative ionospheric storms in low latitudes	
A 3	**Sub area**	**Magnetosphere Processes:** The understanding of the magnetic environment of the earth is important as it protects from high energetic solar wind particles and cosmic rays. Geo effective disturbances are important to be investigated not only to understand the modification of magnetosphere but also to protect earth orbiting satellites.
A 3.1	Plasma instability processes.	
A 3.2	Micro plasma process in magnetic reconnection region.	
A 3.3	Triggering of sub storms and impact on global ionosphere	
A 3.4	Relationship between geomagnetic storm and sub-storm.	
A 3.5	Investigation on plasma waves and their propagation characteristics. Turbulence: MHD Turbulence, Compressible Turbulence.	
A 3.6	Wave particle interaction	
A 4	**Sub area**	**Impact of Space Weather:** Disturbances in the sun, their propagation in the interplanetary medium, interaction of solar wind with magnetosphere decides the effectiveness of the solar disturbances that impact the near Earth environment.
A 4.1	Physics of Shocks.	
A 4.2	Identification of structures and turbulence in solar wind plasma.	
A 4.3	Interaction between solar wind and magnetospheric boundary.	
A 4.4	Impact of space weather processes in ionosphere, thermosphere system.	

A 4.5	Distortion of radiation belt and plasma sphere during extreme space weather events.	
A 4.6	Interplanetary scintillations	
B	**Area**	**Atmospheric dynamics and coupling (NARL)**
B 1	**Sub Area**	**Observations, Modelling and Simulations**
B1.1	Modelling of atmospheric tides	
B1.2	Generation and propagation of atmospheric wave modes.	
B1.3	Numerical simulations of stratospheric sudden warming and their global influence	
B1.4	Gravity wave-tidal -mean flow interactions	
B1.5	Simulations of QBO, SAO and Intra-Seasonal Oscillation	
B1.6	Influence of lateral wave forcing on tropical weather and climate	
B 2	**Sub area**	**Mesosphere-lower thermosphere system along with lower ionosphere (D and E-regions)** This region acts as a buffer between upper atmosphere and lower atmosphere where wave activities are more. The region which filters out a lot of wave modes is not yet understood due to lack of systematic measurements.
B 2.1	Winds and wave activities in mesosphere.	
B 2.2	Mesospheric Airglow and their processes.	
B 2.3	Propagation of VLF waves in the D region of ionosphere and their relation to Earth-quake.	
B 2.4	E-region of ionosphere-electrojet and associated plasma waves.	
B 2.5	Lower and upper atmosphere coupling.	
B 2.6	Effects of dusty plasma.	
C.	**Area**	**Sun and Solar System (PRL)**
C1	**Sub area**	**Planetary atmospheres:** With the advent of various missions to various planets it is necessary to understand the planetary

		atmospheres and ionospheres. Formation of planetary magnetosphere in the presence of intrinsic magnetic field of the planet is yet another interesting problem to pursue.
C 1.1	Formation of ionospheric layers in Mars and other planets.	
C 1.2	Effect of dust in Martian and other planetary atmospheres.	
C 1.3	Formation of planetary magnetospheres.	
C 1.4	Planetary Aurora and Airglow.	
C 1.5	Lightning phenomenon on other planets.	
C 1.6	Non-linear effects in orbital mechanics.	
C1.7	Aeronomy of other planets and comparison with that of the earth.	
C 2	**Sub area**	**Study of Comets:** Comets represent pristine solar nebular matter and hence studying comets is very important to understand the early solar system itself.
C 2.1	Composition of dust and plasma tails.	
C 2.2	Dust formation, distribution and characterization of dust tail	
C 2.3	Plasma processes in plasma tail.	
C 2.4	Processes involving dusty plasma.	
C 3	**Sub area**	**Solar Physics:** Being the energy source for solar system objects, Sun directly controls various physical phenomena in the Solar system. Sun is also closest star and hence offers opportunity to study various stellar phenomena at an unprecedented spatial resolution.
C 3.1	Origin of Sun and Solar system	
C 3.2	Transient Phenomena: Flares, Coronal Mass Ejections	
C 3.3	Surface Phenomena: Granules, Super granules, Sun spots.	
C 3.4	Atmosphere: Chromospheres Phenomena, Coronal Plasma Phenomena	
C 3.5	Radiation: Thermal and non-thermal radiation processes	
C 3.6	Magnetic field and Velocity mapping.	

C 3.7	Solar cycle variation, prediction of activity cycle.	
C 3.8	Multi-wavelength studies.	
C 3.9	Solar dynamo, Magneto-Convection region	
C 3.10	Helio -seismology	
D	**Area**	**Astronomy and Astrophysics (PRL)**
D 1	**Sub area**	This area includes broadly the observational and theoretical studies pertaining to three sub-areas namely, **Galactic Astronomy, Extra-galactic Astronomy and Cosmology**. Galactic Astronomy includes issues still unresolved concerning the physical processes leading to star formation from giant molecular clouds in the interstellar medium and evolution of stars of different masses. Studies on binary systems give opportunity to learn about exotic compact stellar sources and their energetic environments. Extra-galactic Astronomy pertains to investigations on External Galaxies of different types including Active Galactic Nuclei and Star-burst galaxies. Theoretical and observational Cosmology includes studies on dark matter, dark energy, fundamental constants over cosmological time scales, cosmological theories and observational tests and constraints.
D 1.1	Interstellar medium (ISM): Star formation in giant molecular clouds. Disks and Jets around low/high mass proto-stars. Cluster identification, classification and characterization.	
D 1.2	Interstellar medium: Proto Planetary nebulae. Chemically peculiar Planetary Nebulae. Asymmetric Planetary nebulae	
D 1.3	Interstellar medium: Extinction curves and their modelling in various wavelength regions: infrared and far –Ultra-violet. Origin of 217.5 nm feature. Polycyclic Aromatic Hydrocarbon molecules and their contribution to interstellar extinction.	
D 1.4	Astro-biology and Astro-chemistry: Formation of pre-biotic molecules in interstellar matter. origin of life. Formation of interstellar giant molecules in star forming clouds.	
D 1.5	Dust formation in Stellar Ejecta Modelling of Circum-stellar matter	
D 1.6	Star spots: Photometric and spectroscopic variability studies.	

D 1.7	Chemically Peculiar Stars: stars with abundances different from solar abundances.	
D 1.8	Astro-seismology: Variability in spectral line profiles at high resolution.	
D 1.9	Extra-Solar-Planets: Transit observations using a small facility.	
D 1.10	Binary Star Phenomena: Novae, Supernovae Type I, Cataclysmic variables, X-ray binaries with Black Hole and Neutron Star companions. Transient phenomena Quasi-Periodic oscillation in X-ray binaries.	
D 1.11	Ultra-luminous X-Ray Sources, Micro-quasars. Study of environments of Black Holes of different masses: 10^5 Solar mass to Stellar mass.	
D 1.12	Studies on the Galactic centre.	
D 1.13	Studies on Elliptical and Spiral Galaxies. ISM in external galaxies. Star formation and evolution in external galaxies.	
D 1.14	Investigation of Active Galactic Nuclei. Star-burst galaxies. Intergalactic medium.	
D 1.15	Multi-Wavelength observations using Ground-based and/or Space-borne facilities: X ray, UV, Visible, Infrared, Sub-millimeter, Millimeter and Radio regions.	
D 1.16	Theoretical and Observational studies on Dark Matter and Dark Energy. Theoretical and Observational Cosmology	
D 1.17	Data mining and processing techniques with applications to astronomical data.	
E	**Area**	**Space Instrumentation (PRL)**
E 1	**Sub area**	**Ionosphere/Thermosphere**
E 1.1	Plasma Measurements, Airglow emissions. Experiments: 1. Magnetometer 2. Electric Field 3. Electron/ Ion Density & Temperature 4. Imagers/Photometers/Spectrometers 5. Winds and temperature (neutral) 6. Drift Meter, Composition measurements 7. Radio Beacon and Occultation	

E 2	**Sub area**	**Earth's Lower/Middle Atmosphere**
E 2.1	Aerosols, minor constituents & Trace Gases. Experiments: 1. Optical Photometers 2. Infrared Photometers 3. Infrared Spectrometer 4. Visible photometer for lightening 5. Active Experiments like Lidar, SAR, Scatterometer	
E 3	**Sub area**	**Planetary Exploration**
E 3.1	Atmosphere. Experiments: 1. Charge particle measurements 2. Composition (Mass Spectrometer) 3. Vertical distribution of Electron Density 4. Vertical distribution of Species	
E 4	**Sub area**	**Planetary Atmosphere**
E 4.1	Surface measurements (Elemental composition). Experiments: 1. X ray Spectrometer 2. Laser induced breakdown spectroscopy 3. Surface & Subsurface Temperature 4. Dust and surface charging 5. Microwave radar	
E 5	**Sub area**	**Astronomy**
E 5.1	Instrumentation for Ground-based and Space-borne facilities. 1. Visible & Infrared Photometers, Polarimeters and Spectrometers for ground-based and space-based facilities. 2. Ultra-violet spectro-photometers and spectrometers for space-based facilities. 3. X- ray instrumentation for space-based facilities (Imaging and Spectra and	

	polarization) 4. Gamma Ray Spectrometer for space-borne platforms 5. Space telescopes. 6. Active and Adaptive optics for diffraction limited imaging. 7. Detector arrays for UV, Visible, IR and X-ray regions.	
E 6	**Sub area**	**Solar Studies**
E 6.1	Charge Particle & Radiation Flux in X, UV, Optical & IR wavelengths. Experiments: 1. Optical Photometers/ Spectrometers 2. Infrared Photometers/ Spectrometers 3. Charge particle energy & flux measurements	
E 6.2	Active and Adaptive optics for diffraction limited imaging.	
F	**Area**	**Remote sensing data analysis from planetary exploration missions (PRL)**
F 1	**Sub Area**	**Moon**
F1.1	Chemical, mineralogical and morphological studies	
F 1.1	Development of MHD model for solar wind interaction with moon **(SPL)**	
F 2	**Sub Area**	**Mars**
F2.1	Surface and atmospheric processes on Mars	
F2.2	Records of aqueous activities on Mars	
F2.3	Solar interaction and atmospheric loss processes	
F 3	**Sub Area**	**Minor Solar System Objects**
F 3.1	Meteorite asteroid connection- Comparison of reflectance spectra	
G	**Area**	**Laboratory study of Astromaterials (PRL)**
G 1	**Sub Area**	**Meteorites from asteroids**
G 1.1	Early solar system processes and time scales	
G 2	**Sub Area**	**Moon and Mars Meteorites**

G 2.1	Composition, evolution and chronology	
H	**Area**	**Study of terrestrial analogues of Moon and Mars (PRL)**
H 1.1	To understand surface properties and aqueous processes on Mars	
I	**Area**	**Payloads for upcoming planetary missions (PRL)**
I 1.1	Experiments based on EM radiation, particle irradiation and nuclear reactions can be devised to understand surface and subsurface composition and the equipment can be realized in a miniaturized space qualified form	

6.0 Meteorology

A	**Area**	**Weather and Climate (NARL)**
A1	**Sub Area**	**Modelling and computer simulations for weather prediction**
A1.1	Parallelization/Optimization of weather and climate Models	
A1.2	Use / development of remote sensing techniques for high resolution real time monitoring of convective systems (thunderstorms, cyclones etc)	
A1.3	Development of advanced techniques for conventional and satellite based data assimilation in weather and climate models	
A1.4	Satellite weather image processing	
A1.5	Development of techniques for Data mining and Processing	
A1.6	Impact (socio-economic) Analysis of long term climate change predictions under different scenarios	
A1.7	Observational Campaign for understanding of convective systems.	
A1.8	seasonal to centennial scale Climate modelling	
A1.9	now casting and short range weather prediction of convective systems	
A2	**Sub Area**	**Convection/Precipitation/Boundary layer**
A2.1	Understanding dynamical characteristics of Mesoscale Convective Systems and their association with energetics of the atmosphere	
A2.2	Understanding the link among surface fluxes, atmospheric boundary layer and clouds	
A2.3	Understanding the rain processes (both at macroscale and microscale) at a regional level	
B	**Area**	**Radiation, Aerosols and Trace gases (NARL)**
B1	**Sub Area**	**Instrumentation/Observations/Scientific problems**
B1.1	Development of low cost nephelometer	
B1.2	Development of OH analyzer	
B1.3	Study of cloud-aerosol interaction in fog/cloud chamber	

B 3.2	Chemistry of minor and trace constituents that are precursors to ozone chemistry.	
B 3.3	Aerosol and radiative effects affecting the climate.	
C	**Area**	**Microwave atmospheric studies (SPL)**
C 1	**Sub area**	**Microwave Radiative Transfer (RT)code developments and inversions of geophysical parameters**
C 1.1	Developing microwave Radiative transfer codes and inversion techniques for retrieving geophysical parameters including atmospheric hydrometeors are essential for satellite and ground based microwave /mm and sub millimeter wave proofing.	
D.	**Area**	**Signal and Data processing (NARL)**
D.1	**Sub Area**	**Parameter retrieval algorithm developments**
D1.1	Lidar signal inversion methods	
D1.2	Retrieval of temperature and minor constituents in the atmosphere from the satellite based radiance measurements	
D1.3	Retrieval of electron density from GPS occultation measurements	
D1.4	Radar signal processing	
D1.5	Radar Data processing	
D1.6	Improvements in satellite rain retrievals using advanced statistical or physics based algorithms	
E.	**Area**	**Radar and Lidar instrumentation for atmospheric probing (NARL)**
E.1	**Sub Area**	**Development of Radar and Lidar accessories/techniques**
E1.1	Time dependent attenuator for lidar signal	
E1.2	Development of a Fiber optic based IF filter for lidar to solve the problem of temperature dependence of filters	
E1.3	Digital up-converters	
E1.4	Digital synthesizer for radar exciter	

E1.5	Networking of radar subsystems
E1.6	Digital receiver for radar system
E1.7	Digital beam forming techniques
E1.8	Clutter removal techniques
E1.9	Radar imaging techniques
E1.10	Dual-polarized patch antenna for radar applications
E1.11	Design and development of Solid state TR modules for radar applications

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