Capacity Building and Public Outreach
Indian Space Research Organisation
Bengaluru

RESPOND BASKET 2023

Capacity Building and Public Outreach
Indian Space Research Organisation
Bengaluru

Technical Guidance

Dr. M A Paul
Associate Director
RESPOND & Academic Interface, ISRO HQ

Technical Support and Compilation

Smt. Nirupama Tiwari
Dy. Director, RESPOND, CBPO, ISRO-HQ

Shri. M Uday Kumar
Sci./Engr.-SE, RESPOND, CBPO, ISRO-HQ

Shri. K Mahesh
Sr. Asst, CBPO, ISRO HQ

For any queries please contact

Director,
Capacity Building and Public Outreach (CBPO)
Indian Space Research Organisation HQ
Department of Space
Government of India
Antariksh Bhavan
New BEL Road
Bengaluru-560094
e-mail: dir.cbpo@isro.gov.in

Associate Director,
RESPOND & Academic Interface
Indian Space Research Organisation HQ
Department of Space
Government of India
Antariksh Bhavan
New BEL Road
Bengaluru-560094
e-mail: respond@isro.gov.in

भारतीय अन्तरिक्ष अनुसंधान संगठन
अन्तरिक्ष विभाग
भारत सरकार
अन्तरिक्ष भवन
न्यू बी ई एल रोड, बेंगलूर – 560 094, भारत
दूरभाष : +91-80-2341 5241 / 2217 2333
फैक्स : +91-80-2341 5328

सोमनाथ. एस / SOMANATH. S
अध्यक्ष / Chairman

Indian Space Research Organisation
Department of Space
Government of India
Antariksh Bhavan
New BEL Road, Bangalore - 560 094, India
Telphone: +91-80-2341 5241 / 2217 2333
Fax : +91-80-2341 5328
e-mail : chairman@isro.gov.in
secydos@isro.gov.in

Message

Indian Space Research Organisation recognised the roles of academic institutions in R&D and othre promotional initiatives, to support the Indian Space Programme.

Prof. Satish Dhawan, former Chairman, ISRO, who was an academician himself decided to tap this potential for the benefit of space programme. Accordingly, the sponsored research activities called "RESPOND" was launched by him in the early 1970s. Over the years, the RESPOND Programme has immensely contributed towards the development of human resources in high end technological areas, capacity building at the institute level and research and development of space programme.

The organisation is currently venturing into several technologically advanced areas of R & D with the intention of furthering the space programmes to the newer heights. The academic community and other organisations are always welcome to participate and contribute in the focused R & D initiatives of ISRO.

In this scenario, Capacity Building and Public Outreach (CBPO), ISRO Headquarters, Bengaluru, has compiled the major research and development (R&D) requirements of ISRO, wherein the academia can actively participate, in the form of a document called "RESPOND Basket-2023." With great pleasure, I am releasing this document, soliciting R & D proposals in the relevant topics.

I am certain that we will be able to surmount the formidable challenges that lie ahead and uncover new frontiers in space exploration through the collaborative endeavours of ISRO and the academic community. I am excited to see how ISRO and academics work together, and I can already see the ground-breaking results that will result from their synergy.

Date: 11/12/2023

(Somanath S)

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न्यू बी ई एल रोड, बेंगलूरु - 560 231, भारत
दूरभाष : +91 80 2341 5474
फैक्स :

Indian Space Research Organisation
Department of Space
Government of India
Antariksh Bhavan
New BEL Road, Bengaluru - 560 231, INDIA
Tel (Off) : +91 80 2341 5474
Fax :

N Sudheer Kumar
Director, CBPO

December 11, 2023

Preface

The Indian Space Programme has consistently prioritised self-sufficiency ever since its inception. Many technologies were created in-house and in collaboration with other academic and research institutions. This has been an ongoing journey. In order to accomplish more ambitious objectives, including human space travel, landing on the moon, and exploring other planets within the next two decades, ISRO is currently undertaking advanced research. This calls for a collaborative endeavor involving not only the space agency but also all research institutions of the nation in order to equip the nation with the necessary capabilities to accomplish these challenging objectives.

Right now, As the Director of Capacity Building and Public Outreach at ISRO, I am delighted to reach out to you and extend an invitation to join hands in the wonderful journey of the Indian Space Research Organisation (ISRO). I cordially invite you to investigate potential collaborative endeavors that transcend the conventional confines of academia and venture into the ever-evolving domain of space exploration. Together, the theoretical rigor of universities and the operational know-how of ISRO may take our country to new heights in the space race

Each year, "RESPOND Basket" is published. In light of the tremendous interest shown by academics last year, "RESPOND Basket-2023" has been compiled with timely, relevant research subjects in which academics can play a pivotal role. I also acknowledge the efforts put in by the committee chaired by Dr. Unnikrishnan Nair, Director, VSSC to review the inputs for its inclusion in the Basket. The document contains around 190 research proposals highlighted by ISRO/DOS centres. To assist the faculty in preparing R&D proposals, the document also includes a concise summary of each research topic, anticipated deliverables, and so forth.

RESPOND Basekt-2023 is an invitation extended with great enthusiasm to the academic community to participate by submitting proposals and contributing to the ongoing research and development endeavours of ISRO. Join me as we set out on this exciting journey.

(N Sudheer Kumar)

GENERAL INSTRUCTIONS

1. RESPOND BASKET comprises of the most urgent and important research problems identified by ISRO/DOS Centre / Units on the basis of ISRO's upcoming programmatic R&D requirements. Each research problem comprises of a brief write-up about the topic for the faculty of the academic Institutions/R&D laboratories other than the Space Technology Cells (STCs), Regional Academic Centre for Space (RAC-S) and Space Technology Incubation Centre (STICs) to select and prepare the proposals.

2. An individual or group(s) of scientists / faculty members affiliated to any academic institution/autonomous R&D institutions are eligible for submitting the proposals. The Principal Investigator(s) should be a full-time employee(s) of the concerned institution.

3. Principal Investigator shall be a domain expert in the area to which the proposal belongs and the list of publications to be uploaded in the portal at the time of submission of proposal. There may also be co-investigator(s) from the same/different institution(s) working on the project. But satisfactory completion of a project will be the responsibility of the Principal Investigator and the institution involved.

4. The age limit for the Principal Investigator is below 65 years (sixty-five) including the project period. Proposals from individuals not affiliated to any recognized institution/ R & D institutions will not be considered.

5. The signed "Declaration Form" shall be uploaded in the portal at the time of submission of proposal in the prescribed format. Format is given in the Annexure -1.

6. For other information regarding terms and conditions of ISRO Grants, details on research fellowships and Guidelines governing the allocation of funds etc., please visit ISRO website (https://www.isro.gov.in/SponsoredResearch.html).

7. The last date for submitting the proposals online under "RESPOND BASKET-2023' is January 31, 2024.

8. The submitted proposal will be subjected to critical evaluation by the ISRO/DOS Centre experts. The proposal will be evaluated on the basis of novelty, methodology, approach, experience of the PI in the subject area, duration of the project, budget etc.

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VIKRAM SARABHAI SPACE CENTRE
THIRUVANANTHAPURAM

RES-VSSC-2023-001

Name of ISRO Centre/Unit
Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal
Transient moving body simulation CFD capabilities with overset mesh in unstructured grid frame-work

Name of Co PI from ISRO Centre/Unit
Mr. Amit Sachdeva,
Mr. Harichand M V

Contact Address of Co PI and e-mail id
amit_sachdeva@vssc.gov.in,
harichand_mv@vssc.gov.in

Area of Research
Computational Fluid Dynamics (CFD), Aerodynamics

Summary of the proposed research and expected deliverables
Moving body transient simulation is required in order to carry out accurate assessment in various critical scenarios, where significant effect of relative motion, acceleration is present on the vehicle aerodynamics. Such a situation arises in case of Crew Escape System (CES) abort scenario, where CES accelerates with respect to parent vehicle, leading to significant drag differences in comparison to steady state simulations.

This research proposal is invited for the development of accurate and robust overset mesh solver capabilities in the available in house unstructured grid framework of PRAVAHA CFD Software.

Scope of the Work:

- Handling of overset mesh with multiple geometries.
- Algorithm and source code in unstructured mesh framework for -
  - Handling overset mesh topology.
  - Accurate and efficient interpolation schemes for overlapped cells.
  - Implicit time accurate solution.
  - Six-DOF solver.
  - Parallel computing in larger number of CPU cores / GPU.
  - Any other essential components.

Linkages to Space Programme:

The developed code shall be used for carrying out high fidelity simulations on unstructured grids for ISRO launch vehicles.

Expected Deliverables:

Algorithms and source code and their implementation in PRAVAHA CFD Software (Through C++).

RES-VSSC-2023-002

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development of Background Oriented Schlieren system for use in Trisonic wind tunnel

Name of Co PI from ISRO Centre/Unit

Mr. R. Saravanan

Contact Address of Co PI and e-mail id

saravanan_ram@vssc.gov.in

Area of Research

Experimental aerodynamics

Summary of the proposed research and expected deliverables

The proposal envisages development of a background oriented schlieren setup for a viewing area of 500mm diameter in a trisonic wind tunnel.

Scope of the Work:

- Design and procurement of required optics (if necessary).
- Development of algorithm for measuring density preferably in Matlab.
- Validation with standard 2D wedge and 3D cone models.
- Demonstration of the BOS in ISRO Tri- sonic Wind Tunnel on a Crew Module.
- VSSC TWT possess necessary windows, light source and collimated beam.

Linkages to Space Programme:

Once developed this can be used in all wind tunnel models of ISRO.

Expected Deliverables:

A Technical report containing details of algorithm for image processing, experimental results obtained and digital data of all the results in a DVD.

RES-VSSC-2023-003

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Kerosene/Hydrogen combustion modeling with turbulence chemistry interactions

Name of Co PI from ISRO Centre/Unit

Mr. Amit Kumar Singh,
Mr. Jiju R Justus

Contact Address of Co PI and e-mail id

amitkumar_singh@vssc.gov.in
jiju_rj@vssc.gov.in

Area of Research

Computational Fluid Dynamics (CFD), Aerodynamics

Summary of the proposed research and expected deliverables

Multi-step multi species combustion with turbulence chemistry for the scramjet combustor. The turbulence chemistry interaction is required for modeling the supersonic combustion.

Modeling shall be for suitable/candidate fuels for supersonic combustion like kerosene/ethylene and hydrogen. The use of models for the interaction like assumed probability density function, laminar flamelet, Eddy dissipation concept and partially stirred reactor model in RANS framework to bring out the effect of turbulence chemistry interaction.

Scope of the Work:

CFD simulation of scramjet combustor incorporating kerosene combustion with turbulent chemistry interaction can be made by using commercially available software or separate module can be developed and incorporated in open source CFD software's like OpenFoam or SU2.The Code has to be compatible with standard pre- and post-processor/Open source

Linkages to Space Programme:

The deliverables of this project will be useful for the Scramjet Propulsion, HAVA programme.

Expected Deliverables:

CFD code/modules with chemistry model details including combustion mechanism along with documentation, user manual, training and Solving standard test cases for validation.

RES-VSSC-2023-004

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Higher order solver for LES of compressible flows

Name of Co PI from ISRO Centre/Unit

Mr. Chaphalkar Aaditya Nitin,
Mr. Venkata Subrahmanyam B

Contact Address of Co PI and e-mail id

aaditya_chaphalkar@vssc.gov.in
b_subrahmanyam@vssc.gov.in

Area of Research

Computational Fluid Dynamics, Aerodynamics

Summary of the proposed research and expected deliverables

Second order RANS simulations are routinely carried out for aerodynamic design and characterization. Improved fidelity can be achieved by carrying out Large Eddy Simulations with higher order of accuracy. Towards this, a higher order solver is essential. As the configurations on which the solver will be used are not amenable for structured grid, the solver has to be based on 3D unstructured grid topology.

Scope of the Work:

Development of higher order Discontinuous- Galerkin or the Flux-Reconstruction approach based CFD solver for compressible flow with shocks. The solver has to be based on 3D unstructured grid topology with mixed elements such as tetrahedrons, hexahedrons, triangular prisms and pyramids.

Linkages to Space Programme:

The developed code shall be used for jet aeroacoustics and aerodynamics of bluff bodies.

Expected Deliverables:

High order 3D unstructured CFD code along with documentation and user manual.

RES-VSSC-2023-005

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Isrosene /hydro carbon combustion modeling

Name of Co PI from ISRO Centre/Unit

Mr. Sujithkumar R

Contact Address of Co PI and e-mail id

r_sujithkumar@vssc.gov.in

Area of Research

Computational Fluid Dynamics, Aerodynamics

Summary of the proposed research and expected deliverables

Simulation of Isrosene/hydro carbon combustion with multi-step chemistry for utilization of the same for chamber pressure prediction for Semi- cryo/Scramjet combustor including injector performance parameters such as droplet size, evaporation modeling, droplet life time studies and their effect on flow and combustion.

Scope of the Work:

LO2 evaporation models (HRM,Ranz-marshall, Abramzon-Sirignano etc.), fuel/oxidizer droplet size prediction/distribution, droplet life time evaluation, combustion mechanisms with multi- step chemistry. Studies for parametric sensitivity as well as combustor performance parameters such as combustion efficiency. Numerical simulation with scramjet combustor geometry (geometry will be provided) and case validation with experimental data generated in Scramjet Test Facility of VSSC.

Linkages to Space Programme:

The deliverables are linked to the Semi-cryo and Scramjet propulsion systems.

Expected Deliverables:

Model details, jet break up mechanism/droplet size computation details including combustion mechanism.

RES-VSSC-2023-006

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Constitutive and damage model of materials under high strain rates

Name of Co PI from ISRO Centre/Unit

Mr. Aditya Narayan Malla,
Mr. Bishwajyoti Dutta Majumdar.

Contact Address of Co PI and e-mail id

aditya_narayan@vssc.gov.in,
mr_bishwajyoti@vssc.gov.in

Area of Research

Material Modelling

Summary of the proposed research and expected deliverables

Clear understanding of damage caused in materials due to plastic deformation, strain rate and stress concentration effects under dynamic loading environment is essential for design of aerospace structures. The proposed research should focus at the development of failure model for materials used in aerospace applications. This model should produce an accurate estimation of material's flow behavior under the effects of stress tri- axiality, strain, strain rate and temperature. The constructed model shall be used in numerical analyses to predict failure behavior and to be validated with experimental data generated from test under dynamic conditions.

Scope of the Work:

- Comprehensive literature survey to study the sensitivity of existing constitutive models and failure models with respect to stress state, strain, strain rate, and temperature.
- Development of Material models based on Continuum Mechanics as well as Atomistic Modeling Route.

- Experiments under dynamic loading conditions with varying strain.
- rates and low/high temperature to generate the relevant data for curve fitting and optimization of the proposed model.
- Implementation of Material models in numerical analysis codes to capture the physics at macroscopic scale.
- Experimental validation of the constructed model to confirm the reliability and fidelity under various conditions like different type of loading, with different type of materials, service temperature etc.

Linkages to Space Programme:

Designing of new generation of pyro mechanisms and modeling of pyro actuated devices, metal forming, crashworthiness of structures, design of MMOD shields, reentry structures etc.

Expected Deliverables:

- Report on comprehensive literature survey to study the sensitivity of existing constitutive models and failure models for capturing high strain rate deformation behavior.
- Report on details of material model development based on Continuum Mechanics approach.
- Report on details of material model development based on Atomistic Modeling Route such as MD simulations, Coarse Grain Model etc.
- Report on Plan of Experimentation to extract different model parameters based on the type of models developed.
- Details of Experiments under dynamic loading conditions with varying strain rates and low/high temperature to generate the relevant data for curve fitting and optimization of the proposed model.
- Report on the Implementation of Material models in numerical analysis codes to capture the physics at macroscopic scale.
- Final report on Experimental validation of the constructed model to confirm the reliability and fidelity under various conditions like different type of loading, with different type of materials, service temperature etc.

RES-VSSC-2023-007

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

RF-based Non-invasive Sensors and Sensing Systems

Name of Co PI from ISRO Centre/Unit

Dr. Sreelal S,
Mr. Pradeep Kumar P,
Mr. Bibin Varghese,
Mr.Rajiv Ranjan

Contact Address of Co PI and e-mail id

s_sreelal@vssc.gov.in,
bibin_varghese@vssc.gov.in
p_pradeepkumar@vssc.gov.in,
rajiv_ranjan@vssc.gov.in

Area of Research

Sensors (for Instrumentation and Telemetry)

Summary of the proposed research and expected deliverables

Advanced high-performance sensors and sensing systems using RF medium is an evolving area of research for industrial and biomedical applications. They are especially useful for new generation technologies like IoT and Health Monitoring. THz and mm Wave based sensing systems are typical examples of research areas which are being pursued by academic institutions as well as industry and space research organizations like NASA.

Scope of the Work:

To study, design and develop such sensors for aerospace applications relevant in ISRO's context. Sensor prototypes will be realized and characterized for performance.

Linkages to Space Programme:

Can be used to realize compact, miniaturized, harness-free sensing systems for instrumentation and telemetry applications in all Launch Vehicles. Especially relevant for those missions where size and weight constraints are severe such as RLV-ORV. Non-invasive property can be gainfully employed in future missions like inter- planetary ones.

Expected Deliverables:

Sensor prototypes tested and characterized to functional and performance requirements.

RES-VSSC-2023-008

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Cryo Temperature Measurement using Fiber based sensors

Name of Co PI from ISRO Centre/Unit

Ms. Sheeja Mathews,
Mr. Sabooj Ray.

Contact Address of Co PI and e-mail id

Sheeja_mathews@vssc.gov.in;
Sabooj_ray@vssc.gov.in

Area of Research

Sensors

Summary of the proposed research and expected deliverables

Cryo temperature sensors used in the cryo stage are imported. Indigenization through fiber based sensing is envisaged

Proposed temp measurement range	Accuracy
300-1200K	±18K
70-323K	±5K

Scope of the Work:

New sensor for cryogenic temperature measurement will be build that amplifies temperature transduction within fiber grating Sensors (FBG). The FBG has to be coated with a material for good thermal expansion coefficient. The material is to be identified. Optimization of the thickness of the coating, the composition and/or the geometry of the sensing fiber. The sensor will be calibrated for different cryo temperatures to aim at Good sensitivity, response time and recovery time.

Linkages to Space Programme:

The deliverables will be used in cryo stages of GSLV & LVM3.

Expected Deliverables:

Cryo Temperature sensors.

RES-VSSC-2023-009

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Heat sink integrated X- band microstrip antenna array

Name of Co PI from ISRO Centre/Unit

Dr. Manoj Joseph

Contact Address of Co PI and e-mail id

manoj_joseph@vssc.gov.in

Area of Research

Antenna

Summary of the proposed research and expected deliverables

High power active phased arrays are widely used in various satellite based synthetic Aperture RADARs and ground based RADARs.

In an active phased array configuration, each antenna element is equipped with a power amplifier module and these distributed amplifiers produce large amount of heat. This would lead to thermal run away in amplifier modules and affect the performance of both transmitter and receiver modules.

A possible solution is to add heat sinks on the microwave circuit side of the PCB, at the cost of increased real estate and possible EMI problems while encapsulating the entire system. In normal sense the electromagnetic radiation from heat sinks is typically undesirable and should be minimized to reduce electromagnetic interference (EMI). However it can be advantageous to maximize the radiation from a heat sink by using the antenna as a heat sink. In microstrip antennas the radiation structure can be modified as heat sinks by providing proper heat routing strategies. The introduction of heat sinks should not affect the radiation and reflection characteristics of the antenna.

The proposals are invited to develop a heat sink integrated microstrip antenna configurations suitable for X-band phased arrays. Antenna should operate in 10GHz band with dual linear polarization.

Scope of the Work:

The proposed work finds relevance in space as well as ground radars. By using antenna as a heat sink, requirement of additional heat sink and hence the space and weight of the system can be reduced.

Linkages to Space Programme:

The proposed antenna configuration can be attempted for on board debris tracking radar, Ground radars with active phased arrays.

Expected Deliverables:

- The Expected Deliverables are heat sink integrated antenna having dual linear polarizations, wide bandwidth and good impedance matching in the presence of heat sinks.
- An array configuration of 4x4 elements with integrated heatsink Simulation and measurement results need to be provided.
- Finally, a working prototype having RF amplifier module integrated with a novel heat sink integrated antenna array must be demonstrated.

RES-VSSC-2023-010

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Design of a 3kW Interior Permanent magnet linear motor for a no load speed of 200mm/sec and a peak force of 40kN at 60mm/sec and its performance validation

Name of Co PI from ISRO Centre/Unit

Mr. Denil V. Robinson

Contact Address of Co PI and e-mail id

denil_vr@vssc.gov.in

Area of Research

Avionics

Summary of the proposed research and expected deliverables

The increased migration to linear electromechanical actuators and the necessity to improve the performance and efficiency of these systems requires elimination of the mechanisms which attribute to the reduction in efficiency. The usage of linear motors aims to eliminate the requirement of a rotary to

linear conversion mechanism which offers an inefficiency of 15%. The development of the linear motors are targeted to avoid these inefficiencies. The usage of interior permanent magnet technique in these linear motors provide the flexibility of using the reluctance torque and hence offering the scope to augment the control scheme to avoid losses and further improve efficiency.

Scope of the Work:

The proposed research aims to bring out the configuration and detailed design of a Interior Permanent Magnet Linear Motor rated for no load speed of >200mm/sec and peak force of 40kN at 60mm/sec. This is targeted to increase the efficiency of the electromechanical actuation systems avoiding the rotary to linear conversion mechanism. The peak operating voltage is proposed to be around 125V. IPM motors offer the advantage of better mechanical strength and capability for utilization of reluctance torque. This will aid in the development of control strategies which offers to bring in significant advantage w.r.t efficiency and performance.

The realization of the motor and its performance characterization with a suitable drive design is envisaged to be carried out as part of the proposed work.

Linkages to Space Programme:

For the various electromechanical actuation systems of ISRO launch vehicles.

Expected Deliverables:

A linear motor of the above mentioned specifications and a suitable drive to be delivered. The performance of the realized system to be demonstrated through modeling and its validation in hardware.

RES-VSSC-2023-011

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Formal verification of Vikram3201 Ada Cross-Compiler

Name of Co PI from ISRO Centre/Unit

Ms. Anjana S.J.,
Ms. Syamlal L.S.

Contact Address of Co PI and e-mail id

sj_anjana@vssc.gov.in,
syamlal_ls@vssc.gov.in

Area of Research

Language Compiler for Microprocessor, Formal Verification

Summary of the proposed research and expected deliverables

The research proposal aims at formal verification of in-house developed Ada cross-compiler for Vikram3201, a 32 bit processor with indigenous instruction set architecture.

Scope of the Work:

Ada cross-compiler has been developed in-house and used for development of flight software for Vikram3201-based embedded systems. The research is aimed at formally proving that the compiler is error free.

Linkages to Space Programme:

Vikram3201 Ada cross-compiler realized for flight software development is being validated in- house. Formal verification of this compiler enhances the confidence on the usage of this compiler for critical applications.

Expected Deliverables:

- Formal verification models.
- Reports.

RES-VSSC-2023-012

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development of Memristor Switching Memory Technology

Name of Co PI from ISRO Centre/Unit

Mr. Dominic George Joseph,
Mr. Padmakumar K,
Ms. Deepu Roy.

Contact Address of Co PI and e-mail id

dominic@vssc.gov.in;
k_padmakumar@vssc.gov.in;
deepu@vssc.gov.in

Area of Research

Memristors

Summary of the proposed research and expected deliverables

Emerging memristive memory technology is a viable candidate for the next-generation nonvolatile memory. This has advantages of high scalability, compatibility with complementary metal oxide semiconductor (CMOS) technologies, high endurance, retention, low power consumption, and fast switching speed.2D nanomaterials are emerging and attracting interest.Due to their unique structural features and outstanding properties, 2D nanomaterials need to be explored for memristive memory.

The objective of the proposal is to explore suitable 2D nanomaterials using low cost synthesis techniques and on flexible substrate for nonvolatile resistive memory applications. The memory will be optimized for characteristic like ON/OFF ratio, endurance, reliability, switching ratio and low voltage switching.

Scope of the Work:

- Feasibility study of various 2D nanomaterials (like MoS2, MoSe2, MoOx) for fabricating memristors.
- Fabrication of memristors using feasible materials.
- Electrical characterization of the memristors for memristance.
- Choosing the best material based on flexibility, robustness, non-volatility and electrical characteristics.
- Design and fabrication of memristive memory array using the best material chosen.
- Optimization of the memory design and fabrication process for ON/OFF ratio, endurance, reliability, switching ratio and low voltage switching.
- Full-fledged characterization of the optimizedmemory.
- Applying the knowledge gained for development of memristor based AI hardware and in cyber
- security domain in future.

Linkages to Space Programme:

Memristors find direct applications in high density non-volatile memories and computationally intensive spacecraft control applications.

Expected Deliverables:

- Development of underlying device physics of memristors.
- Comparative study of various materials with respect to memristance.
- Process design details of fabrication of memristors using various materials.
- Prototype samples of all memristors using various materials.
- Schematics and Layout of memristor based memory design using chosen material.
- Process design details of memristor memory using chosen material.
- Prototype samples of memristor memory.
- Full characterization details of memristor memory.
- Process and design optimization details of memory array.
- Prototype samples of optimized memristor memory.
- Full characterization details of optimized memristor memory.
- All the above deliverables in case of any further development or application (like integration with CMOS chips) using the above technology.

RES-VSSC-2023-013

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development of toughened epoxy cryo compatible resin system

Name of Co PI from ISRO Centre/Unit

Mr. Sandeep Kumar,
Mr. A Sreekumar

Contact Address of Co PI and e-mail id

kumar_sandeep@vssc.gov.in,
a_sreekumar@vssc.gov.in

Area of Research

Material development

Summary of the proposed research and expected deliverables

Fundamental requirement of the development of toughened epoxy cryo compatible resin system is to provide good elongation at composite level 1>7000UE Transverse-strain capability) even at cryo temperature (20K).

It should have the following characteristics:

- High fracture toughness (resistance to microcracking).
- Low co-efficient of thermal expansion (CT E) to match with carbon fibre.
- Out-of-Autoclave (OoA) curing capability (to handle large component size) and availability.
- Longer out-life for ensuring sufficient time to fabricate large structures.

Scope of the Work:

- Development of toughened epoxy cryo compatible resin system.
- Evaluation of physical properties (viscosity, pot-life, self-life etc.).
- Evaluation of neat resin level mechanical properties at RT and LN2 temperatures.
- Evaluation of composite level mechanical properties at RT and LN2 temperatures with possible support of VSSC/ISRO.

Linkages to Space Programme:

Development of Composite Linerless/cryogenic tankages.

Expected Deliverables:

Toughened epoxy cryo compatible resin system.

RES-VSSC-2023-014

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Theoretical & experimental validation of compression after impact (CAI) strength of CFRP sandwich construction, 2D/3D composite under Low Velocity (<100m/s) Impact

Name of Co PI from ISRO Centre/Unit

Mr. Amar Singh

Contact Address of Co PI and e-mail id

amar@vssc.gov.in

Area of Research

Composite structures for Launch Vehicle applications

Summary of the proposed research and expected deliverables

CFRP composite sandwich structures are widely used for launch vehicle application. Sandwich type constructions, 2D/3D composite are sensitive to the impact loadings due to lesser through thickness strength. Low velocity impact can cause severe internal damages such as delamination, debond, core crush, fiber breakage and matrix crack in the CFRP sandwich structures which can reduce compressive strength significantly.

Hence, it is essential to develop the methodology to assess the damages due to low velocity impact through FEM and validate experimentally.

Scope of the Work:

- To understand the damage types and damage zones and FE analysis using progressive damage failure mode.
- To establish a correlation between impact energy, absorbed energy and damages in CFRP sandwich construction using FE analysis and validate through specimen level tests.
- To establish a procedure for numerical method to predict the compression after impact (CAI) strength (residual strength) of CFRP sandwich construction and validate through specimens level tests.

Linkages to Space Programme:

This work is useful for vertical takeoff and vertical landing (VTVL) - for RLV.

Important for upgrades in existing STS programs, immediate approved programs like RLV-ORV, Gaganyaan, semi-cryo, etc.

Expected Deliverables:

- Analysis methodology to predict damages and compression after impact strength in composite sandwich structures, 2D/3D composite due to low velocity impact.
- Carry out specimen level test to validate FE model and method.
- Analysis code/ User defined material model (if any).
- Specimen test data/Raw material test data.

RES-VSSC-2023-015

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Graphene coating on CFRP Sandwich antenna reflector for high frequency applications

Name of Co PI from ISRO Centre/Unit

Mr. Pankaj Agarwal

Contact Address of Co PI and e-mail id

pankaj_agarwal@vssc.gov.in

Area of Research

Composite structures for spacecraft applications

Summary of the proposed research and expected deliverables

Carbon Fiber Reinforced Plastics (CFRP) is used extensively for structural elements in spacecrafts due to their obvious advantages of higher mechanical performance with lower mass. One of such elements is satellite antenna reflector. CFRP is very good reflective material for Radio Frequencies up to Ku-band. But beyond Ku-band i.e. Ka band and above, CFRP is not a good reflective material. This is overcome by providing a high conductive material such as metals on the reflecting surface of CFRP antenna reflector. Recent studies show that being highly conductive, Graphene can also be good candidate material for the purpose. Hence, it is essential and can be very beneficial to explore that area of Graphene coating on CFRP antenna reflector. Also the coating should withstand the extreme Thermo-vacuum environment of space i.e. should be able to withstand the temperature ran e of -180° C to +130° C. CFRP sandwich substrates are cured at +1750C.

Scope of the Work:

- Development of a sustainable graphene based coating material for CFRP substrates.
- Development of a sustainable processing methodology to for evenly coating the CFRP substrates with above graphene based material.
- Ensuring above material is meeting space application out gassing requirements i.e. Collected Volatile Condensed Mass (CVCM) <0.1% and Total Mass Loss 1%
- Testing of adhesion properties of material over CFRP substrates.
- Measurement of coating thickness to ensure the minimum achieved thickness and its uniformity.
- Testing of coating survivability for the temperature range of -180° C to +130° C under vacuum (10 -5 torr.) at ISRO.
- Testing of RF reflectivity of coating for intended application i.e. Ka-band antenna reflector usage at ISRO.

Linkages to Space Programme:

The deliverables achieved from this proposal will be used in all spacecraft programmes of ISRO.

Expected Deliverables:

- Graphene coated flat CFRP sandwich substrates (20 nos.) of size 100 x 100mm. The specimens will be subjected to Thermo-vacuum cycling test for above mentioned temperature range. (Substrates will be given as FIM from vssc).

- Graphene coated CFRP sandwich Antenna dish ofØ300mm (3 nos.): Will be subjected to various tests like Thermovacuum cycling test, RF test etc. (Dishes will be given as FIM from VSSC).
- Graphene coated CFRP sandwich Antenna dish of size Ø700mm (1 no.)
  (Dish will be given as FIM from VSSC).

RES-VSSC-2023-016

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development and implementation of analysis procedure to assess fatigue induced delamination damage in carbon fiber reinforced plastic

Name of Co PI from ISRO Centre/Unit

Mr. Abhishek Parida

Contact Address of Co PI and e-mail id

abhishk_parida@vssc.gov.in

Area of Research

Composites

Summary of the proposed research and expected deliverables

The study aims to develop an analysis procedure that predicts delamination growth and assess existing delamination under fatigue conditions in laminated carbon fiber reinforced composites. The developed analysis procedure will provide a systematic tool for assessing the susceptibility of composite structures to fatigue-induced delamination growth and help to optimize designs, select appropriate materials, and develop effective mitigation strategies.

Scope of the Work:

- Develop an analysis method that can be implemented in practical scenarios to assess delamination under cyclic loading.
- Develop experimental procedures and setups to conduct fatigue tests at specimen level and generate data.
- Conduct a parametric study using the developed models to analyze the influence of different parameters on the delamination onset and growth.

Linkages to Space Programme:

In reusable missions where structure will subjected to repeated loading.

Expected Deliverables:

- Comprehensive literature review summarizing knowledge on fatigue induced delamination growth in composites.
- Detailed analysis procedure with user guidelines for its application in practical engineering scenarios.

- Detailed experimental procedure to generate data for delamination study.
- Experimental dataset comprising fatigue test results and delamination growth data for various configurations and loading conditions.
- Parametric study findings highlighting the effects of different factors on delamination growth behavior.

RES-VSSC-2023-017

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development of computational design infrastructure based on ab-initio calculations for A3B precipitate strengthened alloys

Name of Co PI from ISRO Centre/Unit

Mr. Anoop S,
Mr. Chenna Krishna S

Contact Address of Co PI and e-mail id

anoop_sasidharan@vssc.gov.in
s_chenna@vssc.gov.in

Area of Research

Materials

Summary of the proposed research and expected deliverables

The proposal aims to develop tools for the alloy design using a combination of high throughput calculations and thermodynamic modeling. Typically, thermodynamic databases, in combination with experimental methods are widely used to explore the alloy systems for commercial applications. This proposal aims to leverage the advanced computational tools utilizing ab initio calculations in a systematic exploration of the phase space. Using this methodology novel alloy compositions are explored to predict the stability of ordered and disordered phases, and identify promising candidates for targeted applications. The tool will enable us to design tailor-made alloys for high temperature applications by predicting the phase stabilities and strength of A3B strengthening precipitates.

Scope of the Work:

- Phase Stability Prediction: Utilize ab initio calculations to assess the thermodynamic stability of various ordered phases within a given alloy system. This will involve evaluating formation energies, enthalpies, and electronic properties.
- Special Quasi-Random Structures (SQS): Generate and analyze SQS to model the complex atomic arrangements in alloys. SQS will provide insights into short-range order, atomic configurations, and composition-dependent properties.
- CALPHAD Modeling: Employ the CALPHAD approach to construct thermodynamic databases that encompass a wide range of temperature, composition, and phase information. These databases will aid in predicting phase diagrams and phase transitions.
- High-Throughput Screening: Develop a computational framework to systematically explore a large space of alloy compositions. Use the generated phase diagrams and thermodynamic data to identify

composition ranges conducive to desired properties.

- Accelerated Alloy Design: By integrating ab initio calculations and thermodynamic databases, it aims to significantly speed up the alloy design process, reducing the need for extensive experimental trials. Framework for specific property to be developed. The proposed approach will enable the identification of alloy compositions that exhibit specific properties required for diverse applications.
- Enhanced Materials Understanding: Through comprehensive computational analysis, it is anticipated to gain deeper insights into the interplay between composition, and properties in complex alloy systems. Helps in understanding and using it for design.

Linkages to Space Programme:

Design and development of advanced structural and high temperature alloys for launch vehicles and spacecrafts applications.

Expected Deliverables:

- Tools for alloy design.
- Exhaustive documentation and training of the tool.
- Technical Report.

RES-VSSC-2023-018

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development of in-situ engineered additive manufacturing technique for fabricating Inconel718 parts.

Name of Co PI from ISRO Centre/Unit

Mr. K. Santhosh Kumar,
Mr. Apurba Roy

Contact Address of Co PI and e-mail id

santhosh_kc@vssc.gov.in
apurba_roy@vssc.gov.in

Area of Research

Novel Additive Manufacturing Technique

Summary of the proposed research and expected deliverables

Inconel 718 is used extensively in structures for space applications. Additive manufacturing of IN718 is being actively pursued to design difficult to manufacture parts. Various metallurgical phenomena to be fine-tuned to achieve defect free components with superior properties. In order to achieve above mentioned objective, in-situ engineering techniques have to be devised.

Various in-situ engineered techniques proposed to be incorporated in the additive manufacturing process such as

- In-situ process monitoring, control, modification of melt pool characteristic,
- Defect rectification,

- In-situ controlled atmosphere variation, etc.

Scope of the Work:

After completion of this project ISRO can use the output of the project to develop superior quality AM products.

Linkages to Space Programme:

Improving yield & efficacy of AM components for launch vehicle applications.

Expected Deliverables:

- Novel additive manufacturing technique to fabricate Inconel 718 structures.
- Development of reliable defect analysis closed loop system for improved yield of DED products.
- The developed system has to installed and demonstrated in DED machines (at VSSC).

RES-VSSC-2023-019

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Simulation of flow forming, welding and heat treatment for metallic motor cases for various aerospace materials such as M250 Maraging steel, 15CDV6 steel, 0.3C-CrMoV ESR steel

Name of Co PI from ISRO Centre/Unit

Dr. Anil Kumar Jain
Mr. Gurpreet Singh
Mr. Chenna Krishna S
Dr. Christopher Solomon
Dr. Biju S

Contact Address of Co PI and e-mail id

anilkumar_jain@vssc.gov.in

Area of Research

Materials/Fabrication

Summary of the proposed research and expected deliverables

1. Flow forming simulation (simulation of mandrel based as well as counter flow forming process) include: optimization of the preform sizes and reduction ratio for difference materials, estimation of residual stresses, strain hardening effect on materials said above after each pass, standardization of flow forming process simulation.

- Cirseam welding simulations of flow formed products; estimation of residual stresses and distortions
- local hardening simulation of M250; estimation of residual stresses, distortions/shrinkage.
- Hardening and tempering simulations for 15CDV6 steel / 0.3C- CrMoV ESR steel, ageing simulation for M250 maraging steel; estimation of residual stresses, distortions/shrinkage.

- Cirseam welding simulations of flow formed products after hardening; estimation of residual stresses and distortions.

Scope of the Work:

Simulation of flow forming (both mandrel based and counter roller), welding and heat treatment for metallic motor cases for various aerospace materials such as M250 Maraging steel, 15CDV6 steel, 0.3C-CrMoV ESR steel and optimization of parameters for various processes.

Linkages to Space Programme:

Currently all solid metallic motor cases (S139/S200/PSO-XL/RS1/RS2/Ullage/S200JM/L110SM/RH2 00/ RH300/RH560) are being fabricated through rolling and welding route and forgings are welded at both ends of a rolled cylinder. By developing flow forming technique, the weld joint can be avoided, therefore reliability for the product will be doubled. In addition to this, mass savings also can be attempted. Initial studies done on flow formed RS1/ RS2 retro motor case have shown promising results. Process capability has been verified and found that it is a reliable process for Motor Case Manufacturing.

Expected Deliverables:

- Documents explaining design of the algorithm.
- Software: Source code and Model definitions if any along with documentation on use of S/W.
- Report(s) which measurably enlist the results achieved on flow formed motor case of RS1/RS2/ RH200/S139 middle segments.

RES-VSSC-2023-020

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Design and development of hollow cathode assembly for the emission characterization and work function measurement of LaB6 emitter

Name of Co PI from ISRO Centre/Unit

Dr. Remyamol T

Contact Address of Co PI and e-mail id

remyamol@vssc.gov.in

Area of Research

Materials

Summary of the proposed research and expected deliverables

LaB_6 emitters are being planned to be used in electric propulsion thrusters. Indigenization of LaB_6 emitter material is in progress. The size of the hollow emitter is 2.5 mm OD, 1 mm ID, and 9 mm length.

For the qualification of the material, emission testing and work function measurement (spec. ≤2.67 eV)

is essential. The emission testing of LaB_6 emitter requires design, validation and fabrication of a hollow cathode assembly with heating capabilities of 1600 °C, Assembly also requires Graphite/molybdenum cathode and keeper tube, W-Re wire as heater, ceramic holder, radiation shielding methods, etc. Hence, there are thermal and mechanical challenges for the design for heating assembly. Cathode design and the material selection is a critical job to obtain such a high temperature for continuous long durations.

Proposed work includes:

- Thermal analyses for LaB_6 hollow cathode to obtain temperature and heat flux distributions.
- Experimental validation of the design parameters.
- Fabrication of the hollow cathode assembly as per optimized design.
- Emission testing and work function measurement of one emitter (supplied by VSSC)- expected work function is ≤ 2.67 eV.
- Supply of realized hollow cathode assembly to VSSC for use in the facility being set up in VSSC.

Scope of the Work:

- Thermal and structural simulation of heating assembly in order to obtain desire cathode temperature (1600 ^{0}C).
- Development of heating assembly based on optimized simulation parameters.
- Experimental validation of simulation result using LaB6 emitter provided by the user (VSSC-ISRO).
- Supply of one heating assembly to VSSC.

Linkages to Space Programme:

Emission characterization of LaB6 emitter is needed for use of indigenous material for electric propulsion thruster.

Expected Deliverables:

- Design of heating assembly.
- Technical knowhow for the realization of heating assembly.
- Emission testing of one sample of LaB_6 emitter supplied by VSSC.
- Supply of one heating assembly to VSSC.

RES-VSSC-2023-021

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Process modeling and simulation of Magnesio-thermic reduction and pyrovacuum distillation operations in Titanium sponge extraction and arrive at optimized reactor design

Name of Co PI from ISRO Centre/Unit

Mr. Pradeep P I

Contact Address of Co PI and e-mail id

pi_pradeep@vssc.gov.in

Area of Research

Extractive Metallurgy

Summary of the proposed research and expected deliverables

VSSC established the first Titanium Sponge plant in the country using the pilot plant technology developed by DMRL, Hyderabad. The plant uses Kroll's Process for manufacturing Titanium Sponge from $TiCl_4$. The process involves magnesio-thermic reduction of $TiCl_4$ followed by pyro- vacuum distillation of the reduced sponge for removing locked up magnesium and MgCl2. Specially made SS 304/430 cladded vessels (reactors) are used for the processing. The extreme operating conditions (temperature upto 975 $^{\circ}C$, pressure down to 50 microns of Hg vacuum and corrosive vapours) for long duration (~250 Hrs). The cyclic heating and cooling is causing severe distortion to the process reactors. Modeling and simulation of the process using FE analysis is proposed for understanding the temperature and stress distribution in the process rectors during the various stages of reduction and distillation operations. Constitutive heat and mass transfer equations involved in the reduction and vacuum distillation processes needs to be solved for optimizing the process parameters to maximize the productivity. The study shall recommend the optimum temperature, vacuum level and duration for achieving complete distillation of magnesium and $MgCl_2$ vapours for a 3.5 MT batch. Simulation studies shall predict the stress-strain distribution, residual stresses and distortion in the reactors. The study shall suggest suitable modifications in the process reactors to keep the distortion within limits.

Scope of the Work:

- 3D modeling of process reactor and allied systems.
- Simulation of $TiCl_4$ reductio process.
- Simulation of Vacuum distillation process.
- FE analysis of the process reactor during reduction and vacuum distillation process.
- Analyzing leakages in the system due to thermal distortion.
- Design analysis of process reactors.

Linkages to Space Programme:

Ti. Alloys are used for PS4 and Satellite propellant tanks, gas bottles, inter-stages etc. TSP is the only plant in the country for extracting Ti. Sponge from Ilmenite minerals. The plant is supporting the Ti. Sponge demands of Space programme as well as Defence requirements in the country.

Expected Deliverables:

- Temperature, stress and strain distribution in the process reactor during reduction and vacuum distillation operations.
- Distortion prediction and suggestion for design modifications to resist the distortion
- Optimum process parameters for vacuum distillation for reducing processing time and achieving maximum purity.

- Development of combined cycle process.
- Comprehensive plan for reduction in energy consumption and improvement in quality and yield of aerospace grade Titanium sponge from TSP.

RES-VSSC-2023-022

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development & demonstration of Proof of Concept (PoC) for Multi- layer Ceramic Capacitor (MLCC)

Name of Co PI from ISRO Centre/Unit

Dr. Venkateswaran C

Dr. Ashok K

Contact Address of Co PI and e-mail id

c_venkateswaran@vssc.gov.in

ashok@vssc.gov.in

Area of Research

Materials / Electronic Component

Summary of the proposed research and expected deliverables

Multi-layer Ceramic Capacitors (MLCC) are miniaturized form of capacitors with range capacitance value and they are conventionally being used in wide variety of application. Basic technology relay on multi-layer printing & stacking of dielectric ceramic & metals to achieve the required impendence/capacitance.

Scope of the Work:

- Identification of suitable dielectric materials for MLCC.
- Development of dielectric ink with suitable rheological properties with sufficient solid loading.
- Development of metal ink with suitable characteristics required for processing MLCC.
- Adopt screen printing or other suitable printing technique and demonstrate the process of realizing a MLCC, surface mountable type with solderable metal surfaces.
- Target Capacitance(i) 10, (ii) 100µF.
- Characterize the ESR/Impedance & Capacitance dependence of Frequency, leakage current (DC), etc.

Linkages to Space Programme:

Large number of surface mount capacitors are widely being used in range of lunch vehicle and satellite applications. They are currently being imported from limited sources.

Expected Deliverables:

- Processing making dielectric ink with suitable rheological characteristics for multilayer printing requirements.

- Processing of making metal inks with suitable requirements.
- Technology demonstration, Proof- of Concept (PoC) making and Process document for realizing MLCCs having minimum foot print area and different capacitance namely 10 µF(PoC-1) & 100 µF(PoC-2).

RES-VSSC-2023-023

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development of TiN, TiCN, AlTiN and Diamond Like Carbon (DLC) coating over Ti6Al4V substrate

Name of Co PI from ISRO Centre/Unit

Mr. Vibhu Unnikrishnan

Contact Address of Co PI and e-mail id

vibhu@vssc.gov.in

Area of Research

Physical/ chemical vapor deposition techniques

Summary of the proposed research and expected deliverables

This work is intended for developing a suitable process/ technique for coating TiO_2, TiN, TiCN, AlTiN, DLC over Ti6Al4V substrate (concave and convex surfaces) with uniform thickness in the range of 1 to 4 microns.

Scope of the Work:

- Identifying coating techniques for TiO_2, TiN, TiCN, AlTiN, DLC coatings.
- Coating trials over Ti6Al4V substrate.
- Evaluation of coating properties such as hardness, abrasion resistance.
- Chemical characterization using SEM, Raman, XRF techniques.

Linkages to Space Programme:

This activity is aimed at development of high hardness wear resistant coating of Ti6Al4V substrates.

Expected Deliverables:

Ti6Al4V substrates coated with TiN, TiCN, AlTiN and DLC coatings of thickness in the range of 1 to 4 microns.

RES-VSSC-2023-024

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Space grade Ion Selective Electrode

Name of Co PI from ISRO Centre/Unit

Dr. Deepthi L Sivadas

Contact Address of Co PI and e-mail id

deepthi_sivadas@vssc.gov.in

Area of Research

Sensors

Summary of the proposed research and expected deliverables

Chemical analysis of aqueous extract of Moon / Mars regolith is important since the analysis determine its chemistry and mineralogy, the nature of oxidants, the potential for past or present biology, and potential hazards to human exploration. Onboard wet chemistry analysis is the technique for studying aqueous chemistry and ionic strength of Moon/Mars regolith.

Similar to the analytical procedure being carried out in wet chemistry laboratories, soil should be treated with water for extracting the analyte. For this purpose, water has to be carried from ground for onboard experiment.

Array of Ion Selective Electrode (ISE) sensors cater the quantitative analysis of analyte cations and anions in onboard wet chemistry laboratory.

Realisation of ion selective electrode is critical as fabricating ISEs rugged enough to survive a journey through space lasting nearly a year, extreme temperature variations, radiation, enduring the ambient Mars conditions upon arrival and several months afterwards.

Ion selective electrode should be very compact and should consist of Housing, filling solution, Membrane (Polymer membrane) and Internal reference electrode.

Scope of the Work:

The scope of the proposal include development, evaluation and supply of space-grade, compact Ion Selective Electrode for water soluble cations and anions (eg: Perchlorate and lithium) with a minimum detectable concentration of 10^{-5} M or 1% of the total ion concentration.

Housing: Material of construction PVC or Teflon with dimension of maximum 3.5 mm x 3.5 mm, thickness of maximum 0.5 mm a well depth of maximum 3 mm. Internal filling solution:

The recommended internal filling solution is a mixture of polymer derived hydrogel and aqueous phase of primary ion salt.

Polymer membrane: Membrane of each ion selective electrode should be made of PVA and plasticizer (DOS or NPOE) with suitable ionophore.

Internal reference electrode: Compact Ag/AgCl reference electrode should be fabricated from 1 mm diameter silver wire, and AgCl has to be deposited using potentiostat.

Miniature ion selective electrode for perchlorate and lithium should be calibrated with respect to 10^{-8} to 10^{-1} M primary ion concentration. It should demonstrate linear EMF response vs. individual ion activity. ISE also should demonstrate its selectivity over interfering ions in the analyte solution.

Linkages to Space Programme:

Inter-planetary missions Though Spectrophotometric techniques provides the information on major and minor constituent elements of Mars or moon regolith, this doesn't disclose the identity, ionic character, or solubility of any salts or compounds.

Identification and quantification of chemical compounds in Moon / Mars regolith is important since it provide information towards origin, evolution, geology and habitability, hazardous nature of the soil to life, future astronauts or planetary outpost. Unlike other instrumental analysis, only onsite measurement is recommended for aqueous chemistry analysis, for accurate result.

Real-time analysis of aqueous extract of regolith can be accomplished using onboard aqueous chemistry experiment payload. It consist of a beaker, water delivery and soil delivery system.

Space grade Ion selective electrode is recommended for sensing the response when analyte species extract into water. Measurement of potential across an interface, which is dependent on the concentration of a selected ionic species on each side of that interface.

Expected Deliverables:

- Development and supply of miniature Space-grade Ion Selective Electrodes for perchlorate ion and lithium ions.
- Performance demonstration of the developed ISE at both the institute and VSSC.
- Transfer of process and technology to VSSC.

RES-VSSC-2023-025

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Synthesis of UV-curable non isocyanate PU coatings

Name of Co PI from ISRO Centre/Unit

Dr. Remya Balakrishnan

Contact Address of Co PI and e-mail id

remya_balakrishnan@vssc.gov.in

Area of Research

Chemical systems

Summary of the proposed research and expected deliverables

Although the current polyurethane coatings used in the aerospace applications meet the stringent performance requirements, they don't comply with the environmental demands, e.g., low VOC contents.

Moreover, containing a significant amount of solvent, they usually need long drying times, which causes significant production burdens.

Furthermore, many of these coatings contain isocyanates, which are hazardous and are likely to be regulated soon.

In this study, a series of sustainable UV-curable non-isocyanate urethane acrylate (NIPU-AC) oligomers, with different structures and acrylate equivalent weights, were synthesized and used as a primary building block of UV-curable coatings for aerospace applications.

The targeted properties of the developed coatings are:

- Flexibility: -100 to +100^{o}C.
- Elongation: 100% (min).
- LSS at RT with Al-Al: 10ksc.
- (min).
- Good adhesion properties.
- Chemical resistance Could be reached through the proper design of NIPU-ACs, selection of appropriate reactive diluents, and UV- cure conditions.

Scope of the Work:

Currently, PUs are moulded using isocyanate synthesized using toxic phosgene. Proposed system is through non isocyanate routes having low VOCs which could be sustainable alternatives for current aerospace polyurethane coatings.

Different methodologies for realizing NIPU coatings, selection of suitable method for realizing the target coating properties and detailed characterization of realized coatings.

Linkages to Space Programme:

Non isocyanate PU coatings on space structures with chemical resistance.

Expected Deliverables:

Radiation curable, non-isocyanate PU coatings.

RES-VSSC-2023-026

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Highly chlorinated natural and synthetic polyisoprenes

Name of Co PI from ISRO Centre/Unit

Ms. Temina Mary Robert

Contact Address of Co PI and e-mail id

temina_robert@vssc.gov.in

Area of Research

Materials

Summary of the proposed research and expected deliverables

There is a wide variety of adhesive compositions currently available for bonding elastomeric materials to metal surfaces. Many of these adhesive compositions utilize various halogenated polymers to provide the adhesive compositions with film-forming capability, enhanced adhesion, and resistance to adverse environmental conditions. One of the most common and most effective halogenated polymeric materials is chlorinated natural rubber or chlorinated synthetic rubber such as chlorinated polyisoprene.

The process traditionally involves the utilization of highly chlorinated solvents. The increasing number of environmental regulations has limited the availability and usability of many chlorinated solvents. The proposal is indented to develop high chlorine containing rubber (chlorine content > 65%) with good solubility in organic solvents and environmental resistance under ambient conditions.

Scope of the Work:

The proposal is indented to develop.

- Chlorinated rubbers with high chlorine content (> 65%).
- Solubility in aromatic and chlorinated hydrocarbons, esters, THF etc.
- Mw around 1,00,000 to 2,00,000.
- Thermal stability up to 250-300 ˚C.

Linkages to Space Programme:

Raw material for contact adhesive formulations for rubber to metal bonding in launch vehicles.

Expected Deliverables:

- Technology for the production of high chlorine containing polyisoprene rubber.
- 1kg Chlorinated rubber for characterisation, processing.
- Evaluation of a typical adhesive composition at VSSC.

RES-VSSC-2023-027

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development of space grade Ammonium Dinitramide (ADN) as energetic oxidizer for composite solid propellant

Name of Co PI from ISRO Centre/Unit

Dr. Sreejith M

Contact Address of Co PI and e-mail id

m_sreejith@vssc.gov.in

Area of Research

Propulsion

Summary of the proposed research and expected deliverables

Ammonium dinitramide (ADN) is a high-performance energetic oxidizer that has potential for solid propellant applications. It is regarded as a possible substitute and green alternative to ammonium perchlorate (AP). It also offers a higher specific impulse (I_{sp}) than AP-based propellants.

ADN is obtained in the form of crystal aggregates which are not suitable for propellant processing. ADN also has inherent hygroscopic characteristics. In order to use ADN for propellant application, these two drawbacks need to addressed. It is therefore desirable to produce hydrophobic coated ADN having controlled particle size/ shape.

Scope of the Work:

Oxidizer particles with spherical or near spherical morphology is preferred due to better solid packing fraction and improved rheological properties in solid propellant formulation. In order to achieve the required morphology, solvent/anti-solvent crystallization method is projected for the production of high purity crystalline ADN with controlled particle size.

This production methodology provides ADN of particle size 300±50 µm and a near spherical crystal morphology.

The proposed research also aimed to develop an optimized process for the hydrophobic coating on ADN particles to avoid inherent moisture sensitivity characteristics of ADN.

Linkages to Space Programme:

ADN is proposed as high-performance oxidizer for advanced 'green' composite solid propellant formulation. The propellant formulation with ADN oxidizer provides higher specific impulse (I_{sp}), higher vacuum Isp and density impulse than the conventional solid propellants and are the suitable options for 1) special purpose motors 2) booster propellant for upper stages 3) high burn rate propellant 4) chlorine-free propellants etc. for the futuristic missions of ISRO.

Expected Deliverables:

- A process for the preparation of ADN with near spherical morphology & hydrophobic coating of ADN.
- Supply of space grade coated ADN with particle size of 300±50 µm (100g x 5 Nos).

RES-VSSC-2023-028

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development of catalyst for electrochemical reduction of carbon dioxide gas to methane in Proton Exchange Membrane (PEM) cells

Name of Co PI from ISRO Centre/Unit

Dr. Shaneeth M

Contact Address of Co PI and e-mail id

m_shaneeth@vssc.gov.in

Area of Research

Energy System

Summary of the proposed research and expected deliverables

Energy efficient conversion of CO_2 gas to methane is highly relevant in manned space missions as well as mars missions. PEM cell based electrolytic conversion of CO_2 gas selectively to methane using water and electricity forms a potentially attractive solution in this regard.

Scope of the Work:

- It is envisaged to develop efficient electro-catalyst for selective reduction CO_2 to methane in PEM electrolytic cells based on the literature or molecular simulation.

Linkages to Space Programme:

- Oxygen generation system for human space programme.
- Regenerative fuel cells for extraterrestrial mission.
- Green Hydrogen for societal application.

Expected Deliverables:

The deliverables shall include synthesis method for optimal catalyst chemistry based on performance data and sample material (~10g) with electrode processing conditions, for evaluation at VSSC.

RES-VSSC-2023-029

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development of 'Hybrid polyhydroxyurethane foam' for aerospace application

Name of Co PI from ISRO Centre/Unit

Dr. Anitha S

Contact Address of Co PI and e-mail id

anitha_sukumarannair@vssc.gov.in

Area of Research

Polymeric foams

Summary of the proposed research and expected deliverables

The objective of this proposal is to synthesis hybrid polyhydroxyurethanes/ Hybrid non- isocyanate polyurethanes (HPHU/HNIPU) foam from synthetic as well as bio-based molecules such as vegetable oils, fatty acids, terpenes etc., via. the synthesis of cyclic carbonate by the incorporation of CO_2 into an epoxy. Among the different PU-based products, PU foams deserve special mentioning as they find applications in thermal protection systems and acoustic insulation systems. Conventionally, PUs are developed through the reaction of a di- or triisocyanate with a polyol.

However, the isocyanates, as per the classification regulation (EC) number 1272/2008, are classified as carcinogenic, mutagenic and reprotoxic, and may cause acute poisoning. In addition, the isocyanates are synthesized from a more toxic precursor phosgene. Therefore, efforts are being carried out, now, across the world to develop PUs through routes avoiding isocyanates.

PU based foam products are in great demand which has application in commercial market as well as in space industry related to thermal insulation including cryogenics, acoustic absorbent, construction, automotiveetc.

Greener technologies are becoming promising worldwide, hence switch over to non-isocyanate route may become mandatory. The project aims to develop room temperature curable non-isocyanate polyurethane foam. The synthesis can be carried out by the addition of epoxy (natural /synthetic) into cyclic carbonate followed by reaction of polyamines in presence of suitable blowing agent and catalyst.

Hence the objective is to realize HNIPU foam having properties better or comparable with the existing PU foam. The HNIPU foam synthesized by the above mentioned routes will be evaluated for physical, thermal, mechanical and morphological properties. The properties are to be compared with the conventional PU foam.

Scope of the Work:

- Synthesis of cyclic carbonate from renewable resources (vegetable oils, fatty acids etc.) or using synthetic epoxy.
- Realization of cyclic carbonate under atmospheric CO_2 and room temperature.
- Realizing solvent free HNIPU foams curable at room temperature.
- Exploring the possibilities of HNIPU based spray foaming
- Evaluation of density, thermal, mechanical properties, morphological and spectroscopical characterization of CC and HNIPU foam (the expected properties of HNIPU foam should be the same or greater than the Conventional PU foam used in aerospace:
  density : 35-40kg/m^3, LSS: 1.6-2.0 ksc, Compressive strength : 1.6-2.2ksc, Thermal conductivity : 0.035-0.04 W/mK, TGA: 260˚C).

Linkages to Space Programme:

PU foam forms an integral part of launch vehicle. In finds application as flexible foam as used in PS4 tank, insulation for cryo storage tanks etc. In all these, PU foams are realized using isocyanates, which is highly carcinogenic. The realization of HNIPU helps in the synthesis of green foam (HNIPU foam).

Expected Deliverables:

- Process document with synthesis methods and optimized parameters along with the achieved properties of CC/HNIPU foam.
- Cyclic carbonate synthesized from renewable/synthetic resources (10gm).
- Catalyst for conversion of epoxy to CC under atm.CO2 and room temperature (1gm).
- Catalyst for room temperature curing of CC to HNIPU (1gm).

- Room temperature curable HNIPU foam (100x100x100 mm block).
- Include as one of the authors in patent, publications and books/book chapters pertaining to HNIPU foam.

RES-VSSC-2023-030

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development of MXene/polyurethane auxetic composite foam for electromagnetic interference shielding and impact attenuation

Name of Co PI from ISRO Centre/Unit

Smt. Monisha K

Contact Address of Co PI and e-mail id

k_monisha@vssc.gov.in

Area of Research

Chemical systems

Summary of the proposed research and expected deliverables

MXene/auxetic polyurethane (MX/APU) composite foam is used for multifunctional EMI shielding and impact attenuation. The MX/APU composite presents a superior EMI shielding effectiveness (SE) of 76.2 dB, 31.2% higher than its non-auxetic counterpart at the same density owing to the larger specific surface area arising from the auxetic structure. Given its ultralow density of 0.063 g cm−3, it yields a specific SE of 1210 dB cm3 g−1, placing it among the best candidates for lightweight applications. The negative Poisson's ratio of MX/APU composite foam also delivers multi-functionalities of impact attenuation, reducing the peak force by 51.4% compared to a non-auxetic foam. This work provides a conceptually new approach to design lightweight multifunctional materials using auxetic structures.

Scope of the Work:

Lightweight electromagnetic interference (EMI) shielding and impact attenuating materials are vital to protect delicate components in portable electronics. While conductive foams are intriguing for lightweight EMI shielding, their impact attenuating properties are essential for functional requirements.

- Incorporation of auxetic behaviour in PU foam.
- Synthesis of various Mxene materials and incorporation into PU auxetic foam.
- Functional characterisation with respect to EMI shielding.

Linkages to Space Programme:

Light weight and durable composite foams for EMI shielding.

Expected Deliverables:

Light weight composite foams with auxetic nature incorporating Mxene for EMI shielding.

RES-VSSC-2023-031

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Epoxies adhesives with high Tg (>300˚C)

Name of Co PI from ISRO Centre/Unit

Dr. Satheesh Kumar B

Contact Address of Co PI and e-mail id

satheesh_kb@vssc.gov.in

Area of Research

Materials

Summary of the proposed research and expected deliverables

The proposed research aims to develop a high performance nitrogen free tetra-functional epoxy (Tg>300˚C) with good thermal and thermo- mechanical properties. Generally, tetra-functional epoxies are indispensable matrix for the aerospace industry, high-temperature adhesives, and encapsulation materials, where high service temperatures are required. Commonly available tetra-functional epoxies are nitrogen containing, and are having several disadvantages.

The distance of the two epoxy groups attached to the same N atom in these are generally close enough to cause unwanted cyclization side reactions during curing which form defects in the networks and deteriorates the integrated properties of the final resin system. Also, the occurrence of lots of weak C–N bonds can trigger thermal degradation, impairing the thermal stability for resin system. In addition to this, the presence of polar N atoms in the structure and the cyclization defects in its networks increase the water absorption of the resin system, which plasticizes the resin system, deteriorating its properties seriously. When these types of resins are used as matrix resin for composites, the absorbed water can migrate to the interface and it exhibited weak the interfacial or inter laminar shear strength.

Scope of the Work:

Commonly available tetra-functional epoxies are nitrogen containing, which are having several disadvantages like unwanted side reactions, intra-molecular cyclization, high moisture absorption, high viscosity etc. By developing a nitrogen free high performance tetra-functional epoxy, the drawbacks can be eliminated and can be used as a matrix resin for high performance composite applications.

- Epoxy value 9-12 eq/kg.
- Tg> 300˚C(with high temperature curing agent).
- Curing temperature (max 180˚C).
- Thermal stability of cured (5% decomposition > 370˚C).
- Viscosity at 50˚C: 50-60P.

Linkages to Space Programme:

Advanced matrix resin for Composite applications in Heat shield of LVs

Expected Deliverables:

- Technology for the synthesis of epoxyresin.
- 500g epoxy resin for evaluation at VSSC.

RES-VSSC-2023-032

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development of three-dimensional physics based ionospheric model for the Indian region.

Name of Co PI from ISRO Centre/Unit

Dr. Ambili K M

Contact Address of Co PI and e-mail id

ambili_km@vssc.gov.in

Area of Research

Space Physics

Summary of the proposed research and expected deliverables

The horizontal nature of the geomagnetic field, in association with many factors such as lower atmospheric forcing, coupling of low latitude with high latitude, and the indirect impacts of geomagnetic storms make the equatorial and low-latitude ionosphere, which encompasses the Indian region, much more complex. In this context, the equatorial ionosphere assumes significance as plasma processes thereat not only affect the electron density in this region but in the entire low latitude, a region covering 15 degrees on both sides of the geomagnetic equator. Although the gross distribution of plasma in the ionosphere at any place and time is fairly known and modeled, its day-to- day variations are still far from being understood properly. Therefore, a theoretical model is much essential to understand the day-to-day variability of the ionosphere and also to understanding the distribution of plasma over the Indian region. The study will be focusing on the expansion of the quasi-two- dimensional model to three dimensions by adding various components such as

- Diffusion of plasma along the magnetic field lines.
- Vertical drift of plasma over the geomagnetic equator.
- Effect of neutral winds on the plasma dynamics.

Scope of the Work:

Though there are different models are available for the ionospheric studies, none of the model were able to reproduce the features associated with the equatorial and low latitude regions of the ionosphere, Indian region. Hence the development of the model suitable for the Indian region is much essential.

The model will be parameterized based on the observations from the region and the efficiency can be improved.

Linkages to Space Programme:

Development of the 3D model for the equatorial/low latitude regions of the Earth's ionosphere is an

important objective of the INSWIM (Indian Network for Space Weather Impact Monitoring) program of ISRO, to understand the impact of the geomagnetic storm events on the near Earth Space environment and on the atmospheric-ionospheric system.

Expected Deliverables:

- Three-dimensional map of electron density distribution.
- Calculation of the delay due to ionosphere which is useful for the prcise operation of the Navigation satellites.

RES-VSSC-2023-033

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development of inversion techniques for Satellite based retrieval of trace and green-house gases.

Name of Co PI from ISRO Centre/Unit

Dr. Prijith S. S.

Contact Address of Co PI and e-mail id

prijith_ss@vssc.gov.in

Area of Research

Satellite Remote Sensing of Earth and Planetary Atmosphere.

Summary of the proposed research and expected deliverables

Measurement of trace and green- house gas concentration over both regional and global scale is essential for air quality monitoring and atmospheric research. Identification of major source and sink regions of green-house and trace gases and quantification of their strength and variability are essential for the better assessment of human impacts on Earth's climate and also for the formulation of appropriate mitigation plans.

Three-dimensional distribution of trace gases, their temporal evolution and long-range transport are major aspects, which need to be addressed adequately in the contest of increased greenhouse gas emission and climate change.

This can be achieved by satellite remote sensing of spectral radiances measured in suitable configurations such as limb viewing, nadir viewing and solar occultation. Thus, the major objective of the proposed research activity is development of state-of- the-art inversion techniques for the retrieval of trace gases from the satellite measured spectral radiances in UV, visible and IR wavelengths. Addressing this objective requires extensive radiation transfer simulations and development of appropriate mathematical inversion schemes.

This activity comprises several components such as theoretical formulation, development of algorithms and software, simulations of satellite measured radiances at different conditions, sensitivity analysis and retrieval of columnar concentration and vertical distribution of trace gases in the atmosphere using satellite measured radiance data and its comparison with other observations.

Scope of the Work:

Satellite based measurements of trace and green-house gases is indispensable not only for the accurate assessment of climate change, but also for the formulation of appropriate mitigation plans.

The methodologies and algorithms intended to develop as part of the present activity can be implemented on future satellite based sensors for the retrieval of gaseous specie in the atmosphere of Earth and other planets.

Sensitivity analyses for different conditions including different viewing configurations (such as limb viewing, nadir viewing and solar occultation) would show the advantages and limitations of each of them and which would be helpful in the design and development of future space based sensors.

Columnar abundance and vertical distribution of different gaseous specie in the Earth atmosphere, measured by employing the algorithms on different satellite based sensors, would be useful for several applications such as climate change assessment and atmospheric research.

The techniques and algorithms based on the radiance measurements in UV, visible and IR channels, are also useful in identification and measurement of various gaseous specie in different planetary atmosphere.

Linkages to Space Programme:

The proposed research activity is mainly linked to the Space Applications for sustainable development, specifically in the assessment of climate change induced impacts.

It is also linked to Space Infrastructure, specifically the development of space- borne sensors for atmospheric science.

Expected Deliverables:

- Algorithms and software for the retrieval of trace gases from satellite observations.
- Retrieval of columnar concentration and vertical profile of trace gases from satellite measurements.

RES-VSSC-2023-034

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development of light weight instruments for the measurement of aerosol size distribution/extinction coefficient at visible wavelength in Earth and Planetary atmospheres at various atmospheric pressure levels/altitudes

Name of Co PI from ISRO Centre/Unit

Dr. S Suresh Babu

Contact Address of Co PI and e-mail id

s_sureshbabu@vssc.gov.in

Area of Research

Atmospheric Science, Planetary exploration

Summary of the proposed research and expected deliverables

Aerosols play a crucial role in the Earth's and other planetary atmosphere's climate and air quality. Understanding their size distribution/extinction coefficient is important for various scientific studies and practical applications.

Measurement of the altitude distribution of aerosol size distribution/extinction coefficient in Earth and planetary atmosphere is very important for the estimation of radiative effects of aerosols that control its climate and temperature profile. The aerosol size distribution in a planetary atmosphere refers to a wide range of particle sizes (typically from nanometers to micrometers) that makes up the aerosols in that atmosphere. The extinction coefficient of aerosols in a planetary atmosphere is a critical parameter that quantifies how aerosol particles in the atmosphere attenuate the intensity of the electromagnetic radiation as it passes through the atmosphere.

The developed instrument should be able to operate from balloon/drone platform. In the Earth atmosphere the developed instrument will be used for profiling the aerosols in the atmosphere up to stratospheric altitudes.

Scope of the Work:

- Design of the instrument for aerosol size distribution/extinction coefficient measurements.
- Development of the engineering model of the instruments.
- Testing and calibration of the instrument at SPL/VSSC.
- Field measurements and inter- comparison experiments.

Linkages to Space Programme:

Climate and Atmospheric science program as well as planetary exploration.

Expected Deliverables:

- Engineering model of the instrument should be delivered.
- Design document should be submitted along with project report.

RES-VSSC-2023-035

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development of Spectroscopic Algorithm for Retrieval of Clouds & Aerosols from Nadir, Limb and Occultation Measurements in the Atmospheres of Venus and Mars

Name of Co PI from ISRO Centre/Unit

Mr. Jayadev Pradeep

Mr. S. V. Sunil Kumar

Contact Address of Co PI and e-mail id

jayadev_pradeep@vssc.gov.in

sv_sunilkumar@vssc.gov.in

Area of Research

Planetary Science, Atmospheric Physics

Summary of the proposed research and expected deliverables

The atmospheres of Venus and Mars are drastically different in composition and physical properties, and both planets host atmospheric aerosols and clouds of different kinds. The Venusian atmosphere has a permanent global cloud deck (~40-70 km altitude) and a mesospheric aerosol haze (~70-100 km altitude), both comprising of concentrated sulfuric acid aerosols. On the other hand, the Martian atmosphere is replete with clouds of solid carbon dioxide and water ice, along with mineral dust aerosols that manifest as global dust storms and background dust haze. Aerosol and cloud particles in both planets play a significant role in radiatively modulating the heating rates of the respective atmospheres, but there remain several outstanding questions on their formation pathways, size distribution, spatio-temporal variability, etc.

The present proposal aims to develop a spectroscopic algorithm for retrieving the characteristics (including vertical altitude profiles of size distribution) of aerosols and cloud particles from multi-wavelength orbital measurements of the Venusian and Martian atmospheres, incorporating different observational modes such as occultation, nadir, and limb-viewing geometries.

Developing the indigenous capability to retrieve aerosol and cloud features from spectroscopic remote sensing data can significantly enhance the science output from ISRO's future missions to Venus and Mars.

Scope of the Work:

- The research will entail the formulation and development of a spectroscopic algorithm from the first principles for retrieving clouds and aerosols in the Venusian and Martian atmosphere.
- The algorithm should be capable of deriving the vertical altitude profiles of size distribution of aerosols and cloud particles, from multi-wavelength flux/radiance measurements in specifically identified wavelength bands of interest.
- The developed algorithm should be robust enough to handle a combination of different observational modes including occultation, nadir and limb-viewing geometries, applying appropriate geometric corrections and other considerations.
- Validation and testing of the developed algorithm is to be carried out using suitable existing data available from the literature on Venus and Mars.
- Establishing indigenous capability to retrieve aerosol and cloud characteristics from remote sensing data will significantly augment the analysis of data from future Venus and Mars missions of ISRO.

Linkages to Space Programme:

Future interplanetary missions of ISRO to Venus and Mars (Venus Orbiter Mission, Mars Orbiter Mission – 2, and beyond)

Expected Deliverables:

- Spectroscopic algorithm and computer code capable of retrieving aerosol and cloud characteristics (altitude profiles of size distribution) using multi-wavelength remote sensing data from occultation, nadir and limb-viewing measurements.

- Extensive validation of the algorithm and code using suitable existing observational/model data on Venus and Mars, and demonstration of accuracy and reliability.

RES-VSSC-2023-036

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development of Artificial Intelligence (AI) and Deep Learning (DL) based Algorithms for identifying, characterizing and tracking of Rain Cells embedded in mesoscale convective systems using Doppler Weather Radar observations

Name of Co PI from ISRO Centre/Unit

Dr. K. Kishore Kumar

Contact Address of Co PI and e-mail id

k_kishorekumar@vssc.gov.in

Area of Research

Atmospheric Science/ Remote Sensing

Summary of the proposed research and expected deliverables

Mesoscale convective systems (MCS) are group of organized thunderstorms that act collectively as a system. These systems comprise of both convective and stratiform regions. The convective regions of MCS are embedded with rain cells capable of producing high intensity rainfall.

Identifying and characterizing these convective rain cells in terms of their vertical and horizontal extent, intensity and life-time are essential to investigate the genesis, evolution and dissipation of MCS.

Among many observational platforms, Doppler Weather Radar (DWR) is one of the best instruments to study the three- dimensional structure of MCS. The high- spatial and temporal resolution scanning capability of DWR provides unique opportunity to study the evolution of the MCS. A state-of-the-art, indigenously developed C-Band Polarimetric DWR is operational at Thumba. This radar provides spatial structure of MCS round the clock.

The proposed research will focus on developing an algorithm using Artificial Intelligence (AI) and Deep Learning (DL) techniques to identify, characterize and track the rain Cells embedded in mesoscale convective systems from the DWR observations. The radar reflectivity structure and radial velocity measurements will be used for the study.

Scope of the Work:

C-band Polarimetric DWR at Thumba provides three base (reflectivity, radial velocity and spectrum width) and three polarimetric (Differential reflectivity, Specific differential phase and correlation coefficient) products.

Measurements of these parameters are employed to characterise the rain cells in MCS. These observations are already used to investigate some of the extreme weather events such as cyclones, extreme precipitation and orography induced organized precipitation. C-band DWR observations, which are available since 2015 over Thumba, will be employed to train the algorithm to identify and characterise

the rain cell using AI and DL techniques. Further, the developed algorithm can be generalized for other DWR operating in India.

Linkages to Space Programme:

The genesis, evolution and dissipation of MCS using ground and space based observations is one of the themes actively pursued by Atmospheric Dynamics Branch of Space Physics Laboratory. The proposed research is envisaged to culminate into now-casting tool for predicting rainfall in short-time scales.

Expected Deliverables:

AI and DL based algorithm for analyzing C-DWR observations over Thumba Characterization of rain cells embedded in the MCS in terms of vertical and horizontal extents and their life-time

RES-VSSC-2023-037

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Identification of significant early signals in data in the area of Sun, solar wind, and terrestrial magnetosphere ionosphere using AI techniques for space weather prediction

Name of Co PI from ISRO Centre/Unit

Dr. Tarun Kumar Pant

Contact Address of Co PI and e-mail id

tarun_kumar@vssc.gov.in

Area of Research

Space Physics, space weather

Summary of the proposed research and expected deliverables

The ionosphere thermosphere and magnetosphere is a complex and dynamic region of the Earth's upper atmosphere. Studying this vast region in a comprehensive way requires processing and interpreting large amounts of solar terrestrial data from experiments on ground, rockets and space.

Data from these various sources and simulations, can be integrated using AI. The proposed research aims at creating comprehensive models of the ionosphere, thermosphere and magnetosphere by combining data from multiple perspectives. Suitable AI tools will be identified and used for processing, analyzing, and interpreting large databases concerning Sun, Earth's or planetary ionospheres, especially those concerning specific space weather events.

The AI will be employed to understand relationships in the data. These relationships will eventually be used to model and predict the occurrence of active space weather conditions and response of magnetosphere ionosphere thermosphere.

Scope of the Work:

The proposed research involving AI encompasses data processing and cleansing, anomaly detection, data fusion, feature extraction, data visualization, and automated analysis.

Linkages to Space Programme:

The proposed research has strong linkages with ISRO's program for Space Weather investigations and forthcoming missions such as ADITYA-L1 and DISHA. In these missions, lot of relevant solar terrestrial data will be generated that will potentially be used in the present research.

Expected Deliverables:

- Specific AI code generation for identification of early signatures of impending solar events.
- Prediction and validation of this for actual geomagnetic storms.

RES-VSSC-2023-038

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Automated Defect Recognition in radiography of Solid rocket Motors and composite Hardware

Name of Co PI from ISRO Centre/Unit

Dr. Girish N Namboodiri

Contact Address of Co PI and e-mail id

girish_nn@vssc.gov.in

Area of Research

Radiography of solid rocket motors and composite hardware

Summary of the proposed research and expected deliverables

X-ray radiography is carried out to detect the defects in solid rocket motors and composite hardware used in space application using 450kV X-ray machines and Linear Accelerators (6MeV/ 9MeV range). Conventional film radiography is being used in most cases and digitization of such films is carried out to get the digital version of such images. Implementation of Flat panel based Digital radiography in solid propellant radiography and composite hardware is also in progress.

Interpretation of radiographs of solid rocket motors and composites requires expertise and skill. The experience of the interpreter is a deciding factor in all the above areas. The process of interpretation takes large amount of time and effort.

Implementation of AI for detection of observation and characterization of the same using trained ML algorithms can reduce the effort and bring in uniformity in interpretation. Requirement of expert interpretation team with experience can be reduced by the implementation of AI and ML. Once the entire radiography activities becomes Digital, interpretation process can be carried out as soon as images are captured with AI and ML.

Scope of the Work:

- Development of software that can simulate radiography images based on AutoCAD drawings and density related information of the items to be tested.
- Creation of artificial defects using simulation software which are exact replicas of radiography defects.

- Creation of a defect library separately for the list of items tested using radiography.
- Development of a AI based system that can detect defects from the digitized images of films/ Digital Radiography images of various solid rocket motors and composite hardware.
- Development of ML systems that can be trained based on real defect observations and that can automatically detect and characterize the observations from digitized images of films/Digital Radiography images.
- Creation of a file for each tested item with proper detection, characterization and labeling of the defects identified by the system.

Linkages to Space Programme:

R&D applicable to all solid rocket motors and composite hardware for future launch vehicles.

Digital radiography for High Energy Radiography is planned to be implemented with 3D Computed Tomography in the Road map. Once digital Imaging is fully implemented in Low/High energy radiography, Automated Defect Recognition will be an essential feature in the future for interpretation of the Images.

Expected Deliverables:

- Software for simulating radiographs of solid rocket motors and composite hardware.
- Algorithms for detecting defects from radiographs.
- Automated defect Recognition and Characterization algorithms that can be directly implemented to the testing facility.
- Installation of the Software and associated systems in High End Workstations and supply of the same for ready implementation.
- All training algorithms, data used in the study, detailed explanation of the studies carried out for implementation in a report form.
- Any license for implementing the system at VSSC valid for lifetime with suitable up gradations.
- All necessary back up for reinstallation of the system in case of inadvertent failure to the system.

RES-VSSC-2023-039

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development of nonlinear beam finite element based on Simo's three dimensional finite strain rod model

Name of Co PI from ISRO Centre/Unit

Mr. G. Sarangapani

Contact Address of Co PI and e-mail id

g_sarangapani@vssc.gov.in

Area of Research

Non-linear finite element development

Summary of the proposed research and expected deliverables

To develop a nonlinear beam finite element based on Simo's three dimensional finite strain rod model and demonstrating the large rotation validation problems such as the simulation of snap-through behavior in hinged right-angle frame under follower load and so on.

Scope of the Work:

Detailed mathematical formulation with consistent linearization of kinematic variables and the corresponding implementation of Simo's finite strain rod model based on the reference paper (J C Simo et al., "A Three Dimensional Finite Strain Rod Model. Part II: Computational Aspects", Computer Methods in Applied Mechanics and Engineering, Vol. 58, 79-116, 1986) and demonstrating the various benchmarks problems therein.

In addition, the demonstration of 3D stress recovery from the 1D solution for various beam cross sections.

Linkages to Space Programme:

Nonlinear finite element development in FEAST software.

Expected Deliverables:

- Document containing the mathematical formulation in detail, validation studies of problems as given in Simo's finite strain rod model paper and Programmer's manual.
- A Standalone Source code in C++/Matlab with proper comments and cross-reference to the formulation document.

RES-VSSC-2023-040

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Vibro acoustic response analysis of structures (inter stages with decks mounted on isolators) due to acoustic excitation

Name of Co PI from ISRO Centre/Unit

Mr. P. Geena George

Contact Address of Co PI and e-mail id

geena_george@vssc.gov.in

Area of Research

Vibroacoustic response analysis

Summary of the proposed research and expected deliverables

The current proposal is aimed to get the code for doing the Vibro-acoustic response analysis due to acoustic excitation.

Structures considered will be typical inter stages with decks mounted on isolators.

Code to carry out the analysis is expected to be delivered as part of the project. Code may be validated with the existing experimental results or new experiments may be carried out to validate the results.

Scope of the Work:

- Development of the software and code.
- Demonstration of the code for a typical interstage structure.
- Validation with experimental data.

Linkages to Space Programme:

The proposed deliverables of this proposal have got applications in all the launch vehicles.

Expected Deliverables:

- Software and code for vibroacoustic response analysis due to acoustic excitation
- Documents giving details of formulation, sample problem solved and validation

RES-VSSC-2023-041

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development of design/analysis criterion for aerospace structures subjected to shock loads of varying intensities and duration

Name of Co PI from ISRO Centre/Unit

Mr. Deepak B.P.

Contact Address of Co PI and e-mail id

bp_deepak@vssc.gov.in

Area of Research

Aerospace structures

Summary of the proposed research and expected deliverables

In aerospace structural engineering, the structures need to be designed to withstand impact / shock loads.

Sometimes the health of the designed hardware needs to be assessed by finite element analysis for specific transient dynamic / shock loads, before the clearance of hardware for launch. Tests on AA 2014 alloy plates has shown plastic yielding in metallic plates for shocks beyond certain levels.

Hence a clear understanding on the dynamic stress / strain response of structures for varying time duration of shocks and intensities and its relation with the structural health is required for optimum structural design and crucial decision making.

Scope of the Work:

The objectives of the study is to develop a methodology for design of aerospace structures subjected to varying shock loads and to develop an analysis methodology for health assessment of structures subjected to shock loads of varying peaks and time duration.

Linkages to Space Programme:

The output of research can be used in all advanced aerospace structural designs subjected to impact loads.

Expected Deliverables:

- Development of analysis methodology for structures subjected to impact / shock loads and prediction of structural health.
- Validation of analysis methodology with test results on specimens.
- Development of nomograms of stress / strain response for various impact loads acting on different materials.

RES-VSSC-2023-042

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Through thickness measurement of non- uniform residual stresses in metallic components with sufficient resolution for aerospace applications

Name of Co PI from ISRO Centre/Unit

Mr. S. Karthigai Selvan

Contact Address of Co PI and e-mail id

email: karthigai_selvan@vssc.gov.in

Area of Research

Residual stress measurement

Summary of the proposed research and expected deliverables

The current technique of incremental hole drilling technique measures the residual stress to a depth of 2mm only. The proposal envisaged is the implementation of an accurate method for measuring residual stress through thickness for metallic materials for thickness more than 5 mm with a resolution better than 10-20 MPa. Use of a combination of different techniques also can be pursued.

Scope of the Work:

The proposal must aim to develop a novel method of measuring through thickness residual stress in metals. The method can be a hybrid one combining experimental and numerical methods. A computer code/program should be developed implementing the methodology and algorithms for automated residual stress measurement. The procedure for measuring residual stress should be properly documented and validated following ASTM or other standards. The procedure also should be demonstrated for measuring residual stress on welds, forgings or castings, whichever the case may be.

Linkages to Space Programme:

The proposed deliverables of this proposal have got applications in all the launch vehicles.

Expected Deliverables:

- Document containing the method of measuring residual stresses.
- Algorithm for residual stress calculation.
- Codes implementing the algorithms.
- Experimental data validating the measurements.

RES-VSSC-2023-043

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

An assessment of knock down factors for cylindrical shells used in launch vehicles based on energy barrier approach

Name of Co PI from ISRO Centre/Unit

Mr. Shijo Xavier

Contact Address of Co PI and e-mail id

shijo_xavier@vssc.gov.in

Area of Research

Structures

Summary of the proposed research and expected deliverables

The current design of launch vehicle structure which are compressively loaded is based on the knock down factors and subsequent qualification tests. However, due to the improvement of computation methods, better estimates of collapse load are now possible and the knock down factors applied on theoretical computations are believed to be conservative. Some estimates show that the current design under-predict the buckling load carrying capacity by about 20%. The lack of reliability (lack of repeatability and the non-availability of a non- destructive testing technique) of cylindrical shell buckling experiments is a major contributing factor for this under estimation. The need for high-fidelity estimates of the buckling loads of shell structures is of critical importance for reliance or to increase payload capability.

Methods based on energy barrier can be used as a non-destructive and non-invasive technique for determining the shock sensitivity and stability of thin-walled structures.

Energy barrier method for shell buckling problems is a new approach for estimating the stability characteristics of cylindrical shells. This method has promising applications in the space industry for predicting the buckling load carrying capacity and the robustness of a cylindrical shell subjected to external undulations.

Information about a structure's stiffness and robustness against buckling in terms of energy and other force parameters can be arrived using this technique. In simple terms, the energy barrier is the energy

that needs to be supplied to drive the shell over buckling. And the determination of this energy barrier in a way helps us to find the buckling load carrying capacity and the shock sensitivity of the structure. The energy barrier of a structure can be determined from simple experiments and numerical procedures by introducing transverse perturbation to cylindrical shell preloaded by axially compressive force.

The research shall include formulation, Finite element analysis and experimental evaluation of the approach to determine knock down factors.

Scope of the Work:

The proposed research can be used to provide better estimates of knock-down factors for buckling of cylindrical shells used in launch vehicles and can result in more optimized structural solutions.

Linkages to Space Programme:

The output of research can be used in all structural designs in launch vehicle systems subjected under compressive loads.

Expected Deliverables:

- Methodology to determine energy barrier for thin shells.
- Formulation of the problem and Finite element models developed for the purpose.
- Knock down factors for thin cylindrical shells subjected to compressive loads.
- Details of the test setup used to validate the approach and knock down factors.

RES-VSSC-2023-044

Name of ISRO Centre/Unit

Vikram Sarabhai Space Centre, Thiruvananthapuram

Title of the research proposal

Development of nonlinear version of three dimensional enhanced strain solid element based on mixed variational principles and in particular Simo and Armero's work

Name of Co PI from ISRO Centre/Unit

Mr. G. Sarangapani

Contact Address of Co PI and e-mail id

g_sarangapani@vssc.gov.in

Area of Research

Non-linear finite element development

Summary of the proposed research and expected deliverables

A nonlinear solid finite element which is based on pure displacement based formulation is more prone for shear and volumetric locking phenomenon in the nonlinear context. The volumetric locking poses difficulty in simulating the incompressible materials such as rubber and elasto-plasticity behavior.

The shear locking poses difficulty in simulating the bending behavior. Both of these locking issues in the nonlinear context are handled in particular by the nonlinear version of enhanced strain element formulation which is based on the work of Simo and Armero.

Hence, it is proposed to develop this nonlinear version of three dimensional enhanced strain solid element based on mixed variational principles and demonstrating the validation problems such as Cook's membrane problem and so on. This classical enhanced strain formulation has inherent hour-glass instability for certain loading conditions and hence handling such instability with Wriggers and Reese work is also required.

Scope of the Work:

Detailed mathematical formulation with consistent linearization and the corresponding implementation of Simo and Armero's work based on the reference paper (Simo J.C. and Armero F., "Geometrically non-linear enhanced strain mixed methods and the method of incompatible modes", International Journal for Numerical Methods in Engineering, 33:1413–1449 (1992)) and demonstrating the various benchmarks problems therein. This classical enhanced strain formulation has inherent hour-glass instability for certain loading conditions and hence handling such instability with Wriggers and Reese work is also required (Ref: Wriggers P. and Reese S., A note on enhanced strain methods for large deformations.

Computer Methods in Applied Mechanics and Engineering, 135:201–209 (1996)).

Linkages to Space Programme:

Nonlinear finite element development in FEAST software.

Expected Deliverables:

- Document containing the mathematical formulation in detail, validation studies of problems as given in Simo and Armero's paper and Programmer's manual.
- A Standalone Source code in C++/Matlab with proper comments and cross-reference to the formulation document.

SPACE APPLICATIONS CENTRE
AHMEDABAD

RES-SAC-2023-001

Name of ISRO Centre/Unit
Space Applications Centre, Ahmedabad

Title of the research proposal
Low frequency ultra wideband antennas for through wall imaging and Ground Penetrating Radar applications

Name of Co PI from ISRO Centre/Unit
Mr. Gaurav Kumar
Mr. Arun Kumar Sharma

Contact Address of Co PI and e-mail id
gaurav.kr2802@sac.isro.gov.in
arunsharma@sac.isro.gov.in

Area of Research
Antenna and Microwaves

Summary of the proposed research and expected deliverables
Proposed research work will be focused on the development of low frequency ultrawideband antenna.

Design of low frequency ultrawide band antenna is a bit tricky due to large variation in antenna impedance at lower frequency. Thus a matching network is required. It mainly involves the selection of antenna element followed by a low loss matching network. Desired frequency range is 1-30MHz. Although the required band can be divided in to 2-3 sub-bands, but antenna has to be common. (i.e multiple matching networks can be realized to cater the whole band). As wavelength is very large at these frequency, size reduction and deployment has to be considered. It should have boresight pattern with typical gain in the order of 2dBi or more. Antenna must have return loss better than 12dB throughout the band/sub-bands.

Antenna mass to be less than 5-6 kg.

Scope of the Work:

- Survey of low frequency ultra-wide band antennas.
- Design and development of selected antenna.
- Design and development of corresponding matching network.
- Analysis and characterization of integrated antenna.

Linkages to Space Programme:

The project has linkages with Future space/rover based GPR missions and Antarctica expeditions.

Expected Deliverables:

- Design methodology of matching networks.
- Developed antenna and its matching network/s.

RES-SAC-2023-002

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Low Frequency Compact Ultra-wideband Planar Artificial Magnetic Conductor (AMC)

Name of Co PI from ISRO Centre/Unit

Mr. Pratik Mevada

Mr. Gaurav Kumar

Contact Address of Co PI and e-mail id

pratik@sac.isro.gov.in

gaurav.kr2802@sac.isro.gov.in

Area of Research

Performance improvement of UWB antennas, being designed for future GPR system based payloads

Summary of the proposed research and expected deliverables

Artificial magnetic conductors (AMC) are the periodic structures, which offers the 00 reflection phase and can be utilized for size reduction of the antennas, by replacing the metallic back reflectors by AMC. The antennas like Bow-tie, dipole, spiral etc. has bi- directional radiation pattern, which usually is required to be converted into uni-directional pattern by placing such AMC on the back side. Usually, the AMC property of the periodic structure can be synthesized over the narrow bandwidth. But, the antennas used for GPR systems are compact in size and require ultrawide bandwidth and hence, compact planar AMC with ultrawide band performance.

Scope of the Work:

The periodic structures designed to offer AMC property do not have ultrawide band performance. Therefore, the design of compact ultrawide band AMC surface is challenging and requires the significant amount of research work, including analytical modeling, design and its optimization. The proposed AMC surface should offer ≤(±100) reflection phase for more than 100%(preferably>120%) bandwidth at 1.25GHz center frequency. The scope of this research work also includes the fabrication and characterization of the AMC surface.

Linkages to Space Programme:

The project has linkages with Future GPR system based payloads.

Expected Deliverables:

- Design files of compact UWB AMC.
- Fabricated AMC surface.
- Characterization results of developed AMC.

RES-SAC-2023-003

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Design and development of compact polarization / phase modulator for Quantum technologies

Name of Co PI from ISRO Centre/Unit

Mr. Praveen Kumar

Mr. Jay Bhatt

Contact Address of Co PI and e-mail id

praveenk@sac.isro.gov.in

jay@sac.isro.gov.in

Area of Research

Quantum Communication, Photonics, electronics design for laser based systems

Summary of the proposed research and expected deliverables

Quantum Key distribution (QKD) is an emerging area in the field of communication which involves implementation of cryptographic protocols to generate a shared random secret key between two parties. These protocols often need different polarization / phase states as fundamental signals for key generation.

A compact polarization / phase modulator will be generating different linear / circular polarization states to be used for generation of secret key using any QKD protocol. This device will be receiving pulsed optical input from a PM fiber terminated laser diode and will be generating controlled polarized states through SM fiber. Control of polarization states will be through electric bias control, developed design should incorporate this characteristic. The device should generate different polarization states with pulse repetition rate of up to 1 GHz pulse rate. Operating Wavelength for the device will be 800 nm and/or 1550 nm band.

Scope of the Work:

- Indigenous design and development of polarization / phase modulator.
- Test and Characterization of polarization /phase modulator, generating different polarization states using electrical input signal up to 1 GHz for 800 and/or 1550 nm waveband.

Linkages to Space Programme:

The project will lead to the development of polarization / phase modulator which is instrumental in the design of transmitter unit for quantum communication.

Expected Deliverables:

Design details, developed polarization/phase modulator hardware for 785 nm and/or 1550 nm.

RES-SAC-2023-004

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Development of simulation and system engineering tool kit for Quantum Key Distribution (QKD) protocols for fiber based systems

Name of Co PI from ISRO Centre/Unit

Mr. Abhishek Khanna

Mr. Adarsh Jain

Contact Address of Co PI and e-mail id

akn@sac.isro.gov.in

adarshjain@sac.isro.gov.in

Area of Research

Quantum Mechanics, Quantum Communication

Summary of the proposed research and expected deliverables

A suitable software tool kit is required for extensive simulation and performance analysis of various QKD protocols. It should also include a toolkit for end-to-end modelling, simulation and analysis of various fiber based QKD architecture to aid in system engineering. The software toolkit should support detailed modelling architecture for analysis of a full system (including link budget analysis, QBER, secure key rate etc.) for fiber based prepare and measure as well as entanglement based QKD protocols like Decoy state BB84, BBM92, E91, DPS, COW, CV-QKD etc. considering non- ideal/practical systems and limitations.

Based on detailed simulation & system engineering of various QKD protocols offered by this toolkit, suitable protocol can be selected as per given application scenario to achieve maximum secure key rate generation while maintaining lowest QBER considering non-ideal components/sub-systems without actual experimental implementation.

Scope of the Work:

- Development of a user-friendly GUI based software toolkit to enable perform end-to-end study, modeling and simulation various QKD protocols with realistic/non-ideal subsystems for fiber based networks.
- The software should help estimate various system parameters to achieve desired performance specifications like secure key rate, QBER etc. at various distance for any given QKD protocol.
- The software should have provision of including random birefringence induced by single mode fibers as well as its compensation, an important aspect in realizing polarization state based QKD protocols.

Linkages to Space Programme:

The developed software toolkit will be extensively used in carrying out study, simulation and analysis of fiber based QKD protocols and associated systems.

Expected Deliverables:

- Comprehensive software toolkit with user friendly GUI for analyzing various QKD protocols with detailed block diagrams.
- Provision to include non-ideal behaviors of system components to get accurate estimation of over-all system performance prior to practical/experimental implementation.

RES-SAC-2023-005

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Development of Compressive Sensing Techniques for SAR Image Reconstruction

Name of Co PI from ISRO Centre/Unit

Mr. Partha Sarathi Nandy

Contact Address of Co PI and e-mail id

partha@sac.isro.gov.in

Area of Research

Radar Signal Processing

Summary of the proposed research and expected deliverables

Synthetic aperture radar (SAR) is an important remote sensing technique due to its distinctive advantages of imaging ability in almost any weather, day or night.

Acquisition of space-borne high-resolution wide swath SAR imagery restricted by the classical coverage limitations imposed in range or azimuth direction. To meet future requirements for high spatial along with wide swath, conventional SAR techniques have to be improvised. Presently, many different SAR configurations like Digital Beamforming (DBF) SAR, SweepSAR, DPCA SAR, MIMO SAR etc. are considered to meet these requirements. But practical limitations like Payload DC Power, data rate requirement etc. limits applicability of the same in many situations.

Parallely, several studies have been carried out regarding Compressive Sensing (CS) technique for sparse signals. It is seen that sparse targets can be reconstructed using CS technique even if imaging is done at Sub-Nyquist rate and also using part of receive signal bandwidth. This will help both in reducing data rate and also allowing coverage of wider swath as PRF is reduced than Nyquist requirement. Also, CS can be applied in case of SAR imaging from small platform, where it is not possible to acquire azimuth samples at uniform spatial interval due to speed variation.

So, the present research topic should envisage applicability and prerequisite of Compressive Sensing methods for proper reconstruction of SAR image for different wave bands, resolution and targets. Research should conclude demonstrating the effectiveness of Compressive Sensing techniques for sub-Nyquist mode SAR imaging in SAR image reconstruction for different type of targets using SAR raw data and also by bringing out limitations/drawbacks if any.

Scope of the Work:

This technique can be applied for many applications where wide swath high resolution imaging is required.

Linkages to Space Programme:

The project has linkages with Future Space-borne/Airborne Radar Sensors.

Expected Deliverables:

Software/Algorithm, simulation results and project report.

RES-SAC-2023-006

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Development of M-type Dispenser Cathodes

Name of Co PI from ISRO Centre/Unit

Mr. Ramagiri Santhosh Kumar
Ms. Shilpi Soni

Contact Address of Co PI and e-mail id

santhoshr@sac.isro.gov.in
shilpi@sac.isro.gov.in

Area of Research

Thermionic Cathodes

Summary of the proposed research and expected deliverables

The M-type Dispenser Cathode is used in Vacuum electron devices as a source of an electron beam. It emits an electron beam by thermionic emission. A heater is placed behind the emitting surface for heating the surface. The proposed research is towards indigenization of development of cathodes.

Scope of the Work:

To develop M-type Dispenser cathodes with an emission Density of 2 A/Cm^2, operating at a temperature of 950 ±20°C (operated in space charge limited region) and with expected life of 2.0 lakh hours of continuous operation.

Linkages to Space Programme:

The project has linkages with Indigenous TWTs for future Ku and Ka payloads.

Expected Deliverables:

- 5 prototypes of Cathodes.
- Report on weight gain of Tungsten pallet.
- Inspection report of cathode surface.
- Inspection report of temperature uniformity on cathode surface.
- Life estimation report.

RES-SAC-2023-007

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Quantum memory development

Name of Co PI from ISRO Centre/Unit

Mr. Shashank Kumar
Mr. Pankaj Kumar Gupta

Contact Address of Co PI and e-mail id

shashank20@sac.isro.gov.in
pankaj@sac.isro.gov.in

Area of Research

Quantum Information, Quantum network, Quantum Key distribution

Summary of the proposed research and expected deliverables

To overcome the exponential attenuation of quantum signal over a larger distance, quantum repeaters had been proposed. For successful implementation of quantum repeater as a system there is requirement of storing of quantum states. Quantum memories are used to store these quantum states. The quantum memories also have usefulness in quantum computers/ quantum internet. This development aims towards literature survey of working of quantum repeaters and further quantum memory. Study of current topologies with state-of-the-art along with development of proof-of-concept model of a quantum memory at lab level. The overall development of fully functional quantum memory will further lead to development of future quantum repeaters which will lead to quantum communication over larger distances paving the way toward quantum internet.

Scope of the Work:

- The study will be focused on study of quantum memory and quantum repeaters. Feasibility of quantum repeaters to be studied in a QKD network.
- Design and development of quantum memory in Lab environment. Study of further upscaling to ambient environment.

Linkages to Space Programme:

The project has linkages with Quantum Network development, Satellite based quantum communication, Quantum Radar development.

Expected Deliverables:

Development of quantum memory technology in Lab environment for use in Quantum Radar and Quantum Key distribution.

RES-SAC-2023-008

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Extraction of Pure Rubidium from Rubidium Chloride

Name of Co PI from ISRO Centre/Unit

Shri Deepak Attri
Dr. Richa Sharma Kesarkar

Contact Address of Co PI and e-mail id

deepakattri@sac.isro.gov.in
richasharma@sac.isro.gov.in

Area of Research

Metallurgy/Chemistry

Summary of the proposed research and expected deliverables

Pure Rubidium (Rb) bulbs are used in various spectroscopic experiments and techniques. Extracting and storing metallic Rb is a challenge, since Rb is a highly reactive alkali metal. It is therefore generally available as Rubidium chloride (RbCl), which is more stable. To extract pure Rubidium (>98% pure) from its chloride, and also to separate it into its respective isotopes, (Rb85 and Rb87), a researcher needs to look for efficient methods.

Scope of the Work:

The following experimental tasks can be initiated in two separate stages:

Stage 1: Development and demonstration of an experimental procedure for the extraction of pure (> 98%) natural-mix of Rubidium from its chloride and its eventual storage inside alkali resistant glass ampoules with capacity 15 ± 5 mg.

Stage 2: Development and demonstration of an experimental procedure to obtain isotopically pure (>98%) Rb85 and Rb87 and their subsequent storage inside separate ampoules, each with capacity 15 ± 5 mg.

Linkages to Space Programme:

Indigenous Rubidium Atomic Frequency Standard (iRAFS).

Expected Deliverables:

- Development and demonstration of the experimental setups mentioned in Stage 1 and 2.
- Separate ampoules containing natural-mix Rb, Rb85 and Rb87, each with purity >98%.
- ISRO access to the developed facility in Future.

RES-SAC-2023-009

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Tilted Wave Interferometer for testing of aspheric and freeform surfaces

Name of Co PI from ISRO Centre/Unit

Mr. Kumar Rishav

Contact Address of Co PI and e-mail id

rishav@sac.isro.gov.in

Area of Research

Design and Development of Optical Systems (Electro-Optical Sensor Technology)

Summary of the proposed research and expected deliverables

The use of aspheric and freeform surfaces becomes more and more important in the design of modern optical systems. These surfaces offer additional degrees of freedom to the optical design, allowing to improve the optical imaging as well as to reduce the number of surfaces needed for an optical design. However, testing of such surfaces is still a difficult task. This issue can be addressed using the technique of Tilted Wave interferometer. TWI is non-null, full-field interferometric measuring technique for aspheric and free-form surfaces with a new degree of flexibility. The interferometer uses a set of tilted wavefronts to locally compensate the deviation of the surface under test from its spherical form. Also since its non-null technique, hence the costly optics is not required for testing. The main difference of this approach to the scanning type interferometers is that the acquisition of the data is highly parallelized, since all test wavefronts are applied to the surface in only four steps. Further, the surface under test (SUT) does not have to be moved during the measurement process. Both these advantages lead to a very short measurement time of far under a minute.

Scope of the Work:

To design and develop the software and hardware for interferometer using the technique of Tilted wave interferometry.

Linkages to Space Programme:

Testing of aspheric and freeform surfaces of optical components used in imaging systems and telescopes.

Expected Deliverables:

Software and hardware of the interferometer based on TWI.

RES-SAC-2023-010

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Design and Development of Non Binary LDPC codes for Navigation systems

Name of Co PI from ISRO Centre/Unit

Dr. Deepak Mishra

Contact Address of Co PI and e-mail id

deepakmishra@sac.isro.gov.in

Area of Research

Channel coding for Navigation systems

Summary of the proposed research and expected deliverables

The NB-LDPC codes have proven their superiority in term of performance compared to their binary counterparts under certain transmission channel conditions and system applications. This was confirmed by a state-of-the-art review of the literature. NB-codes offer good error decoding performance when compared to binary LDPC codes. The major advantages are NB-LDPC codes over binary LDPC codes are:

- Better resistance to errors.
- Good parity-check matrix structure.
- Good performance with high spectral efficiency transmission.
- Better performance under AWGN channel.

Recently Beidou has introduced NB-LDPC codes in their B-1C band. So the development of NB-LDPC codes is very useful for future new navigation signals for NavIC.

Scope of the Work:

- Arriving at suitable optimum matrix of NB-LDPC codes for navigation signals.
- Developing an efficient decoding algorithm to improve the coding gain.
- End to end simulation and hardware implementation of selected NB-LDPC codes.

Linkages to Space Programme:

All new navigation signals of NavIC will require this type of channel codec for better performance and better link margin. This development will be very useful as not much work is done in this type of channel codec.

Expected Deliverables:

Optimum NB-BINARY LDPC matrix design with hardware implementation of encoder and decoder.

RES-SAC-2023-011

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Design of acquisition and tracking algorithm and architecture development for Frequency Hopped BOC GNSS Signals

Name of Co PI from ISRO Centre/Unit

Mr. Rohan S. Urdhwareshe
Mr. Rakesh Kr. Bijarniya

Contact Address of Co PI and e-mail id

rohansu@sac.isro.gov.in
rakeshkb@sac.isro.gov.in

Area of Research

NavIC/GNSS

Summary of the proposed research and expected deliverables

In recent advances in the modulation schemes for advanced GNSS signals, frequency separation using binary offset carrier scheme is widely being used. However, it incurs ambiguity in correlation function. Further, frequency hopping signals provide improved anti-jamming capability and tracking jitters. In this regard, a signal structure based on frequency hopping scheme suitable for GNSS signals may be designed and optimized. One example is Frequency Hopped Binary Offset Carrier. In addition to this, the constant envelope constraint at the output may be considered. With this kinds of signal structures, the development of efficient acquisition and tracking architecture are of very importance in terms of performance and resource constraints. The development activity for efficient algorithms and architectures for acquisition and tracking of FH-BOC signals may be carried out and its performance evaluation may be presented.

Scope of the Work:

- Exploration of GNSS Baseband Signal Processing and modulation signal structures based on Frequency-hopping.
- Signal design parameter analysis in frequency-hopping.
- MATLAB and C based development of acquisition and tracking algorithms for frequency hopped BOC signals.

Linkages to Space Programme:

NavIC is a regional navigation satellite system developed by ISRO. The new signal structures are under study for futuristic NavIC satellite signals. This work will be useful for studying and exploring FHBOC modulation.

Expected Deliverables:

- Theoretical and analytical description for Frequency.

- Hopping GNSS signals.
- Acquisition and tracking algorithms and their analysis.
- MATLAB and C codes for the algorithms.

RES-SAC-2023-012

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Development of Non-cyanide Autocatalytic Silver Plating Chemistry

Name of Co PI from ISRO Centre/Unit

Mr. Sharad Shukla

Contact Address of Co PI and e-mail id

sharadshukla@sac.isro.gov.in

Area of Research

Surface Treatment

Summary of the proposed research and expected deliverables

In the development of Radio Frequency (RF) related packages required for satellites, Silver plated components plays the pivotal role for transporting RF through wave guide. Miniaturization of mechanical assemblies and usage of higher frequency bands like K-band & Ka-band, dimensions of wave guides have been decreased greatly in length and cross section as well. Additionally, they are being used with twists and turns in various planes, making it extremely difficult for plating Silver on the inner wall of waveguide using the conventional electrolytic, cyanide based silver plating methodology. Though, this has been overcome by developing cyanide based autocatalytic Silver plating chemistry and qualified for satellite components. However, this process is highly hazardous. Thus, developmental efforts are invited to bring out non- cyanide based, autocatalytic Silver plating chemistry for Aluminium alloy 6061 T6 to obtain uniform Silver thickness of ≥ 2 micron inside complex multi-planar wave guides.

Scope of the Work:

- Development of non-cyanide based chemistry for autocatalytic Silver plating on Aluminium alloy 6061 T6 with.
- The process must provide uniform Silver deposition of ≥ 2 micron within a reasonable plating duration of less than 2 hours.
- The chemistry must be stable over a good range of temperature, pH and time.

Linkages to Space Programme:

The proposal has linkages with RF waveguides for miniaturized and advanced payloads.

Expected Deliverables:

Chemistry and the technology for uniform deposition of Silver as per requirement mention and its demonstration.

RES-SAC-2023-013

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Development of Superconductor-Insulator-Superconductor (SIS) thin film stack for THz application

Name of Co PI from ISRO Centre/Unit

Mr. PNV Anil Kumar

Mr. Ishan Chaturvedi

Contact Address of Co PI and e-mail id

anilpeddiraju@sac.isro.gov.in

ishan@sac.isro.gov.in

Area of Research

Electronic Systems

Summary of the proposed research and expected deliverables

Superconductor-Insulator-Superconductor (SIS) is the technology of choice for realizing mixers for heterodyne reception of THz signals. SIS Mixer based receivers, operating at cryogenic temperatures, can achieve state-of-art noise performance, of the order of 2-5 times of the quantum limit at mm-wave and sub-mm wave frequencies. SIS device is composed of a thin film of Insulator sandwiched between two thin film Superconducting layers like NbNx -AlNx- NbNx on Si-SiO2. Optimized thickness and properties of the above stack is required for obtaining the required DC nonlinear Current(I)- Voltage(V) characteristics for THz sensing applications. Proposals are invited for growth and characterization of SIS thin film stack through development of associated ultra-high vacuum processes, suitable for THz sensing applications.

Scope of the Work:

- Development of ultra-high vacuum processes for development of SIS thin films suitable for THz applications.
- Characterizing of above thin films using a range of experimental techniques, like XRD, XRR, SEM, TEM, etc. to know the phase, crystallinity, chemical composition, constitution, layer thicknesses, uniformity, etc.
- Cryogenic temperature characterization of Superconductor thin films.
- Fabrication of SIS stack deposited wafers.

Linkages to Space Programme:

The proposal has linkages to the THz Telescope Programme.

Expected Deliverables:

- Developed Process recipes.
- SIS stack deposited wafers – 5 nos.

RES-SAC-2023-014

Name of ISRO Centre/Unit
Space Applications Centre, Ahmedabad

Title of the research proposal
Development of measurement technique for rubidium atoms in Rb-bulb and Rb-cells

Name of Co PI from ISRO Centre/Unit
Mr. Naveen Kumar Mishra

Contact Address of Co PI and e-mail id
nkm@sac.isro.gov.in

Area of Research
Accurate Measurement technique and set-up for material inside a bulb

Summary of the proposed research and expected deliverables
Rb-bulbs and cells are used in rubidium atom frequency standards (RAFS). Amount of rubidium in the bulb is an important parameter for a stable RAFS and it has to be monitored during different phases of screening and qualification of the Rb-bulbs and cells. Highly accurate and precise quantification of amount of Rb within the bulb are required for selecting a reliable Rb-bulb.

Scope of the Work:

To develop a technique for accurate and precise measurement of Rubidium in Rb-bulbs and cells.

Linkages to Space Programme:

The proposal has linkage to RAFS for Navigation Payloads.

Expected Deliverables:

- Documents on literature review, details of the technique and simulation results.
- Developed hardware and software.

RES-SAC-2023-015

Name of ISRO Centre/Unit
Space Applications Centre, Ahmedabad

Title of the research proposal
Design and development of AI/ ML enabled algorithm for a static code analysis tool and its implementation as a software product

Name of Co PI from ISRO Centre/Unit
Mr. Akhilesh Sharma
Mr. Jagadamba Prasad Singh

Contact Address of Co PI and e-mail id

akhilesh@sac.isro.gov.in
jpsingh@sac.isro.gov.in

Area of Research

Software Quality Assurance

Summary of the proposed research and expected deliverables

Static code analysis is an activity to analyze source code in order to detect defects, vulnerabilities, non-conformances with standards and other shortcomings of source code without executing computer program/ package/ software. The proposed tool should have capability to perform static code analysis of a software program consisting one or more programming languages. The support for C, C++, python and Java programming languages is mandatory. The tool should be configurable and extensible.

The algorithm of tool, while analyzing source code should find defect, inter alia, based on coding conventions/ standards/ rules, software quality attributes, software performance, security, comment density etc. The algorithm of tool should have AI/ ML enabled self-learning capabilities. The algorithm of tool should categorize issues/ defects reported into various categories along with severity score. The algorithm should support addition of new programming language(s) in future. The tool should be evolvable and open for future development by ISRO team/ ISRO authorized team to add new programming language(s)/ new feature(s).

The tool should have a user-friendly user interface with capability to perform activities of software quality assurance (SQA) and software development team members. The tool should be deployable in server client mode with support for multiple users with multiple active analysis sessions. The developed tool should support standard features such as user management, role-based dashboard, reporting module, SQA module, software developer module etc. The tool should be integrated with a suitable open source-based database. The tool should have capability to provide its analysis report in user friendly manner, preferably over web.

The tool should have a search and comparison module to search source code/ defects detected etc. from previous analysis scans. The tool should support version control of previous scans of same source code. The tool should provide detailed explanation of each defect detected and provide its recommendations for solutions.

Scope of the Work:

- Design and development of AI/ ML enabled algorithm for a static code analysis tool and its implementation as a software product.
- The developed tool should provide detailed explanation of each defect detected and provide its recommendations for solutions.
- The support for C, C++, python and Java programming languages is mandatory.

Linkages to Space Programme:

Static code analysis is an essential activity in order to certify a software for operational usage. The proposed research will cater to the need of software quality assurance activities for various software products such as DPGS/ DQE of various satellite projects, web applications, scientific applications and other software applications.

Expected Deliverables:

- Algorithm and source code of developed tool, supporting libraries/ tools/ APIs developed or used, all project documents and artifacts including SRS, SDD, test plan document, test cases, test results, simulated/ actual data for testing user/ operational manual,
- installation guide etc. Installation and demonstration at Space Applications Centre Ahmedabad.

RES-SAC-2023-016

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Development of Techniques for Scalloping and Banding removal in Scan-SAR

Name of Co PI from ISRO Centre/Unit

Dr. Bhaskar Dubey

Contact Address of Co PI and e-mail id

bhaskard@sac.isro.gov.in

Area of Research

Image Processing - SAR Image Restoration

Summary of the proposed research and expected deliverables

Scan-SAR have the advantages of enhanced swath and high revisit frequencies of a given area, however Scan-SAR images are corrupted with noisy artifacts arising in the form of Scalloping and Banding. The aim of this research work is to develop efficient and effective post-processing technique for removal of scalloping and banding arising in Scan-SAR imagery.

Scalloping is the inherent phenomenon in Scan-SAR due to discontinuous sampling of Doppler histories. The scalloping patterns hamper a correct interpretation of signatures of wind streaks, waves, and other phenomena. Scalloping is often modelled as along track wavelike periodic modulation of intensity. Similarly banding is a phenomenon observed in Scan-SAR images arising mainly due to the radiometric imbalance across various beams and their noise/gain characteristics. Banding is manifested in the image as the periodic modulation of intensity in the across track direction, predominantly, near the beam junctions.

Several studies available in the literature suggest that the complete removal of scalloping and banding is not possible through post- processing techniques. However, there are various approaches suggested in the literature for removal of scalloping and banding in Scan-SAR imagery, for example, identification and filtering of Scalloping harmonics in frequency domain, Kalman filter based algorithms and Wavelet MRA based approaches. While it is important to remove the scalloping and banding visually from the image, it is also equally important to retain the statistical properties of image so that the geo-physical parameters, for instance, $\sigma 0$ should not change significantly.

The objective of this research to develop new techniques or suitable modifications in the existing techniques so that they can be effectively applied and significantly improve the overall quality of the Scan-SAR data-products of the Indian SAR satellite.

Scope of the Work:

The developed techniques will contribute towards further improving the quality the ISRO's SAR data products. In addition, due to the post-processing framework, the developed techniques may also be applied to any Scan-SAR data product.

Linkages to Space Programme:

EOS-04, NISAR and other ISRO's SAR Missions.

Expected Deliverables:

Algorithms, Software, Technical Report.

RES-SAC-2023-017

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Design and Development of Algorithm for illumination, scale, translation and rotation invariant image matching

Name of Co PI from ISRO Centre/Unit

Mr. K. Suresh

Mr. Amitabh

Contact Address of Co PI and e-mail id

ksuresh@sac.isro.gov.in

amitabh@sac.isro.gov.in

Area of Research

Computer Vision

Summary of the proposed research and expected deliverables

Design and Development of on-board Algorithm for illumination, scale, translation and rotation invariant image matching on space qualified FPGA platform at a minimum update rate of 1fps. It should able to provide absolute position (latitude and longitude) with an accuracy <10m.

Scope of the Work:

Development of an algorithm and implementation in space qualified FPGA hardware and testing using simulated images from interplanetary missions and images surveyed using drone platforms.

Linkages to Space Programme:

The proposal has linkages to Interplanetary, Comets and Asteroid Landing Missions.

Expected Deliverables:

FPGA hardware, on-board software, ATBD document and documents covering design and implementation details of algorithms in FPGA hardware.

RES-SAC-2023-018

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Interferogram quality improvement by developing algorithms for baseline refinement, phase noise reduction, etc

Name of Co PI from ISRO Centre/Unit

Mr. Qamer Saquib

Contact Address of Co PI and e-mail id

qmr_saquib@sac.isro.gov.in

Area of Research

SAR Interferometry

Summary of the proposed research and expected deliverables

SAR Interferometry has a wide range of areas for usage. In SAR Interferometry, two observations of the same region either in a single pass or repeat pass are required. Phase difference of the two SAR images for same feature is a combination of phase differences from sources like orbital position of two sensors, atmospheric delay, target elevation and target deformation over time. For analysis related to target elevation and deformation, phase difference induced due to different orbital positions must be cancelled.

Thus, it becomes utmost important to have precise knowledge of orbital positions of sensors. Imprecise knowledge of sensor positions results in inaccurate baseline (distance between two sensor positions) which is used for compensating phase difference due to different orbital positions.

Also, depending upon the duration between two passes, decorrelation between target occurs. Larger the time duration between the two observations, more is the phase noise and hence it directly affects the quality of unwrapped phase.

Developed techniques will help in improving the Interferogram quality & there by improving accuracies in various interferometric applications.

Scope of the Work:

Proposed research work has following areas for work:

- Interferogram generation.
- Development of baseline improvement algorithm and implementation.
- Exploring and defining the existing/new quality metrics for interferogram quality assessment.
- Exploration and implementation of techniques for reducing the impact of decorrelation on phase unwrapping.
- Assessment of the techniques explored / proposed on phase unwrapped interferograms.

Defining the metrics for assessing the impact of baseline errors and decorrelation on interferogram quality.

In order to achieve the mentioned goals, interferometric datasets from various missions like RISAT-1A, TerraSAR, Sentinel-1/1A etc. can be used.

Linkages to Space Programme:

This proposal has linkages to the upcoming RISAT1A/1B/NISAR missions.

Expected Deliverables:

Algorithm, Software, Technical Report.

RES-SAC-2023-019

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Modelling for frequent and long-lead area-production forecast of major crops

Name of Co PI from ISRO Centre/Unit

Mr. Mukesh Kumar

Mr. Ayan Das

Contact Address of Co PI and e-mail id

mukesh263@sac.isro.gov.in

ayandas@sac.isro.gov.in

Area of Research

Crop production and Price Forecasting

Summary of the proposed research and expected deliverables

The multiple crop area and production forecast during the cropping season for short and long duration crop is well needed at block to state level. At present for only few crops twice and thrice crop forecast is done. This will provide enough time window to assess the procurement requirement and generation of storage facilities. This will also add to the export-import polices and input for the ago-based industries. The data from multiple satellite in optical and SAR domain open a new avenue to have multiple data over a targeted area in short span of time. The conventional and AI/ML and hybrid technique can be explored to provide frequent crop area and production forecast.

Scope of the Work:

- Food Security.
- Procurement planning at district and state level.
- Crop loss due to adverse condition.
- Mitigation plan to avoid losses.
- Minimum Support Price.

Linkages to Space Programme:

The output will directly be linked to ongoing programmes such as SUFALAM, Ministry of Agriculture & Farmers' Welfare and FASAL at MNCFC. This will also provide input for Pradhan Mantri Fasal Bima Yojana.

Expected Deliverables:

- Methodology to generate frequent forecast for crop area and production.
- Validation in multiple locations.
- Operationalization of automated methodology in MNCFC, New Delhi.

RES-SAC-2023-020

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Prediction of market arrival & price through statistical and AI/ML approaches

Name of Co PI from ISRO Centre/Unit

Mr. Ayan Das

Contact Address of Co PI and e-mail id

ayandas@sac.isro.gov.in

Area of Research

Agriculture Crop production and Price Forecasting

Summary of the proposed research and expected deliverables

Price fluctuations in agricultural commodities is an important area of study in economics and development. High prices increase the expenses of retail consumers while low prices reduce the incomes of farmer producers. In India, rainfall is a significant source of price variation since the majority of agricultural production is rainfed rather than reliant on robust irrigation systems. Several commodities for export such as cotton and oilseeds are also affected by global dynamics including speculation, when rising prices prompted cultivators to grow certain crops. Time-series modeling for price forecasting has been an active area of research.

Standard techniques include the Auto Regressive (AR) and Moving Average (MA) models, the ARIntegrated-MA (ARIMA model), and seasonal ARIMA. Crop acreage and production at district level will be derived using remote sensing data based geospatial crop growth driving variables and various ML algorithms. Mandi arrivals as well as commodity price for the selected crops will also be forecasted with the help of forecasted acreage and production estimates.

Scope of the Work:

- Price transmission and trading linkages across geographies.
- Mandi price forecasting.
- Anomaly detection & classification on retail prices.

Linkages to Space Programme:

The output will directly be linked to ongoing programmes such as SUFALAM and Ministry of Agriculture & Farmers' Welfare.

Expected Deliverables:

- Crop Price Forecasting for crops.
- Prediction of Mandi arrivals for agricultural commodities.

RES-SAC-2023-021

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Ionospheric properties of Earth with modeling and satellite observations for understanding the space weather

Name of Co PI from ISRO Centre/Unit

Dr. Imran Girach

Dr. Mehul Pandya

Contact Address of Co PI and e-mail id

imran@sac.isro.gov.in

mrpandya@sac.isro.gov.in

Area of Research

Study of Earth's atmosphere through theoretical modeling and satellite data

Summary of the proposed research and expected deliverables

Topside ionosphere (above F peak) is a dynamic and transition region between F-peak and protonosphere, whose variability is driven by influences from below atmosphere and solar forcing from above including EUV fluxes. Top-side Ionosphere has remained relatively less explored as it is not easy to probe it from ground and there is a relative scarcity of in-situ measurements. Ionospheric models, analytical/ theoretical as well as empirical, are advancing towards accurately representing the top-side ionosphere. Comprehensive understanding of this region is evolving with the use of satellite observations too.

Scope of the Work:

Ionospheric modeling using theoretical modeling and satellite observations available from various missions. Modelling related to reproduce the variations of top-side ionospheric state (Ion Density, Temperature and composition) along with in-situ observations from satellites (FORMOSAT-1, Inspiresat-1 etc).

Linkages to Space Programme:

This proposal has linkages to ISRO's Inspiresat-1 CIP mission.

Expected Deliverables:

- Understanding of Earth's ionosphere.
- Temporal global maps of Ion Density, Temperature and Ion composition (O^+, H^+, He^+).

RES-SAC-2023-022

Name of ISRO Centre/Unit
Space Applications Centre, Ahmedabad

Title of the research proposal
Sub-mm astronomy for understanding the cold components of the Universe on scales of galaxies, molecular clouds, star and planets using THz telescope

Name of Co PI from ISRO Centre/Unit
Mr. Manish Chauhan
Dr. Mehul Pandya

Contact Address of Co PI and e-mail id
manish.chauhan@sac.isro.gov.in
mrpandya@sac.isro.gov.in

Area of Research
Terahertz astronomy

Summary of the proposed research and expected deliverables
A majority of the observable universe lies in the form of cold dust and gas. Thermal emission from such cold sources peaks in the millimeter and sub-mm/THz regime. THz continuum observations are widely used in the study of the planetary surfaces and atmosphere, thermal emissions from young stars and star-forming regions and synchrotron radiation from active galactic nuclei and supernova remnants. Apart from the continuum emissions, various molecular line transitions in the sub-mm regime also provide clues to our understanding of various astrophysical phenomena. Sub-mm astronomy can answer some of the most profound questions related to cold components of the Universe on scales of galaxies, molecular clouds, star and planets.

Scope of the Work:

Studies using multi-wavelength observations from global sub-mm telescopes for developing the required techniques for scientific utilization of the Indian THz telescopic data.

Linkages to Space Programme:

This proposal has linkages to ISRO's THz telescope project.

Expected Deliverables:

Precursor studies using multi-wavelength observations from global sub-mm telescopes for developing the required techniques for proper handling and scientific utilization of Indian THz telescope data.

RES-SAC-2023-023

Name of ISRO Centre/Unit
Space Applications Centre, Ahmedabad

Title of the research proposal
AI/ML based mapping of planetary morphology/morphometry

Name of Co PI from ISRO Centre/Unit

Mr. Aditya Dagar

Dr. Satadru Bhattacharya

Contact Address of Co PI and e-mail id

adagar@sac.isro.gov.in

satadru@sac.isro.gov.in

Area of Research

Planetary Morphology

Summary of the proposed research and expected deliverables

AI/ML based detection of surface features, their morphometric analysis for estimation of age and understanding the evolutionary history of planetary surface. This will involve detecting, mapping and classification surface features along with their morphometric characteristics.

Scope of the Work:

To identify, map and classify planetary surface features & understand the evolutionary history.

Linkages to Space Programme:

Ongoing and future inter - planetary missions of ISRO, Chandrayaan, MoM-2 & Venus missions.

Expected Deliverables:

AI/ML based Algorithms and programs for detection, mapping and classification of planetary surface features. Reports / Research papers.

RES-SAC-2023-024

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Use of Artificial Intelligence based technique for the retrieval of Atmospheric Motion Winds

Name of Co PI from ISRO Centre/Unit

Dr. Sanjib K Deb

Contact Address of Co PI and e-mail id

sanjib_deb@sac.isro.gov.in

Area of Research

Retrieval of Atmospheric Winds using satellite data

Summary of the proposed research and expected deliverables

Horizontal atmospheric wind can be estimated from feature tracking of remotely sensed cloud top or moisture fields across a specific time interval. These feature-tracking wind products, usually called atmospheric motion vectors (AMVs) are available from various meteorological organizations around the world. The AMV products can roughly be divided by the type of satellite (or instrument) used to retrieve

them: Geostationary (GEO) satellites, Low-Earth-orbiting (LEO) satellites, mixed, and stereoscopic. All these types have their strengths and weaknesses.

Now-a-days different empirical techniques such as Machine Learning, Artificial Intelligence or Optical Flow based techniques are available to derive atmospheric winds using both GEO and LEO satellites and shows considerable improvement in the retrieved winds. These types of techniques can be explored to derive winds using Indian Satellite data.

Scope of the Work:

Retrieval of Atmospheric winds using satellite data, especially for next generation of ISRO satellites in GEO.

Linkages to Space Programme:

This proposal has linkages to INSAT data utilization programme.

Expected Deliverables:

AI/ML based algorithm for Atmospheric winds.

RES-SAC-2023-025

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Stable Isotopic investigation of surface water bodies for hydrologic flux partitioning applications

Name of Co PI from ISRO Centre/Unit

Mr. Rohit Pradhan

Contact Address of Co PI and e-mail id

rohitp@sac.isro.gov.in

Area of Research

Isotope Hydrology

Summary of the proposed research and expected deliverables

Variations in stable isotopic composition of water ($\delta^{18}O$ and δD) in various water bodies is an important indicator of the processes within the hydrological cycle. Isotopic signature of water in lakes, reservoirs and rivers along with local precipitation can be helpful in partitioning evaporation and transpiration fluxes at catchment scale. Isotopic studies of rainfall have regularly been carried out to determine the sources of precipitation and understand atmospheric processes.

Similarly, isotopic analysis of water bodies can provide important information on hydrologic processes within its catchment. This data along with isotopic signature of water vapor in atmosphere can present a unique understanding of catchment-scale hydrology. Regular collection and isotopic analysis ($\delta^{18}O$ and δD) of water samples is required to assess their variability. Along with this, collection of rainwater samples during each rain event is necessary to fully solve the isotopic water balance equations. Water temperature, pH, conductivity etc are some other parameters required for analysis. Sampling of

evaporated and transpired vapor will further reduce dependence on models and help to better constrain the hydrologic fluxes.

Scope of the Work:

Isotopic analysis of water opens a new domain of research that helps in better understanding of the hydrological cycle. However, this is still an emerging area of research in India with huge scope for improvement. With more data points being available from different water bodies of the country, a better understanding of the underlying processes can be obtained.

Linkages to Space Programme:

Land Hydrology Division (SAC/ISRO) has undertaken SARITA Program with isotopic investigation of water as one of its major objectives. Satellite-based isotopic analysis of water vapor has been extensively carried out under this programme.

Expected Deliverables:

- Temporal variability of stable isotopic signature of water ($\delta^{18}O$ and δD) from water bodies (lakes/ rivers/wells) within the selected catchment.
- Partitioned hydrological fluxes in terms of evaporation, transpiration and runoff at catchment scale.

RES-SAC-2023-026

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Development of process for metallization on Anisotropic Pyrolytic Boron Nitride rods

Name of Co PI from ISRO Centre/Unit

Mr. Ramagiri Santhosh Kumar

Ms. Shilpi Soni

Contact Address of Co PI and e-mail id

santhoshr@sac.isro.gov.in

shilpi@sac.isro.gov.in

Area of Research

Metallization on Anisotropic Pyrolytic Boron Nitride (APBN) rods

Summary of the proposed research and expected deliverables

The Vacuum Electron Devices used as amplifiers have an interaction circuit which interacts with the electron beam for amplification of RF signal. The interaction circuit is held by APBN rods. For proper heat sink (to sink heat dissipated by RF losses), the APBN rods are to be brazed with interaction circuit at their inner surface and with barrel at their external surface. The present proposal is to develop a process for metallization on these APBN rods to make brazing feasible.

Scope of the Work:

To develop process for metallization (preferably moly-manganese/nickel) on APBN rods as per the profile

of interaction circuit

- Brazing Temperature: 1000 ˚C.
- The metallization shall survive temperatures up to 1050 ˚C.

Linkages to Space Programme:

This proposal has linkages to High power TWTs (400 -500 W) for future Ka-band missions.

Expected Deliverables:

- 20 sets of APBN rods (each set consisting of 6 rods).
- Dimensional inspection report including surface roughness and metallization thickness.
- Report of adhesion of metallization and maximum working temperature.

RES-SAC-2023-027

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Realization of chalcogenide glasses for use in common dual band IR optics for both MWIR and LWIR on the same or different imaging sensors

Name of Co PI from ISRO Centre/Unit

Mr. Sukamal Kumar Paul

Ms. Barkha Gupta

Contact Address of Co PI and e-mail id

sukamalpaul@sac.isro.gov.in

barkha@sac.isro.gov.in

Area of Research

Realization of chalcogenide glasses for broadband IR imaging applications

Summary of the proposed research and expected deliverables

The summary of the proposal is as follows:

- Study and design of a dual band IR common optics using chalcogenide glasses that will image both MWIR and LWIR on the same or different imaging sensors.
- Collaboration with external agencies for realization of Chalcogenide optics via. fabrication, assembly and testing for achieving the desired performance goals.

Scope of the Work:

Realization of chalcogenide glasses will be a new development for ISRO. The indices of refraction and dispersion characteristics of these glasses will be tuned to reduce chromatic aberrations for wide spectral bands from MWIR to LWIR. Further the thermo-optic properties will be tailored to achieve improvement in a thermalization. Such glasses can be used for realization of broadband IR imaging systems.

Linkages to Space Programme:

The use of Chalcogenide glasses find potential in future projects/programs for IR imaging applications.

Expected Deliverables:

With the design and development of Chalcogenide glasses, compact IR imaging systems can be realized utilizing common optics and detector for both MWIR and LWIR applications.

RES-SAC-2023-028

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Precise Baseline/Orbit Determination (PBD/POD) Algorithm for Tandem Satellite operations for high precision GNSS receiver

Name of Co PI from ISRO Centre/Unit

Ms. Durga Digdarsini

Mr. Hem Raj Shau

Contact Address of Co PI and e-mail id

digdarsini@sac.isro.gov.in

hemraj81092@sac.isro.gov.in

Area of Research

NavIC/GNSS

Summary of the proposed research and expected deliverables

Determination of accurate baseline vector between the two satellites is critical for accurate height determination through tandem SAR signals. The height resolution depends on baseline that should be accurate to a few centimeters. Precise baseline/orbit determination (PBD/POD) is a crucial subsystem for Tandem SAR satellite operation. The system employs High Precision NavIC/GNSS Receiver using double differential GNSS technique, Dynamic force models with extended Kalman filter.

PBD/POD method involves double differential GNSS technique, and application various force models like gravity, atmospheric drag, solar radiation pressure etc & extended Kalman Filter for the prediction.

Scope of the Work:

- An algorithm development for Precise Baseline/Orbit Determination (PBD/POD) targeting Tandem Satellite operations.
- Double differential GNSS technique.
- Dynamic force modelling in orbit determination.
- Extended Kalman filter in PBD/POD.

Linkages to Space Programme:

This proposal has linkages to the Payload – "Precise satellite relative location estimation system with high precision NavIC/GNSS receiver development" for **Tandem SAR satellites**.

Expected Deliverables:

- Developed PBD/POD Algorithms in Matlab & C codes.
- Documentation with result & supporting data sets for testing.

RES-SAC-2023-029

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Identification and characterization of Thermal Interface Materials (TIMs) for Cryogenic temperature in range of 4 to 100K to reduce thermal contact resistance between metal joints

Name of Co PI from ISRO Centre/Unit

Mr. Ashish Kumar Shukla
Mr. Mohit Kumar
Mr. Ulkesh B Desai
Mr. Arup Kumar Hait

Contact Address of Co PI and e-mail id

dks66058@sac.isro.gov.in
mohitkumar@sac.isro.gov.in
ulkesh@sac.isro.gov.in
akh@sac.isro.gov.in

Area of Research

Heat Transfer

Summary of the proposed research and expected deliverables

Objective of this research is to identify various thermal interface materials, which can be used at cryogenic temperature to reduce thermal contact resistance. Various TIMs such as Indium Foils, Indium-Gallium foils, Cryocon Grease, Apiezon-N grease etc. are already being used but a known comparison of these TIMs for different operating conditions are not available in open forum.

In this work all possible TIMs which can be used at cryogenic temperature range are to be explored. All efforts are to be made to find out maximum number of materials which can be used at cryogenic temperature to reduce thermal contact resistance. These TIMs can be metal foil or grease or an epoxy or a combination of these.

Subsequent to this, a test procedure is to be established to characterize all potential TIMs for various temperature range, such as 5 to 20K, 20 to 50K and 80 to 100K, heat input and surface roughness. All possible combination of these factors along with other factors which affect thermal contact resistance such as contact pressure, surface finish, oxide layer etc. are to be studied experimentally.

Number of samples should be decided such that a minimum of ten samples are tested to represent results of one set of input parameter. Same philosophy is to be repeated for each set of input parameters.

Based on literature and experiments, a guideline for selection of TIMs based on application and dominant factors is to be developed. Generate a Numerical model based upon the experimental data.

Scope of the Work:

- Identification of thermal interface material and their characterization.

Linkages to Space Programme:

This proposal has linkages to Cryogenic system of future and ongoing THz Projects.

Expected Deliverables:

- Report containing merits and de-merits of all identified thermal interface materials along with test procedure, test results and recommendations for their usage.
- Numerical model based on the experimental data.

RES-SAC-2023-030

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Development and Characterization of Processed Shape Memory Alloy (SMA) components for Space Applications

Name of Co PI from ISRO Centre/Unit

Mr. Ravi Kumar Varma

Contact Address of Co PI and e-mail id

rkv@sac.isro.gov.in

Area of Research

Alloy Material Development and characterization

Summary of the proposed research and expected deliverables

Shape Memory Alloys (SMA) are a class of newer alloys that can withstand immense deformations and yet return to their original shape under certain conditions. In addition to this, they also possess excellent corrosion resistance, wear resistance and superior thermomechanical properties. SMA components also offer a weight reduction up to 45%. These shape memory alloys are usually a combination of two or three constituents and are often challenging to be characterized. Several applications of these alloys are researched upon and thus a careful investigation of the characterization of the components of these Shape Memory Alloys can enable them to be considered as a candidate material for aerospace and space related components which could lead to weight reduction and possible cost reduction.

Scope of the Work:

A detailed analysis of the post-processing characterization of competent SMA with required properties can enable them to be considered as candidate materials for space applications. The properties include

- Required NDE (NDT) feasibility of SMA components.
- Mechanical and metallurgical properties such as corrosion resistance, wear resistance, microstructural investigation etc.
- Post-processing shape recovery phenomenon.

Linkages to Space Programme:

This proposal has linkages to all futuristic pay-load developments, Advanced R&D.

Expected Deliverables:

- A detailed structure property relationship with the characterized results and its analysis.
- Development of standard prototype part and performance demonstration under defined space environment conditions.

RES-SAC-2023-031

Name of ISRO Centre/Unit

Space Applications Centre, Ahmedabad

Title of the research proposal

Development of fast curing epoxy based EMI shielding material

Name of Co PI from ISRO Centre/Unit

Ms. Nandini Deshpande

Contact Address of Co PI and e-mail id

nandinigodhe@sac.isro.gov.in

Area of Research

Development of fast curing epoxy as a shielding material reinforced with thermally and electrically conductive materials

Summary of the proposed research and expected deliverables

Activity involves identification of suitable materials, finalization of their chemical composition, process optimization, material fabrication and characterization.

The epoxy will be used to improve shielding effectiveness of the metallic enclosures/connector flanges of electronic hardware. Thus, the material should have high electrical & thermal conductivity and provide high attenuation/ absorption to Microwave signals from L-band to Ku-band frequency range. Subsequently, the epoxy may further be optimized for higher frequency ranges like Ka-band. Possibility for usage of Nano-composites shall be explored.

Scope of the Work:

Developed epoxy can be used to provide shielding against EMI in all the metallic packages of Electronic systems of all payloads.

Fast curing of epoxy will lead to a considerable reduction in turn-around time of hardware preparedness for testing/ further activities.

Linkages to Space Programme:

This proposal has linkages to Electronic systems of all payloads.

Expected Deliverables:

Epoxy based EMI shielding material

U R RAO SATELLITE CENTRE
BENGALURU

RES-URSC-2023-001

Name of ISRO Centre/Unit
U R Rao Satellite Centre, Bengaluru

Title of the research proposal
Experimental evaluation of thermal accommodation coefficients for hypersonic rarefied flows

Name of Co PI from ISRO Centre/Unit
Mr. Y Bishal Singha

Mr. Chaitanya B.S

Contact Address of Co PI and e-mail id
bishal@ursc.gov.in

chai@ursc.gov.in

Area of Research
Rarefied Gas Dynamics

Summary of the proposed research and expected deliverables
Aerobraking is a sophisticated spacecraft (S/C) maneuver to reduce the orbital eccentricity and altitude using the atmospheric drag of upper planetary atmosphere instead of propellant burn which leads to significant mass and cost savings. During aerobraking, flow experienced by the spacecraft will be hypersonic and in rarefied regimes. The interaction of atmosphere with the S/C can impose significant heating and forces on the spacecraft elements. Correct estimation of aerodynamic heat flux and forces is essential for the success of aerobraking operations.

Accurate estimates of heat flux and forces depend on the appropriate use of gas-surface interaction models in simulations. Typical gas-surface interaction models are modelled using a parameter called Thermal a Accommodation Coefficient (TAC). It defines the nature of interaction of a gas with a solid surface. It quantifies the extent to which the gas molecules exchange energy with the molecules of the colliding surface. Correct determination of TAC is essential to accurately estimate the heat flux and drag experienced by the S/C elements during aerobraking.

Currently there is a limited body of literature for the prediction of TAC for engineering surfaces. The research proposal is intended to experimentally and numerically investigate TAC specifically for the surfaces present on S/C external elements underflow conditions expected during aerobraking.

Scope of the Work:

- Experimental studies with simulated surfaces (samples) of various substrates for estimation of TAC under high speed rarefied flow conditions.
- Comparison of experimental data with numerical simulations or any other numerical investigation if required.
- Development of a database or correlations for TAC using data driven approaches if possible.
- Uncertainty analysis.

Linkages to Space Programme:

Aerobraking technique is planned to reduce the orbit eccentricity in upcoming interplanetary missions such as Mars Orbiter Mission -2 and Venus Orbiter mission.

Expected Deliverables:

Predictive tools (correlation or database) for accurate estimation of thermal accommodation coefficients or any other gas-surface interaction models for various substrates (used in spacecraft external elements) for high speed rarefied flows.

RES-URSC-2023-002

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Development of Artificial Intelligence (AI)/Machine Learning (ML) based models for efficient surface engineering processes

Name of Co PI from ISRO Centre/Unit

Ms. Bhavana Sahu,
Mr. Rahul Ghosh,
Mr. Gunjan Rastogi
Mr. Arjun Dey
Mr. Hari Krishna Thota

Contact Address of Co PI and e-mail id

bsahu@ursc.gov.in
rghosh@ursc.gov.in
gunjan@ursc.gov.in
arjundey@ursc.gov.in
harik@ursc.gov.in

Area of Research

Artificial Intelligence (AI)/ Machine Learning (ML) techniques for Materials and Coatings

Summary of the proposed research and expected deliverables

Surface engineering processes such as conversion coatings, electroplating, paintings and thin film technologies are used for various spacecraft functional applications. These processes are developed and characterized through several experimentations. Being an iterative process, it is resource extensive and time-consuming approach and hence requires an alternate method which can provide better insight of process development with less turn-around time. In view of this, to harness the potential of data driven methodology, Artificial Intelligence (AI)/ Machine Learning (ML) based approach in optimization and predictive model development, is essential.

Scope of the Work:

- To develop and train AI models, TSG/URSC will provide raw database to academia on 1) PVD based thin films, and 2) Conversion coatings.

- Academia will generate AI/ML based models along with model sensitivity study, predictive & prescriptive data analytics.
- Developed models will be validated through experiments by TSG/URSC.

Linkages to Space Programme:

New functional coatings for thermal control applications such as Smart Radiative Device (SRD), High Performance OSR/ Meta-OSR, Anodized 3D printed alloys for upcoming science and interplanetary missions.

Expected Deliverables:

- Prescriptive data analytics results.
- Model sensitivity analysis results.
- Validated model (AI/ML based).
- Final closure report.

RES-URSC-2023-003

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Heat pump for heat rejection at elevated temperature

Name of Co PI from ISRO Centre/Unit

Mr. Dhananjay Wasudeorao Tijare
Mr. Pijush Kanti Pattanayak
Mr. Satyam Kumar Jayashawal

Contact Address of Co PI and e-mail id

tijare@ursc.gov.in
pijushk@ursc.gov.in
satyamj@ursc.gov.in

Area of Research

Spacecraft Thermal System

Summary of the proposed research and expected deliverables

In spacecraft applications, heat rejection capacity of a space thermal radiator is limited by its temperature. The temperature of a radiator of a passive thermal control system is limited by the operating temperature of equipment supplying the heat, and it is lower than equipment (source). Heat rejection capacity of a radiator can be enhanced by raising its temperature.

A heat pump-enabled thermal control system absorbs heat from the source region and transfers heat to a radiator at higher temperature; this requires additional operating power. The radiator rejects heat absorbed from the source and the operating power.

One of the important characteristic feature of this device is that the total radiator area requirement reduces vis- à-vis that for a passive system. The radiator may be deployable or fixed as the mission

objectives and spacecraft configuration demand. This research proposal is for design and development of heat pump system for spacecraft application and validations through ground experiment.

Scope of the Work:

The proposed realisation of heat pump system shall use vapour compression cycle. The scope of this project are outlined below:

- Source temperature: 0 to 60˚C; Heat load at source: 50 to 500 W; Radiator temperature: 100 to 150˚C Coefficient of performance: >= 2 (for Evaporator at 45˚C and condenser at 100˚C).
- The heat exchanger in the heat pump unit should be compact and high heat transfer capability heat exchangers that enable efficient heat absorption from source (generally heat pipe embedded honeycomb panels) and heat rejection to the radiators. Various design approaches shall be explored and rational/ selection criterion shall be evolved.
- The active systems (viz. compressor, valves, etc.) used in the system shall be oil free and the design will be evolved keeping in mind spacecraft application.
- The selection/ design of components used or proposed in the heat pump shall adhere to the following:
  - System shall have close loop control for temperature maintenance at source.
  - Input power to various units is 70/ 42 V DC
  - Materials and processes compatible for space application
  - System compatible for launch quasi-static load of 25g normal to mounting plane and 15g in- plane to mounting plane (g is acceleration due to gravity of Earth)
  - During operation of active elements total micro vibration level imparted to the spacecraft platform should be less than 0.1g.
  - Design scheme which shall meet EMI/EMC levels for package/ elements as per MIL-STD-461G or 461/462 C (ESA standard)
  - Design scheme which shall have Monitoring parameters through 1553 interface for Pressure, Temperature, Pump/Compressor voltage, Pump/Compressor speed, Mass flow rate, System status and other relevant parameters
  - Mathematical model of the heat pump system and the components to estimate thermos-hydraulic performance of the unit is required to substantiate the design and negate the other design options.

Linkages to Space Programme:

The proposal has linkages to Geo-stationary communication satellite, interplanetary missions, lunar missions, etc.

Expected Deliverables:

Design and development of the heat pump using commercially available hardware for the parameters as outlined in Scope and mathematical model that aids in selection of various design parameters such as –

- Identification of thermodynamic cycle;
- Working fluid;
- Compressor/pump and valves;
- Design parameters of heat exchanger at source and radiator.
- Design of scheme for closed loop control

- Computer program of the mathematical model in programming language.
- (C/C++/Python) and/or based on open source software like FEAST (from VSSC) or OpenFoam. UG-NX may be used for interface development, if needed.
- Any additional information pertinent to above study.
- Demonstration of performance of heat pump through ground experiment. Validation of mathematical model through from experimental data.

RES-URSC-2023-004

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Assessment of microbial diversity inside cleanrooms facility – (biological contamination control activities) for scientific satellites and human missions

Name of Co PI from ISRO Centre/Unit

Dr. R. Uma Rani

Contact Address of Co PI and e-mail id

rurani@ursc.gov.in

Area of Research

Contamination Control, Microbiology, Microbial Bio burden, Clean room cleanliness

Summary of the proposed research and expected deliverables

Establishment of methods to identify the microorganisms present in Clean Rooms where Spacecrafts are integrated and providing mitigation methods to establish better biological contaminant control.

Scope of the Work:

Clean rooms (where satellites are integrated) are certified by particle counts and are humidity-controlled, temperature-regulated, and oligotrophic in nature for assembling spacecrafts. Microorganisms, which are not part of the clean room certification protocol, should not be overlooked when assessing the cleanliness of the facility since they can enter through soil or air, shed from humans. These microorganisms may adapt to the oligotrophic conditions, and subsequently could contaminate the spacecraft. Hence, these biogenic particles need to be identified to extend our knowledge of biological contamination for future scientific and human missions.

Linkages to Space Programme:

All future scientific programmes, viz, Human Space Missions, Interplanetary Missions and Landing Missions.

Expected Deliverables:

- To determine the bacterial diversity of clean room environments.
- To evolve sterilization technologies for spacecraft preparation.
- Evolving procedures and techniques to achieve the desired level of microbial control.
- To identify potential sources of contamination, characterization and mitigation.

RES-URSC-2023-005

Name of ISRO Centre/Unit
U R Rao Satellite Centre, Bengaluru

Title of the research proposal
Self-lubricating ceramic materials for spacecraft applications

Name of Co PI from ISRO Centre/Unit
Dr. R. Uma Rani
Mr. Aravindram P
Mr. Pradeep Kumar

Contact Address of Co PI and e-mail id
rurani@ursc.gov.in

Area of Research
Materials, Tribology, Solid Lubricants

Summary of the proposed research and expected deliverables
These are based on ceramic powders and manufactured using powder metallurgy processes. Useful for future Venus and solar probe missions.

Scope of the Work:

In the case of no liquid/gas/grease lubrication, considerable adhesion exists between the sliding surfaces of solid contact if two solid surfaces are operating in ultra-high vacuum as in space environments. Novel self- lubricating high temperature (500 ˚C – 900 ˚C) solid lubricating materials are required for future satellite missions (such as Venus, solar Probe etc). Methods include powder metallurgy processes such as pressure less sintering, hot pressing (HP), hot isostatic pressing (HIP), and spark plasma sintering (SPS) are envisaged.

Linkages to Space Programme:

All programmes especially for future Venus and Solar Probe Missions.

Expected Deliverables:

- Laboratory scale preparation of ceramic powders to work in the temperature range 500 ˚C – 900 ˚C.
- Technical knowhow on preparation methods need to be transferred.
- Evaluation of functionality at 500˚C – 900 ˚C temperatures.

RES-URSC-2023-006

Name of ISRO Centre/Unit
U R Rao Satellite Centre, Bengaluru

Title of the research proposal
Development of self-healing composites for satellite structural applications

Name of Co PI from ISRO Centre/Unit

Mr. Satheesh R
Dr P Subbarao
Dr. R. Uma
Mr. Rani Pradeep Kumar
Mr. Shehin P. U

Contact Address of Co PI and e-mail id

sateeshr@ursc.gov.in
subbarao@ursc.gov.in
rurani@ursc.gov.in
pradeep@ursc.gov.in
shehin@ursc.gov.in

Area of Research

Materials & Structures

Summary of the proposed research and expected deliverables

Micro cracks, de-bonds, de-lamination in composites due to changes in environmental conditions or due to external forces like debris can be life limiting problem in space. Self- healing or autonomic healing is a way to address this problem which can effectively extend the life of structure with better structural integrity. A suitable self-healing method along with its implementation in a composite product needs to be developed and demonstrated for satellite structural applications.

Scope of the Work:

To develop method for self-healing involving development of suitable materials and manufacturing techniques for self repair of cracks and debonds restoring the structural integrity and performance.

Linkages to Space Programme:

Future spacecraft structures for interplanetary missions. MOM-2 , LUPEX, Manned mission to moon etc.

Expected Deliverables:

Structural composite laminates / CFRP / Aluminium sandwich panels etc.

RES-URSC-2023-007

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Development and characterization of multifunctional epoxy adhesive system for satellite applications

Name of Co PI from ISRO Centre/Unit

Mr. Shehin P U

Contact Address of Co PI and e-mail id

rurani@ursc.gov.in
shehin@gov.in

Area of Research

Materials, Adhesives

Summary of the proposed research and expected deliverables

The proposal is to develop a RT curing two part epoxy based adhesive comprising a single type resin base and 4 different types of hardeners part or vice versa (Single hardener/4 resin parts). Such that the all combination of part A (Resin/ Hardener) with each Part B (Hardener/resin) should yield a cured product with unique combinations properties of mechanical properties, electrical properties and thermal properties listed as follows:

Combination 1/ Equivalent to Araldite AV 138 and HV 998)

High strength and toughness adhesive for high temperature and chemical resistance application. The material shall be electrically and thermally non conductive

The final cured product should have following Characteristics.

- Lap shear strength (LSS) : ≥ 10 MPa with Aluminum substrates on RT curing.
- SHORE D- ≥ 80.
- Electric strength: ≥ 40 KV.
- Volume Resistivity: ≥ 10^{16} Ω-cm.
- CTE : (50-75) X $10^{-6.}$

Combination 2 /Equivalent to Stycast 2850FT and Catalyst 24LV

Electrically insulating and thermally conducting encapsulant for heat dissipation applications with good thermal coefficient of expansion

The final cured product should have following Characteristics:

- Thermal conductivity: ≥ 1.0 W/m.K.
- SHORE D- ≥ 90.
- Surface resistivity : ≥10^{15}.
- Volume resistivity : ≥10^{14} Ω-cm.

Combination 3 / Equivalent to Stycast 56C

Electrically and thermally conducting adhesive for reliable electrical connections. The final cured product should have following Characteristics:

- LSS - ≥ 5 Mpa with Al substrates
- Operating Temperature: -40˚C to 135˚C.
- Thermal conductivity: ≥ 7 W/m.K.
- Volume Resistivity: ≤ 0.0002 Ω-cm.
- CTE : (30-40) X 10^{-6}.

Combination 4/ Equivalent to 3M EC 2216

RT curing Flexible adhesive with excellent peel strength and shear strength suitable for cryogenic applications. The material shall have high resistance to mechanical shocks and vibration. The final cured product should have following Characteristics:

- Operating Temperature: -250˚C to 80˚C.
- LSS - ≥ 15 Mpa with Al substrates @-200˚C & ≥ 2.5 Mpa @ 80˚C.
- Shear Modulus: ≥ 300MPa at RT and : ≥2000 Mpa at -80˚C.

All cured products shall have excellent Outgassing characteristics such as %TML≤5.0 and %CVCM ≤ 0.1 (test standard ASTM E 595).

Scope of the Work:

- Characterization and evaluation of existing flexible adhesive systems (DuralcoTM4538) and other adhesives with required target properties.
- Development, synthesis and characterization of adhesive system with required properties.
- Development of curing process for each resin-hardener combination.
- Evaluation and characterization of cured systems.
- Qualification of each resin-hardener combination for space applications.

Linkages to Space Programme:

- Developed products can be used as structural adhesives, potting components, Adhesive applications in electrical connections and cryogenic applications demanding various thermal, electrical and mechanical functional requirements.
- The resultant adhesive system will reduce the dependency on imported adhesives such as Araldite AV 138, Stycast 2850FT, 3M EC 2216, Stycast 56C etc.
- Development will lead to better material control in procurement, storage and testing.

Expected Deliverables:

- Products and processes development document for the flexible adhesive system.
- Lab scale production of Resin-hardener composition for qualification testing.

RES-URSC-2023-008

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Characterization & training of indigenously developed Ni-Ti based Shape Memory Alloy (SMA) for spacecraft application

Name of Co PI from ISRO Centre/Unit

Mr. Pradeep Kumar

Mr. Aravindram P

Contact Address of Co PI and e-mail id

pradeep@ursc.gov.in

aravindr@ursc.gov.in

Area of Research

Materials, Shape Memory Alloy, Smart Materials, Active Materials

Summary of the proposed research and expected deliverables

Shape Memory Materials have the ability to recover seemingly permanent strains induced by appropriate temperature and/or stress and are characterized by two properties that ordinary metals do not exhibit;

Shape Memory Effect (SME) and pseudo-elasticity. SME is used for actuation and pseudo-elasticity for applications such as vibration isolation and dampening.

Compared to standard devices, the SMA-based mechanisms are much smaller and lighter, and superior in control and accuracy.

The proposal is to characterization and training of the indigenously developed Ni-Ti SMA for space components to improve retention, release, and deployment of crucial structures.

Scope of the Work:

The followings are the scope for Ni-Ti SMA;

- Procurement of Ni-Ti based indigenously developed material.
- Material and Functional characterization.
- Training of material.
- Demonstration of the material for actual spacecraft applications.

Linkages to Space Programme:

This proposal has linkages to all Projects: Deployment of Spacecraft Components.

Expected Deliverables:

- Characterization and training of material.
- Demonstration of SMA for spacecraft application.

RES-URSC-2023-009

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Development and Performance Evaluation of Portable Real time Applications on (COTS/open source) Multi Core Processor systems

Name of Co PI from ISRO Centre/Unit

Mr. Kiran Desai

Contact Address of Co PI and e-mail id

kirandes@ursc.gov.in

Area of Research

Application of RTOS based systems on Multi Core/Many Core

Summary of the proposed research and expected deliverables

The proposal is for the effective usage of the Multicore systems in spacecraft applications. Such solutions need to ensure for cost effectiveness while meeting the mandatory reliability and safety requirements.

Scope of the Work:

The project objectives are

- Design a framework for migrating legacy and real time systems to multicore.
- Performance improvements with multicore systems - using appropriate scheduling algorithms and synchronization protocols.
- Assurance of determinism in avionics applications.
- The safety net approach to mitigate the risk associated with COTS microprocessor in space environments using passive and active methods.

Linkages to Space Programme:

Future Missions involving Miniaturized Integrated Avionics Packages (Gaganyaan) and Interplanetary missions like MLM.

Expected Deliverables:

- Framework for migrating legacy RT software into Real time software for Multi core.
- Assurance mechanisms/Tools for determinism in avionics.
- The safety net approach to mitigate the risk associated with COTS microprocessor.

RES-URSC-2023-010

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Fabrication and design of nano- materials based prototype for future EUV/ X-ray polarimetric missions

Name of Co PI from ISRO Centre/Unit

Mr Ankur Kushwaha

Mr. Anand Jain

Contact Address of Co PI and e-mail id

ankurksh@ursc.gov.in

anandj@ursc.gov.in

Area of Research

EUV/X-ray Polarimeter

Summary of the proposed research and expected deliverables

Polarization measurement in Extreme Ultra-Violet (EUV) and X-rays for Astrophysical sources are not yet carried out systematically. One of the major reason is due to the non- availability of suitable polarization components. EUV uses thin film coated mirrors for narrow band polarimetry. In X-rays special detectors are developed for measuring the polarization (Gas-Electron Magnification based detector or high-Z scatterer based polarimeter). Both these techniques are being developed and space missions are being planned for the same.

Carbon Nano Tubes (CNTs) are nanotubes with high electrical conductivity. It has been theoretically shown that aligning these nanotubes in specific directions and spacing can make them an efficient polarizer like wire grid polarizers used in Infra-red polarimetry. A detailed study of the characteristics of these aligned nanotubes through simulation is required to understand its polarizability for different

energy bands (wavelengths) along with its efficiency. The simulation will also provide an opportunity to optimize the distance between the CNTs for maximum efficiency in any particular band of wavelength (or energy). Such studies can results in a development of aligned CNTs based polarimeter for laboratory as well as space usage.

Scope of the Work:

The scope of this work is to validate the basic concept of utilizing CNT for polarization studies in the X-ray energy band. The work would include,

- Understanding the interaction of single walled CNT with incident photon in X-ray energy band, its absorption cross-section parallel and perpendicular to that of the CNT orientation.
- Arrange the single walled CNTs in an array for increasing the efficiency of the system. The parameters like the length of the CNTs, the distance between them, and growth direction on the substrate will need to be studied for different energies for optimization.
- Identify the limitations and required space qualification aspects for the designed CNT structures. List out the advantages and disadvantages compared to the existing technologies for X-ray polarimetry.
- A design of CNT based prototype polarizer which can be fabricated as sample for initial testing and characterization at URSC.

Linkages to Space Programme:

URSC has already proposed an X- ray polarimeter for future Astronomy mission. However, it will be limited for energies above 2keV. The proposed polarization system using CNT will be the next generation polarimeters for future missions, especially for energies below 2keV though it can also be optimized for above 2keV. This project will develop the design which will be used to develop a system in the future.

Expected Deliverables:

- A Carbon nano tube (CNT) based prototype polarizer, fabricated as per the simulation results and optimization which can be tested and verified at URSC laboratory for future polarimteric missions.
- An optimized space worthy design of CNT based polarizer to detect polarized photons at different energies.
- Simulations and modelling results for utilization such polarizers for space based polarimeters.
- The design optimization software tools or methodology that is developed under this project.
- Feasibility study for the laboratory development of the CNT structure to work as polarizer.

RES-URSC-2023-011

Name of ISRO Centre/Unit

UR Rao Satellite Centre, Bengaluru

Title of the research proposal

Design studies and prototype development for Inflatable and Rigidizable Tubular Boom

Name of Co PI from ISRO Centre/Unit

Ms. S N Malarvizhi

Mr. K V Muralidhar

Contact Address of Co PI and e-mail id

snmalar@ursc.gov.in
muralidr@ursc.gov.in

Area of Research

Structures, Material Science, Composite Materials

Summary of the proposed research and expected deliverables

Recent Technological advances have presented a new possibility to the space community with ultra-light Inflatable structures, one among them is the inflatable, rigidizable boom. It is proposed to develop an inflatable and rigidizable boom of length 15m, with a capacity to support antenna systems of 500gms. The stowed packing can be through folding, origami packing, coiled wrapping, or any other innovative method which can improve the packaging efficiency. The inflation and rigidzation can be through pressurisation, UV curing, or by any other innovative method.

The post-deployment rigidization ensures the necessary structural stiffness for long-term space applications. Another important aspect is deployment control, which serves to improve reliability and predictability of deployment paths, reduce the reaction loads to the satellite during deployment, and thereby minimize the vibrations after deployment.

- The deployed frequency should be around 0.1Hz and the mass should be around 1kg.
- Material should be space-qualified.
- Controlled Inflation method using inflator systems compatible to space environment.
- Self-sustained controlled rigidization scheme.
- Packaging efficiency should be around 1/10.
- Simulation through finite element software.

Scope of the Work:

The compact configuration of the boom will be launched into space and then deployed by pressurization using a gas or other means to its full intended form. For some of the applications, rigidization of an inflatable structure is necessary whereby; following deployment via inflation, the structure is physically rigidized to the point where it will maintain its intended shape without reliance on continued pressurization and will be capable of taking load.

Linkages to Space Programme:

Development of booms for Future missions that require light weight systems to be kept far away from the main structure of the satellite.

Future missions like deep space missions and large orbital platforms have a requirement for these booms.

Expected Deliverables:

Key technologies for developing inflatable and rigidizable boom and its demonstration.

Prototype boom of length 15m, with a capacity to support antenna systems of 500gms. Material

used is to be space- qualified material with boom mass of around 1kg. Stowed/packed configuration to be compact (around 1/10), and a controlled inflation method suiting to the space environment to be demonstrated. Self-sustained rigidization scheme is required. Simulation through finite element software to be included.

RES-URSC-2023-012

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Development of CNT infused CFRP prepregs with enhanced thermal and electrical conductivity for satellite structural applications

Name of Co PI from ISRO Centre/Unit

Mr. M. Kotresh

Dr P. Subba Rao

Contact Address of Co PI and e-mail id

kotreshm@ursc.gov.in

subbarao@ursc.gov.in

Area of Research

Composite Materials & Satellite Structures

Summary of the proposed research and expected deliverables

Space grade composite prepregs with resin and fibers of moderate stiffness and strength are available indigenously. Carbon nanotubes and functionalized CNTs known for high strength, stiffness and conductivity are also available indigeneously. It is required to develop new processes to incorporate these CNTs/fCNTs during the process of manufacturing of prepreg so as to improve thermal and electrical conductivities without compromising on the strength and stiffness of laminates made. It involves arriving at the optimized quantity of CNTs/ functionalized CNTs to be dispersed in the prepreg balancing the structural and thermal requirements through development of different sets of laminates. It also involves material characterization of cured laminates along with measurements of thermal and electrical conductivities of cured laminates. A final report needs generated and submitted explaining the process along with all test results.

Scope of the Work:

To develop CNTs/functionalized CNTs infused Carbon Fibre Prepreg for improving the Thermal and Electrical Conductivities and the process developed for Satellite Structural applications.

Linkages to Space Programme:

The outcome of the research can be used in realizing the equipment panels of satellites, Payload panels, thermal diffuser plates , ESD panels replacing usage of metallic materials.

Expected Deliverables:

The deliverables of the proposed research are the following:

- Carbon Composite Prepreg incorporated with CNTs/fCNTs.

- Composite laminates cured with CNTs/fCNTs based prepregs.
- Process Development report detailing the processing steps and optimized process parameters evolved.
- Measured structural, thermal and electrical Conductivities of Carbon Composite Laminates.

RES-URSC-2023-013

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Health Monitoring of Spacecraft Structural Members made of Honeycomb sandwich / composite materials

Name of Co PI from ISRO Centre/Unit

Mr. M.N.M. Patnaik

Contact Address of Co PI and e-mail id

patnaik@ursc.gov.in

Area of Research

Structures

Summary of the proposed research and expected deliverables

Reentry missions like Gaganyaan, recovery experiments etc., unlike regular spacecraft missions need verification of their structural integrity post launch to orbit to enable it to safely withstand the reentry structural loads.

Structural health of critical structural members like bulkheads, structural joints need to be assessed for any damage due to launch loads and during on-orbit service environment.

On-board Structural Health Monitoring (SHM) using guided wave technique, which is used for in-service aircrafts, civil structures etc. is an efficient proven method. However, considering the materials used for spacecraft construction like composites, honeycomb sandwich decks, the damage detection method has to be evolved for identifying typical structural failures involving these materials.

Scope of the Work:

- Development of theoretical methods for guided wave based SHM in composite honeycomb sandwich structures and structural joints.
- Experimental demonstration of implementation of above methods on Spacecraft structural members with sensors, actuators and necessary acquisition, data processing and instrumentation.

Linkages to Space Programme:

Deliverables of this project will be useful for Future reentry crafts / human missions etc.

Expected Deliverables:

- Theoretical study and experimental demonstration results of Damage detection algorithms and

quantification methods for detecting typical structural damages.

- Algorithms and methods used for the above.

RES-URSC-2023-014

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Multi-scale Modelling of Additive manufactured Structural Components

Name of Co PI from ISRO Centre/Unit

Mr. Kiran Kalbhor Jalindar

Mr. Vivek Prabhakar

Contact Address of Co PI and e-mail id

kiranjk@ursc.gov.in

vivekp@ursc.gov.in

Area of Research

Structures, Material Science, 3D printing, additive manufacturing, Finite Element Analysis

Summary of the proposed research and expected deliverables

With the rise of Additive Manufacturing (AM) in aerospace applications, there is a significant need to accurately predict the behaviour of 3D printed components, especially those intended for use in spacecraft. Multi-scale modelling is a methodology in which multiple models at different scales are used simultaneously to describe a system. Conventional structural analysis considered Homogenized material properties. The mechanical properties of the 3D printed component are highly process dependent. To account for heterogeneity, it is essential to develop analytical models to a scale lower than the conventional material characteristics estimation. Currently we rely on tests to estimate the homogenous properties. This proposal aims to develop a software tool capable of modelling these non-homogeneous characteristics at both the micro and macro scale.

Scope of the Work:

Research & Data Collection

- Gather data on current additive manufacturing processes and materials used in space applications. Including ULTEM, metal alloy, short carbon fibre reinforced materials etc.
- Study existing models and tests that estimate properties of 3D printed materials.
- Collect data on inherent variabilities in materials used in AM.

Software Development:

- Design a user-friendly interface to input data and get predictive outputs.
- Incorporate algorithms that account for multi-scale modelling, considering both micro and macro levels.
- Conversion of micro scale to macro scale for incorporating as localized homogeneity. Algorithm to convert micro to macro material models. Software to map / transfer the localized property to

conventional FE model. Finally, macro level results to be translated to micro level by means of localisation technique.

Model Calibration & Validation:

- Use real-world test data to calibrate the predictive models within the software.
- Conduct validation tests to ensure the software predictions are in alignment with real-world results.
- Adjust algorithms as necessary based on calibration and validation results.

Integration & Compatibility:

- Ensure the software tool can be integrated with existing aerospace design and testing platforms like Nastran/Abaqus.

Linkages to Space Programme:

Additive manufacturing components have the potential to be used in all future projects.

Expected Deliverables:

- Software Tool: A fully functional software application capable of simulating non-homogeneous properties of 3D printed space components on micro and macro scales.
- User Manual: Comprehensive documentation detailing the software's features, functionalities, and best practices for effective utilization.
- Validation Report: A document showcasing the results of validation tests, comparing software predictions against real-world data to demonstrate accuracy.
- Integration Guidelines: Instructions on how to seamlessly integrate the software with existing aerospace design and testing platforms.
- Final Project Report.

RES-URSC-2023-015

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Hypervelocity impact modeling on Aluminum foam sandwich panel

Name of Co PI from ISRO Centre/Unit

Dr. Rajeev Chaturvedi

Contact Address of Co PI and e-mail id

rajeevc@ursc.gov.in

Area of Research

Materials

Summary of the proposed research and expected deliverables

Open cell Aluminum foams panels are a relatively new material with novel mechanical properties that have shown promising results in preliminary hypervelocity impact shielding evaluations. Key benefits of

Open cell Aluminum foam panels are

- Protects against Space debris.
- EMI Shielding.
- Acoustic noise isolation.

Scope of the Work:

Objective of the research proposal is to develop numerical model to simulate hypervelocity impact phenomenon on Al foam sandwich panel. Development of constitutive models for Al foams and validating with the reference published papers.

Linkages to Space Programme:

The proposal has linkages to Low Earth Orbit Missions.

Expected Deliverables:

- To numerically simulate the phenomenon of hypervelocity impact on Al foam sandwich panel by Aluminum projectiles using nonlinear finite element method. The formation of debris cloud and its impact with the plates will also be attempted.
- To develop constitutive models for mechanical behavior of Al foam panels deforming at very high strain rates and to implement them within the finite element framework.
- To compare the simulation results with available experimental data in terms of penetration depth and spall behavior/damage.
- Ballistic Limit Equations (BLE) for Al foam sandwich panels based on the computational simulations.
- Thermal material/ Empirical models for Al foam sandwich panels.
- Prediction of Shock loads on the Al panel during HVI impact Phenomenon.

RES-URSC-2023-016

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Precise trajectory propagation and Events prediction for Highly eccentric Orbits

Name of Co PI from ISRO Centre/Unit

Mr. Pramod Kumar Soni

Contact Address of Co PI and e-mail id

psoni@ursc.gov.in

Area of Research

Navigation

Summary of the proposed research and expected deliverables

Precise trajectory propagation process should have state of the art modeling of the perturbations, by including all known forces.

Precise trajectory modeling should Include:

- Gravity (Point mass and Spherical Harmonics).
- Third Body Perturbation of all planets.
- Solar Radiation Pressure.
- Drag (In Presence of Atmosphere).
- Relativistic effect.

Precise trajectory Should Have:

- Choice of forces as mentioned above.
- Constant and Variable Step Integration.
- Single and Multi Step Integration Method like Runge Kutta, Guass Jackson.
- Should have ability to include Attitude Information.

Precise trajectory software Outputs:

- Satellite Orbit ephemeris in terms of position and velocity in UTC.
- Ephemeris should in text and binary format.
- Text formats such as OEM and Binary files such as Bsp which are standard formats for ephemeris.
- Should have ability to include Attitude Information.
- Should have propagation accuracy information.
- Should have information of orbital events such as Eclipse, Visibility, Station- look angles Pole Crossing, Occults etc.

Scope of the Work:

Scope of this project is to develop the precise trajectory propagation for the Highly eccentric Orbit (Eccentricity > 0.95) of spacecraft around Earth, Estimation of propagation accuracy, events (Eclipse, Visibility, Station-look angles Pole Crossing, Occults etc) prediction.

Linkages to Space Programme:

The proposal has linkages to Inter planetary missions – MOM2,Venus.

Expected Deliverables:

- Algorithm.
- Software.
- Design Document.

RES-URSC-2023-017

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Indigenous Development of Epoxy/Carbon Fiber (CF)/ Carbon Nano Tube (CNT) based Ternary Nano Composite Filament for Composite 3D Printing for Satellite Applications

Name of Co PI from ISRO Centre/Unit

Mr. Kotha Divya
Mr. Amit Kumar Sharma

Contact Address of Co PI and e-mail id

kdivya@ursc.gov.in
aksharma@ursc.gov.in

Area of Research

Materials, Composites, 3D printing

Summary of the proposed research and expected deliverables

3D Printing of composites is one of the new areas where light weight and complex features can be manufactured. However, fabricating the composite filament (feed stock) that consists of required matrix and reinforcements with a uniform size (diameter 1.75 mm) is a big challenge. Variation in diameter of the filament results in non-homogeneity and will also introduce defects in the fabricated structural components. Optimum rheological properties of the composition ensure that the filament which comes out is of uniform dimension with consistent reinforcements.

The 3D printing composite filament consists of epoxy matrix with carbon fibers and carbon nano tubes as reinforcements. Challenges involved in developing the filament involves

- Mixing of the constituents uniformly and extruding the same to get the filament.
- Functionalization and uniform dispersion of the reinforcements along with the better adhesion among the constituents to have consistent filament properties.
- Rheological characterization of the composition to check the flow of fluid and deformation during filament fabrication.
- Basic mechanical and physical characterization of the ternary composite filament.
- 3D Printing of the standard specimen structures using the ternary composite filament to check various mechanical properties.
- Scalability and challenges involved in terms of the manufacturing of the space structures and components.

Scope of the Work:

- Fabricating an Epoxy/Carbon Fiber (CF)/ Carbon Nano Tube (CNT) based ternary composite filament.
- Uniform circular cross section filament with consistent reinforcements.
- Optimum rheological composition to make sure uniform filament with better consistency.
- Printing of a basic lattice structure using the filament.
- Characterization of the 3D printed ASTM standard specimen for the mechanical and physical properties.

Linkages to Space Programme:

- Advanced Light weight Satellite Structures.
- Long Boom Structures.
- Lattice Structures.

- The filament is being currently imported and this technology of the filament development is an import substitution.

Expected Deliverables:

- Detailed Filament extraction procedure along with few sample filaments for 3D printing of the structural components.
- 3D Printed ASTM standard specimens along with tested mechanical and physical properties.

RES-URSC-2023-018

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Field Oriented Control (FOC) based BLDC/Stepper Motor Drive Electronics

Name of Co PI from ISRO Centre/Unit

Mr. Manoj Kumar

Mr. Dhruti Ranjan Gaan

Contact Address of Co PI and e-mail id

manojk@ursc.gov.in

dhrutiga@ursc.gov.in

Area of Research

Space Robotics/ Electro-mechanical Drives System

Summary of the proposed research and expected deliverables

FOC Mode of Motor Control Algorithm is the most advanced form of algorithm in today's scenario. It allows motor to run more efficiently, smoothly with quick dynamic response. FOC mode feeds the winding currents via throttle/accelerator. It involves the use of Clarke and Park transforms which is computationally complex activity in real time and needs DSP/ Microcontrollers. It makes stator and rotor magnetic fields orthogonal to each other to maximize electromechanical torque. This method involves measuring motor phase currents and rotor position. FOC mode of motor control produces lowest audible noise, takes care dynamic load conditions and provides highest motor efficiency.

Scope of the Work:

At present Chopper based PWM control mode is used for Motor control in spacecraft systems at URSC. This mode is less complex and easily implementable without the need for Microcontrollers. But it produces torque ripple and handling dynamic load condition is difficult. FOC mode is advanced control mode which overcomes these difficulties in challenging situation in space environment.

FOC control needs

- Embedded Programming.
- Power Electronics.
- Control systems knowledge.

It is highly applicable for all BLDC/Stepper Motor drives.

Linkages to Space Programme:

- Robotic arm in space for in- orbit servicing, birthing/docking.
- Motor control for Human space docking systems.
- Mars helicopter/quadcopter/ Drones experiment.
- Planetary Complex Rovers mobility systems.
- Gimballed Payload/Communication antenna control.

Expected Deliverables:

- Algorithm Development.
- BLDC and Stepper Motors Modelling.
- Python/C based Algorithm implementation & Simulations.
- Prototype Motor drive electronics for BLDC/Stepper Motors for FOC control demonstration on hardware.
- GUI based test setup development for parameters and output performance plots.
- Detailed Documentation preparation.

RES-URSC-2023-019

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Gyaan Portal for Astronauts (GPA) consists of: 1. AI & ML based Onboard Decision Support System (ODSS) and, 2. Continuous Onboard Simulator System (COSS) using “digital twin” of Human Mission Spacecraft Module (HMSM)

Name of Co PI from ISRO Centre/Unit

Mr. Rahul Mishra

Contact Address of Co PI and e-mail id

rahulm@ursc.gov.in

Area of Research

Artificial Intelligence and Machine Learning

Summary of the proposed research and expected deliverables

- The GPA will be an AI based evolutionary system that will capture all the knowledge, training and onboard experiences of Crew (past and present Crew members), both onboard and during the training; and present it to the crew/searcher based on their requirements. As this is an AI based system, this will help in evolution of the ODSS with every new knowledge addition and thus improve its performance over time for future space missions, space station programs and human transportation systems. By making it rating/credit based system, the ODSS can be made a reinforcement learning system, which will improve its performance based on its application.
- In the eventuality of loss of communication from ground, it will act as a training repository and knowledge base for onboard decision support system (ODSS). This will guide Astronauts and give

inputs based on their immediate and past searches, requirements, training performance and feedbacks. The prediction of expected behavior of Crew and suggestions to improve the actions based on the training data of each crew member.

- Additionally, GPA contains software based continuous training support for Astronauts for Human space missions. It will have Avionics/CAD model of entire HMSM, which can be expanded/detailed using a Mouse click/button press. This can be used to provide software based training to Astronauts and usable as a continuous onboard simulator system (COSS) to provide the onboard support and situational awareness to crew members.
- COSS will thus provide a "digital twin" of the HMSM and thus facilitate a realistic and portable training. Some of the systems already deployed in ISS are Linux based Thinkpad Systems. Such systems can easily be used as a platform to build such simulations and thus impart better learning to crew and continuous knowledge support.
- GPA can be further augmented (a) using speech to word processing for capturing the real-time experience of Astronauts; (b) Helping in better information search and ODSS enhancement; (c) Adding various catalogs eg. SATCAT, for spacecraft and crew safety.

Scope of the Work:

- The COSS and ODSS system are specifically relevant to the HMSM programme for training and supervision of HMSM-Crew members, Mission team and Crew-Medical teams.
- The scope of GPA can be expanded to the trainees of other countries or private players who will be trained on HMSM or similar type of space-crafts for a nominal fee. This can also be used as a test and certification mechanism for the Crew-able candidates.
- As this system gets realized, it can be released as an open source software for outreach purpose thus motivate and train simultaneously, the vast human resource of India.
- It can be used to train new entrants of ISRO, thus help in training of space officers and orientation towards HMSM mission.

Linkages to Space Programme:

- Future Interplanetary and complex human missions.
- Space based situational awareness programme and debris management.
- HMSM crew simulation and training using COSS and AI based expert system for crew decision making using ODSS.
- Space transportation systems.
- Simulation and institutional training.

Expected Deliverables:

- A C++ based software that incorporates the following components:
- ODSS: An AI based near real-time software incorporating multiple CNN, LSTM, Pooling, and fully connected layers, avoiding overfitting of the data.
- ODSS: Provision for interfacing the queries through speech, data and image as inputs.
- COSS: Visual training and navigation support for HMSM Specific training module.
- GPA: Demonstration of each aspect on a Think pad like system (used in onboard systems eg.

International Space Station) with Linux OS.

- The sample input training data, knowledge base, and experiential data need to be generated for demonstrating the software.
- Subsequently, ISRO will provide these inputs to evaluate the efficacy of algorithm/software.
- The software and the algorithms used should contain the following features:
  - Modularity.
  - High accuracy with ambiguity resolution.
  - Near real-time with upper bound on the query outcome.
- The software interface between ODSS and COSS needs to be clearly brought out.
- Software Design and Test Documents indicating software architecture and test results.
- The periodic T&E of the developed software needs to be carried out at ISRO in phased manner.

RES-URSC 2023-020

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Development of OFDM Modem system for Satellite application

Name of Co PI from ISRO Centre/Unit

Mr. Satish Sharma

Contact Address of Co PI and e-mail id

satish@ursc.gov.in

Area of Research

High data rate & Fading resistant communication, Satellite Communication system, Signal Processing

Summary of the proposed research and expected deliverables

- Multipath fading is one of the critical issue in interplanetary missions involving Lander- Rover communication.
- Orthogonal Frequency Division Multiplexing (OFDM) technique is one of the best method to counter the fading.
- Apart from Fading, it is suitable for High bit rate transmission of Payload data.
- It uses FFT for generating orthogonal carrier.

Scope of the Work:

- Study of various algorithms for OFDM modulation & Demodulation and selection of suitable algorithm to support upto 4 Mbps data rates.
- Design of modem system for transmission and reception.
- Implementation, testing and demonstration of Modem.

Linkages to Space Programme:

The proposal has linkages to Interplanetary Missions, IRS missions.

Expected Deliverables:

- Matlab Simulation Model – System & Bit Level.
- VHDL Simulation & Code.
- Validation in real time on FPGA evaluation board.

RES-URSC 2023-021

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Development of Indigenous Instruction Set Simulator (ISS) & Profiler for SPARC V8 architecture (UT699 and GR740 processor in particular) for Linux OS

Name of Co PI from ISRO Centre/Unit

Ms. Sowbhagya

Contact Address of Co PI and e-mail id

italsow@ursc.gov.in

Area of Research

Software, SPARC-v8 LEON-3 ISA single core and multicore

Summary of the proposed research and expected deliverables

The aim of this project is to develop an indigenous instruction set simulator for SPARC V8 architecture with all resources as in UT699 and GR740 processor– including caches, memory controller, I/O, load Program Counter, simulate interrupts, CPU reset. Should be able to invoke multiple instances in a single system. The ISA developed has to be available in shared memory which will be accessed by custom application program. Block diagram of proposed ISS based system is as in Fig.

The Profiler will be used during debugging, measure software execution times.

Provision to execute all the above in Real time / Fast simulation provision.

Scope of the Work:

This Instruction set simulator will be the basic building block of Software in Loop Simulator and also it will be used as test bed for onboard software development.

Linkages to Space Programme:

Software in Loop Simulation for NGC system of all satellites.

Testing of onboard software for LEON based systems.

LEON emulation

SPARC-V8 emulation including cache memories, on-chip peripherals and memory controller, cache.

I/O emulation

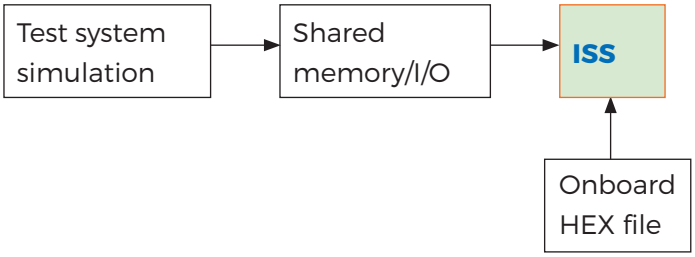
to simulate user-defined I/O devices. The user can provide a module emulating an I/O device, which

can be loaded at run-time. The I/O module has access to the simulator event queue, interrupts and other internal data structures, allowing for accurate and timing true emulation. The I/O module is typically written in C, and can use any feature of the host operating system. This provides high simulation performance and capability to communicate with external simulator frameworks.

Expected Deliverables:

- C++ based instruction set simulator with source code for Linux based systems which includes:
  - SPARC-v8 LEON-3 processor UT699 ISA.
  - Emulation of Memory & I/O.
  - Caches.
  - Interrupts.
  - CPU reset, Program Counter.
  - Debugger.
- Profiler.

Fig: Block diagram of ISS based system



RES-URSC-2023-022

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Real Time Anomaly Detection Using AI/ML for Spacecraft NGC applications

Name of Co PI from ISRO Centre/Unit

Ms. Priyanka V

Contact Address of Co PI and e-mail id

priyav@ursc.gov.in

Area of Research

AI/ML

Summary of the proposed research and expected deliverables

The research work aims at real anomaly identification and its root cause AI/ML techniques. For spacecraft, this is essential for detecting off-nominal situations and responding accordingly. The software should able to classify the parameters to identify the anomaly in real time. A distinction is made between point anomalies, contextual anomalies and collective anomalies. For autonomous systems and anomaly detection, however, a consistent storage all mission data is essential to have a board database for state estimation, pattern recognition and decision-making. Anomaly detection is performed on time-

series data like temperature readings over time for detecting off-nominal situations and states, but also on multi-dimensional like images, mostly to detect science opportunities or filter the amount of data selected for downlink. Support Vector Machines (SVMs) present another exploitable approach to anomaly detection. SVMs are a mathematical procedure for classification and regression that transforms its input data to higher dimensions under the assumption that the data becomes linearly separable by a hyperplane. The anomaly can be software or hardware, autonomous operations and recovery for NGC algorithm.

Scope of the Work:

- The software should able to classify the parameters required to identify the anomaly in real time.
- A distinction has to be made between point anomalies, contextual anomalies and collective anomalies.
- Anomaly detection is performed mainly on time-series data like temperature readings over time.
- for detecting off-nominal situations and states but also can be on multidimensional data like images.
- It should have a consistent storage of all test data and it is essential to have a broad database for state estimation, pattern recognition and decision-making.

Linkages to Space Programme:

The proposal has linkages to All future mission.

Expected Deliverables:

- The anomaly detection tool developed to be run on Linux/Windows platform with source code and front end user interface.
- Simulations and Results to be shown for correct detection of anomaly from existing data.
- Anomaly Detection and Root cause report to be generated.

RES-URSC-2023-023

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Vision Based Pose Estimation for non-cooperate Docking/Inspection satellite using Deep Learning AI algorithms

Name of Co PI from ISRO Centre/Unit

Ms. Shakti Bangare

Contact Address of Co PI and e-mail id

shaktib@ursc.gov.in

Area of Research

Deep Neural Network algorithms for pose estimation

Summary of the proposed research and expected deliverables

A vision-based AI navigation approach to estimate the real time relative pose (3D translation and

rotation) for cooperative and non- cooperative spacecraft is proposed. Select innovative light weight, highly accurate and computational efficient deep neural network and do verification and Validation of pose estimation using experimental results.

Synthetic Dataset generation for 3D animated model has to be done for training, testing and validation using appropriate tool.

From appropriate Deep Learning Algorithms select some best state-of-the art algorithms and evaluate all of them with the same dataset. Evaluate and validate the selected Deep Learning Algorithm on pose accuracy and time trade-off using experimental result.

Scope of the Work:

Solution can be adopted to estimate real time relative pose of cooperative and non-cooperative targets by adding only just small weight in the chaser satellite which can be used for future missions like debris removal, on orbit satellite servicer missions and docking missions.

Linkages to Space Programme:

Solution can be adopted for future missions like on-orbit satellite servicing, debris removal, formation flying, rendezvous and docking missions.

Expected Deliverables:

Vision based Deep Learning algorithms and its implementation to get pose of satellite, Mathematical models for relative dynamics and estimation. Effective Dataset generation tool with proper validation like space images, Deep Learning algorithms evaluation results in terms of computational time and accuracy.

RES-URSC-2023-024

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Development of Signal processing framework for debris detection using space-borne Radar System

Name of Co PI from ISRO Centre/Unit

Mr. K Hussen Basha

Contact Address of Co PI and e-mail id

hussen@ursc.gov.in

Area of Research

Radar & satellite Communication Systems

Summary of the proposed research and expected deliverables

One of the largest problems for the survival of space infrastructures is to safeguard our space assets from collision threats. The large number of operating or abandoned satellites in space, fragments from space vehicles and other celestial objects pose a significant threat to satellites, especially in low earth orbit (LEO). Mid-size debris ($1mm^2$-$10cm^2$) are not easy to detect from ground and are a threat to satellites in orbit.

The proposal is envisaged to involve the following activities:

- Mathematical formulation for debris detection algorithms.
- MATLAB simulation of algorithms/models for Pulsed radar systems, which are cable of debris detection using space –borne radar.
- VHDL implementation of digital signal processing algorithms such as Pulse compression, Matched filtering, clutter reduction, Binary moving window detector, C-Far threshold detection, Doppler filtering, Clustering, Beam forming etc., which are required for Target detection.

Scope of the Work:

The development would consist of:

- Mathematical formulation for debris detection.
- Evolving signal processing framework / algorithms for debris detection using space-borne radar.
- Target and range simulator for end-to- end validation of the proposed algorithms.
- Demonstration of developed algorithms using FPGA/SoC boards.

Linkages to Space Programme:

This research work has got relevance to augmentation of NEtwork for space object Tracking and Analysis (NETRA) project.

Expected Deliverables:

- Mathematical formulation and MATLAB source code for debris detection methodology / algorithms.
- VHDL source code for the algorithms.
- Detailed report capturing the design and test results.

RES-URSC-2023-025

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Algorithms design, development and VHDL implementation for automatic modulation recognition for various analog and digital modulations

Name of Co PI from ISRO Centre/Unit

Mr. Aditya Ganesh

Ms. Shravani Y

Contact Address of Co PI and e-mail id

aditya@ursc.gov.in

Area of Research

Communication and Signal processing algorithm development and implementation in VHDL

Summary of the proposed research and expected deliverables

It is proposed to incorporate modulation recognition capability to develop an FPGA based adaptive telecommand receiver. This proposal is for design, development and implementation in VHDL of various

algorithms for recognition of different types of analog/digital modulation schemes and their associated parameters (Eg: modulations such as FM, PM, PSK (all variants of MPSK), FSK and MSK). This development shall be in a form where it can be integrated with our existing functionality of the receivers. All the designed algorithms to detect, characterize and indicate the type of modulation and its associated parameters based on the received signal upto a received CNDR of the order of 25dBHz.

Scope of the Work:

Currently TTC Receiving systems are implemented in FPGAs for all the space communication systems. The implemented algorithms should be in form where they can be integrated with the current and future receiving systems at URSC. The design should be compatible with the existing designs in terms of sampling rates for easy migration.

Linkages to Space Programme:

Future scientific space missions which require cross-agency support.

Expected Deliverables:

- Theoretical understanding of the designed algorithms for their relative performance.
- MATLAB simulation for all the algorithms/models for various types of modulations.
- VHDL implementation of digital signal processing algorithms.
- MATLAB simulation algorithms/models for recognizing the parameters of various modulations.
- Designed algorithm along with comparative study with the existing algorithms indicating the performance metrics.
- VHDL source code with target as MICROSEMI/XILINX FPGAs along with all necessary documentation including test results.
- Final closure report.

RES-URSC-2023-026

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Robust adaptive integrated translation and rotation control of a flexible inorbit servicing spacecraft with application to free

Name of Co PI from ISRO Centre/Unit

Ms. Chinna Ponnu V

Contact Address of Co PI and e-mail id

chinna@ursc.gov.in

Area of Research

Guidance and Control system

Summary of the proposed research and expected deliverables

Develop a guidance and control scheme in such a way that the spacecraft with a free flying space manipulator system is able to track the command position and attitude signals in the presence of external.

Scope of the Work:

Handles the integrated translation and rotation tracking control problem of a flexible spacecraft in space robotics application

Linkages to Space Programme:

On orbit Servicing(OOS) Missions such as Docking, Berthing, Refueling, Repairing, Upgrading, Transporting, Rescuing, Orbital debris removal, Robotic servicing of a non

Expected Deliverables:

- Given the nominal case, theasymptotic convergence of the system states should be ensured by the proposed control scheme.
- Demonstration of the effect of the designed Guidance &Control strategy through.

RES-URSC-2023-027

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Strengthening of Aluminum Alloys by Severe Plastic Deformation (ECAP) for Spacecraft applications

Name of Co PI from ISRO Centre/Unit

Mr. Aravindram P

Contact Address of Co PI and e-mail id

aravindr@ursc.gov.in

Area of Research

Materials, ECAP, Metallurgy, Aluminum Alloys, Plastic Deformation, Mechanical Strength

Summary of the proposed research and expected deliverables

Severe Plastic Deformation (SPD) is achieved when a material can be repeatedly plastically deformed without a net change of shape, i.e., the overall shape at the beginning of the deformation is the same as that at the end. Materials that have undergone severe plastic deformation exhibit unique properties not usually observed in conventional coarse- grained (CG) alloys. Various methods of SPD are Equal Channel Angular Pressing (ECAP), High Pressure Torsion (HPT), Accumulative Roll Bonding (ARB) etc.

Scope of the Work:

The Scope of the work is to study the feasibility of realization of small cylindrical components like fasteners, pins, Tie rods, etc from raw materials (preferably Aluminium alloys) that were processed by Equal Channel Angular Pressing. The study provides the detailed insight in realization process of spacecraft hardware's, fabricated from ECAP raw material and the opportunity to replace components made up of Stainless steel and titanium.

Linkages to Space Programme:

Cylindrical components, fasteners made up of Stainless steel, Titanium etc used in spacecrafts may be replaced with lighter alloys thus imparting weight reduction in the spacecraft.

Expected Deliverables:

Proto type hardware's like pins, fasteners, cylindrical mechanical components fabricated with lighter alloys.

RES-URSC-2023-028

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Development GMSK modem for high bit rate TM data transfer system

Name of Co PI from ISRO Centre/Unit

Mr. Satish Sharma

Contact Address of Co PI and e-mail id

URSC

satish@ursc.gov.in

Area of Research

Satellite Communication system, Signal Processing

Summary of the proposed research and expected deliverables

- Bandwidth efficiency is the prime requirement for Data transmission from satellites. GMSK stands for Gaussian Minimum Shift keying. It is one of the most bandwidth efficient modulation schemes. It uses Gaussian filter at baseband to achieve the bandwidth efficiency.
- CCSDS recommended GMSK modulation for TM system.
- Already this modulation is used by Herchell& Plank satellites of ESA.

Scope of the Work:

- Study of various algorithms for GMSK modulation & Demodulation and selection of suitable algorithm to support upto 8 Mbps data rates.
- Design of modem system for transmission and reception.
- Implementation, testing and demonstration of Modem.

Linkages to Space Programme:

The proposal has linkages to Gaganyaan missions, GISAT missions.

Expected Deliverables:

- Matlab Simulation Model – System & Bit Level.
- VHDL Simulation & Code.
- Validation in real time on FPGA evaluation board.

RES-URSC-2023-029

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Compiler design for translation of DNN networks from python based AI frameworks to URSC's custom AI chip ISA

Name of Co PI from ISRO Centre/Unit

Mr. Kaustubh Anand Kandi

Contact Address of Co PI and e-mail id

URSC

kaustubh@ursc.gov.in

Area of Research

AI, Software development, compiler design

Summary of the proposed research and expected deliverables

Python based libraries and frameworks like Tensorflow, Caffe and Pytorch and very popular among AI developers for constructing DNN networks and subsequent training. Translating these high level libraries based DNNs to low- level-languages requires design and development of compilers which can convert HLL scripts to the format as required for chip level functioning. This requires knowledge of the chip's ISA and broader proficiency in HLL like python and familiarity with popular AI libraries.

Scope of the Work:

A Python-to-ISA compiler can ease the workflow from software based DNN design and training to real time on-chip deployment of the network. This effort can significantly reduce the time from network conceptualization to flight readiness of the DNN code.

Linkages to Space Programme:

The proposal has linkages to onboard deployment of AI algorithms.

Expected Deliverables:

Python-to-custom ISA compiler code

RES-URSC-2023-030

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Modeling & simulation of packaging effects on MMIC die Performance in HTCC (High temperature co-fired ceramic) based RF Package at microwave frequencies (S-band to Ka-band)

Name of Co PI from ISRO Centre/Unit

Ms. Rashmi Behera

Contact Address of Co PI and e-mail id

rashmib@ursc.gov.in

Area of Research

Communication

Summary of the proposed research and expected deliverables

Monolithic Microwave Integrated Circuit (MMIC) performance varies significantly from its on wafer, when assembled inside a package. Packaged MMIC performance degrades due to package resonance, interconnection & coupling effects. Inside the RF package, resonance effects are due to ring resonances and cavity resonances. Radiation produced by the different circuits in the package couples to adjacent circuits and degrades the module performance. Also wire bond interconnects exhibits extra parasitic inductance and radiate the RF energy. A systematic methodology for comprehensive analysis of the packaging and enclosure effects of packaged MMIC die is one of the prime requirements for many applications. In the proposed research degradation of intrinsic MMIC die performance due to packaging effects will be analysed & mitigation techniques will be studied.

Scope of the Work:

- 3D-Modeling of the High Temperature Co-Fired Ceramic (HTCC) based RF Package.
  - Modeling of the RF package.
  - EM (Electro Magnetic) Simulation of package response using FEM (Finite Element Method) techniques in commercial software.
- 3D-Modeling of RF Package with circuit inside it.
  - Modeling of the RF package with MMIC, passive components, interconnections, base plate and RF connectors etc. This should include both RF and thermal modelling.
  - EM Simulation of Package response with circuity inside it.
- (URSC will provide details of package, circuit & materials used).

Linkages to Space Programme:

MMIC dice are being used in space applications to meet miniaturization and high performance requirements. Packaging of the MMIC dice is necessary to high reliability requirements of space applications.

The package degrades the RF performance of the MMIC die. A study on the packaging & enclosure effects are useful in every application wherever MMIC dice are packaged.

Expected Deliverables:

- 3D-Package model of RF package.
- 3D-Package model of RF package with active, passive and bond wire interconnections.
  - The format of 3D package model shall be compatible with standard EM simulation software (ADS/ HFSS/Microwave office/CST).
- Simulation results of the Package & package with MMIC circuit- S2P file.
- Mitigation techniques to improve packaged MMIC performance which should include the effect of RF absorber and getters and optimization of no. of bond wires.

RES-URSC-2023-031

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Development of Processing Tools for Generation of UV Point source Catalog using AstroSat/UVIT Data

Name of Co PI from ISRO Centre/Unit

Mr. Swapnil Singh

Contact Address of Co PI and e-mail id

swapnils@ursc.gov.in

Area of Research

UV Sky/Computer Algorithms/Machine Learning

Summary of the proposed research and expected deliverables

The Ultra-Violet Imaging Telescope (UVIT) on- board AstroSat provides the highest spatial resolution images in multiple filters both in Near Ultra-violet (NUV) as well as in Far Ultra-violet (FUV).

Numerous proposal driven observations are carried out with UVIT for a specific target of observations. In the first 5 years of operations, UVIT completed observations for over 500 proposals with ~800 unique pointings. The regions ranges in all Right Ascension (RA) and Declination (Dec) except for galactic planes where bright objects would present which would make the UVIT detector reset. UVIT has been operating for 8 years and a large database of images exists from the proposed observations.

While the PI of the proposer would use the main target, there are many foreground and background stars which would be present and they are not studied. Hence, these proposal driven observations can be used to identify the star, its location along with existing other waveband catalogs. This would provide the known source catalog in UV with better astrometry due to its high spatial resolution than earlier catalogs.

The catalog will have position, photometric flux and associated errors derived using standard and well proven methods.

Scope of the Work:

The project would be divided in to two major phases:

Phase 1: In the UVIT images, identify the stars in the field of observations and its position using advanced automatic software/processing tool which can identify and generate the required data for the catalog. The UVIT observations will be compared with other catalogs in UV as well as other wavebands to match for the known sources and derive the photometric flux value for all the stars with associated error bars. It is preferred if Machine Learning Algorithms are used for analysis, which could be scaled for future missions as well. The software would be developed and validated using few months of UVIT data - against some published UV catalogs and matched with visible catalogs.

Phase 2: Obtain all the UVIT observations which are open to the public. At the end of the project, the deliverable would be to provide the UVIT catalog of stars with position and flux in multiple bands (wherever it is available) along with its uncertainties using all 8 years of UVIT data.

Linkages to Space Programme:

AstroSat is an ISRO space science mission and this project will utilize the available data in a direction which has not been carried out using proposal mode observations. This catalog will provide information which would then evolve more science aspects compared to currently done. Such a catalog is not available currently from UVIT.

Expected Deliverables:

An UV star catalog of the observed sky with UVIT. The catalog should include the position of the star in RA and DEC with errors associated with it and the flux in multiple bands (whichever bands available from the observations) along with associated error bars. The catalog should be available in ASCII as well as FITS formats.

Along with the catalog, a log sheet of all the data which were used to create the catalog and those observations which were not used with reasons should be available.

A detailed manual along with documentation of the methods and algorithms used to be provided. The algorithms which are to be developed in Python (preferably) also should be provided to ISRO.

RES-URSC-2023-032

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

High Speed Accelerators Development for Software In Loop Simulation (SILS)

Name of Co PI from ISRO Centre/Unit

Ms. Pratibha Srivastava

Contact Address of Co PI and e-mail id

pratibha@ursc.gov.in

Area of Research

High performance computing

Summary of the proposed research and expected deliverables

The objective of this project is high speed accelerators development for SILS for NGC applications targeting to carried out thousands of MC simulations quickly (less than a half day).

The software simulator is a software- based platform used to carryout simulation which include mathematical models, estimators, NGC algorithms and logical and functional blocks on workstations. The verification and validation of NGC spacecraft advanced R & D Projects demands thousands of digital simulations (Monte Carlo simulations).

Hence, advanced techniques (Parallel Processing and improved computational techniques) are

required to have faster execution time (>=50x where x is real time) which can be carried out with software accelerators and hardware accelerators for Software In Loop Simulation (SILS) platforms. The NGC algorithm is run using an Emulator for the instruction set (SPARC V8) interacting with Simulations models that are generally written in C/C++ and python.

Scope of the Work:

This can be invoked through various techniques on RHEL Linux based platforms, parallel processing and containers etc. However, in-order to accelerate further execution time improvement in single Work Station advanced techniques can be used, like usage of GPU or TPU based accelerators. Essentially, this research work aims running the emulator (grmon based Leon emulator software) and other C++ applications on GPU systems to speed up the simulation operations.

Linkages to Space Programme:

The scope of this research work shall be applicable to all deep space missions, interplanetary landing missions, formation flying, docking and manned missions where multiple simulations will be needed to bring out performance of the system in all kinds of nominal and non-nominal scenarios.

Expected Deliverables:

- The accelerator tool running on a RHEL 7 or above platform for C/C++ and python-based applications.
- The accelerator tool for running SPARC instruction set simulator (for LEON3 processor) on a GPU based platform with the custom binary file for loading the software.
- The tool should be capable of importing any custom software for linking with the accelerator for both application software and Emulator.
- Results should be demonstrated.

RES-URSC-2023-033

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Smart wireless accelerometer along with receiver

Name of Co PI from ISRO Centre/Unit

Mr. Prashant A R

Contact Address of Co PI and e-mail id

prashant@ursc.gov.in

Area of Research

Sensors and wireless communication

Summary of the proposed research and expected deliverables

Vibration tests are conducted on all spacecraft before launch. Vibration tests helps in ensuring the structural integrity of the spacecraft. Nearly, 200 numbers of wired accelerometers are mounted at various locations of the spacecraft to capture the dynamics of the spacecraft during vibration test. The

cables are then connected further to the patch panels at vibration test facility which are terminated to signal conditioners. The cable adds additional weight to the spacecraft during testing and difficult for proper routing. The cable is then connected to the patch panel at vibration test facility which involves human interventions and consumes precious project schedule time. In order to simplify all these process wireless accelerometer is proposed which should have capability to measure the acceleration in the given frequency range and transmit the measured data with minimum latency period. The wireless accelerometer should also have smart features similar to industry standard TEDS format.

The receiver system should be able to receive the acceleration data in engineering format from the wireless accelerometer. Provision should exist to provide the measured data in analog form as well as in digital format with time stamping.

Scope of the Work:

- Wireless accelerometer should have minimum of below mentioned feature.
  - Axis of measurements: Tri-axial preferred.
  - Mass: Typically, less than 10 grams.
  - Frequency Range: minimum upto 200 Hz.
  - Measurement range: 500 g.
  - Form factor (LxWxH): typically, of 25 mm x 25 mm x 12 mm.
  - Smart sensor Feature: Industry.
  - Standard TEDS.
  - Transmitter coverage area: Radial distance of 10 meters.

Receiver system should have minimum of below mentioned feature

- Receiver coverage area: Radial distance of 10 meters.
- Output 1: Analog data equivalent to acceleration being measured.
- Output 2: Digital data equivalent to acceleration being measured along with time stamp.

Linkages to Space Programme:

This is for ground-based application and can be used during vibration test of a spacecraft and their subsystems. This can also be used for on-site vibration in-situ vibration measurement.

Expected Deliverables:

- Smart wireless accelerometer.
- Receiver system.
- Design and Test document.

RES-URSC-2023-034

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Database centric Software life cycle and management tool with Machine learning

Name of Co PI from ISRO Centre/Unit

Mr. Prashant Kulshreshtha

Contact Address of Co PI and e-mail id

prakul@ursc.gov.in

Area of Research

Database, Server, Machine learning

Summary of the proposed research and expected deliverables

- Though there are tools available for Software life cycle, but none of them having comprehensive approach. Improvising with machine learning is one totally new area, which will ensure efficient ways to connect them together.
- Onboard computer requirements covering requirement ranging from Interfaces, NGC Algorithms, Fault handling, Data interfaces, HK monitoring, Calibrations, Autonomy functions. These requirement gets refinements/update during due course of project life cycle. Basically all these requirements are required to be collected and organized. (Requirement/Change Managements).
- Requirement association: Requirements are associated with others as constraint/dependency etc. Requirement shall be able to connect among them. Once connected, Requirement listing can be done Top- down, dependency, Constraint, Pending status, Reviews, Recommendations etc. Tool should be able to generate Requirement documents: Functional requirement Documents, Software Requirement documents, Minutes of meetings (FRR/SRR), Interface Control documents.
- Design phase: Onboard design shall be connected with requirement with bi- directional traceability along with multiple version release. SRS, SDD, TC, TM association/generation.
- Testing phase: Multilayer (OILS/HILS/Spacecraft level/ Special Test) of testing results, findings/ recommendation shall be linked with each requirement, design, test plan.
- People/Schedule management: Dependency, Input pending, timeline, basically predictability and observability for project realization.
- Machine learning shall be able to connect/improvise/statistical analyze all the points of Requirement, Design, Testing, Reviews, Recommendations, Schedule, People.
- So this unique integrated approach would be offering single window platform to function Software design team. Designers, Project, Management etc., to function in efficient way and in a flawless manner.

Scope of the Work:

- Right from beginning of Project life cycle to Mission operation, and support. This would be providing the connectivity of technical details.
- This unique integrated approach would be offering single window platform to function Software design team.
- Designers, Project, Management etc to function in efficient ways, and flawless manner.

Linkages to Space Programme:

Software development life cycle for LUPEX, Mars Landing mission or other complex missions.

Expected Deliverables:

- Tool with Database (SQA/Oracle/...), Front end GUI, multi-node connectivity, Document import (Word/Excel, Txt , PDF, ..).
- Tool should be platform independent (Window/Linux).
- Change tracking, Statics generation.
- Documentation output: SRS, SDD, TC, TM, Minutes of meeting etc.
- **It may be a combination of multiple technologies, but they all should be unified and provide a seamless interface to the various users.

RES-URSC-2023-035

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Modeling & design of GaN HEMT amplifier at S- band frequencies

Name of Co PI from ISRO Centre/Unit

Mr. Srinivasrao Bollu

Contact Address of Co PI and e-mail id

sbollu@ursc.gov.in

Area of Research

Communication

Summary of the proposed research and expected deliverables

Circuits based on gallium nitride high electron mobility transistor (GaN HEMT) have demonstrated exceptional performance in a wide range of high-power and high- frequency applications. GaN HEMT are widely used in space, radar and mobile communication systems to achieve high power and high efficiency systems. As a critical intermediary between GaN HEMT devices and circuit-level design, GaN HEMT circuit model play a pivotal role in the design, application and development of GaN HEMT device based circuits. An equivalent circuit model is developed by constructing an electric circuit based on standard components that behaves in a manner analogous to the behavior of the actual device during application. As shown in Fig. 1, an equivalent circuit can be divided into two parts: the intrinsic part and extrinsic one. The intrinsic part usually refers to an ideal transistor, while the extrinsic part usually refers to the structures used to construct the HEMT. By using an equivalent circuit model, device characteristics related to the desired PA performance may be identified and modified in simulation. An equivalent circuit model is useful in the design of circuits, and by basing the model parameters on measurements of specific devices it can achieve higher precision in terms of electrical properties in a designed circuit than a physics based model. In the proposed research work development of the equivalent circuit model will be described for a commercially available GaN HEMT device. Also, a harmonically tuned class-AB power amplifier will be designed and fabricated using a commercially available GaN HEMT device.

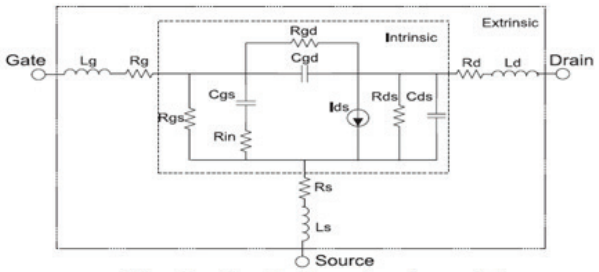


Fig. 1. Equivalent-circuit model

Scope of the Work:

- Extraction of the equivalent circuit model for discrete GaN HEMT die using manufacturer physical model (URSC will specify the GaN die).
  - Extraction of Intrinsic & extrinsic circuit elements of GaN HEMT at design frequency & bias conditions.
  - Extraction of non linier capacitances (C_{gs}, C_{gd}, C_{ds}) with respect to V_{ds}/V_{gs}.
  - Analytical Expressions for C_{gs}, C_{gd} & C_{ds}.
  - Extraction of Nonlinear trans-conductance.
- Design of harmonically tuned amplifier
  - Design of stable amplifier meeting design goals (Frequency Band: 2.1-2.3 GHz, 40 dBm output power and 60% PAE).
  - Design of fundamental & harmonic termination networks (input & output) at design frequency.
  - Stability, gain, PAE, output power simulations.
  - voltage and current wave form plots at drain & gate.

Linkages to Space Programme:

Conventionally, Travelling Wave Tube Amplifiers (TWTAs) have been widely used to attain high output power in satellite transponder applications. Recently, gallium nitride high electron mobility transistors have been used as solid state power amplifiers (SSPAs) to attain high output power that cannot be generated by conventional gallium arsenide field effect transistors. SSPAs are increasingly replacing the travelling wave tube amplifiers (TWTA's) used in the satellites. GaN HEMTs offer higher efficiency due to high voltage operation. GaN provides orders of magnitude longer life than GaAs devices due to high thermal conductivity of SiC substrate. Due to these advantages more compact & highly reliable power amplifier modules can be realized using the GaN HEMT dice. The developed power amplifier module can be used in telemetry transmitter of the satellite at S-band frequencies for deep space missions.

Expected Deliverables:

- Equivalent circuit model of GaN HEMT.
- Simulation results of the power amplifier circuit.
- simulated layout of the circuit in DXF/GERBER format.

RES-URSC-2023-036

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Enhanced spectrally aware RF front end of Receiver under various types of practical non-linearities

Name of Co PI from ISRO Centre/Unit

Ms. Sandhya Yogi

Ms. Jyoti A K B

Contact Address of Co PI and e-mail id

sandhyay@ursc.gov.in

Area of Research

Radio Frequency Front end for S-Band TC receiver

Summary of the proposed research and expected deliverables

The proposed development is expected to work at S-Band over the dynamic range of -20dBm to -130dBm and also the concept to be easily extendable to other frequency bands such as X, Ka, Ku etc. Radio receivers being used in spacecraft environment are bound to work over a RF dynamic range varying between -20dBm to -130dBm based on the orbital dynamics. Almost all of the RF radio receiver's performance is bound to be limited by the nonlinearities that are inherent to analog circuit processing. This is due to the presence of strong unwanted signals close to the bandwidth of the intended signal or due to the excess power in the intended signal based on the distance. In both cases, receiver BER gets deteriorated greatly. In this proposal, it is intended to address this aspect of equalization of nonlinearities to improve the BER performance of the receiver. Its proposed to develop RF front end of S-Band TC receiver which is enhanced and spectrally aware and equalizes itself based on the received signal for its inherent non-linearities.

Scope of the Work:

To develop a proof of concept and hardware model of a spectrally aware S-band TC receiver in order to enhance its linearity over the RF receiver dynamic range of -30dBm to -130dBm. To point out pros and cons of the state- of-the-art methods, and then develop the concept for the proposed radio receiver RF front end.

Linkages to Space Programme:

The proposal has linkages to Future Miniaturized TTC Receiver for space missions.

Expected Deliverables:

- Proof of concept in hardware for the spectrally aware S-Band RF radio receiver front end.
- RF design software simulations and hardware design details.
- All design and simulation files (MATLAB, ADS).
- Final closure report.

RES-URSC-2023-37

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

GUI based MIL STD 1553B Spacecraft Onboard data analyzer

Name of Co PI from ISRO Centre/Unit

Ms. Suma Hiremath

Contact Address of Co PI and e-mail id

sumu@ursc.gov.in

Area of Research

Onboard Data Analysis tool

Summary of the proposed research and expected deliverables

The MIL STD 1553B communication is prevalent in all classes of satellites from IRS series, IMS series, Macro sat series, IRNSS series, GISAT series to interplanetary missions.

Mission critical data is being handled that includes various sensors, actuators, antenna tracking systems, satellite positions systems, payload systems.

Bus Monitor (BM) tool is used in all phases of testing from developmental to integrated phase to monitor Bus Controller (BC) & Remote Terminal (RT) performance.

Today the existing tool finds place in capturing the needed data for the defined time. Further activities of probing, analyzing, ascertaining & arriving at conclusion is being carried out by the Designer.

The need of the hour is to have a GUI based advanced tool that aids in assessing behavior of subsystems & generating reports from voluminous data with click of button.

The requirement is highly applicable for Gaganyaan projects with multiple chains architecture to analyze the data from multiple Bus Controllers & across chains.

Scope of the Work:

Design & deployment of the tool for the given requirements

- Reporting the behavior of specified parameter in terms of periodicity, jitter, deviations if any & representing graphically or in terms of data values as needed for defined time duration.

Reports on Bus Controller scheduling with respect to

- cycle numbers, margins, bus load etc.
- assessing deviations such as cycle skipping, cycle overflow, margins violations, cycle jitters.
- Reports on Remote Terminal in terms of timing.
- data protocol being followed.
- violations (by comparing with previous records).

Capturing all spacecraft commands executed & telemetry independently from single source (without additional inputs from TC sent or HK TM) to assist probing in case of any observation either during Designer level testing or S/C level testing

Report on subsystem behavior across multiple chains in Gaganyaan

- Comparing BC scheduling across multiple chains, generating scheduler tables & capturing differences.
- Comparing RT's messages transactions & highlighting differences across multiple chains.
- Assessing performance of subsystem in terms of parameter behavior across chains.
- Assessing SM-OBC performance across two Bus Controllers (MC & NGCE) & across multiple chains.
- Assessing MC synchronization behavior across chains & reporting.

Linkages to Space Programme:

Applicable for all projects with MIL-STD- 155B interface requirements.

More apt for Gaganyaan Missions with Multiple chain architecture that demands two Bus Monitors per chain.

Expected Deliverables:

- Commands history generator.
- House-keeping Telemetry report.
- Identified parameter behavior wrt specifications.
- Identified channel & frame number detection & behavior graph.
- Cycle margins/violations report.
- Timing assessment in terms of periodicity, jitter, deviations etc.
- Bus controller/Remote Terminal Health check.
- Bus load calculation report.
- Scheduler table generation report 10.Identify unintended transaction or unintended sequence of transactions & report.

RES-URSC-2023-038

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Dynamic Multi Star Field Simulator (DMSS)

Name of Co PI from ISRO Centre/Unit

Bhanu Kartikeyan G

G. Murali Krishna Bhagavan

Contact Address of Co PI and e-mail id

bhagavan@ursc.gov.in

Area of Research

Optical simulator with high resolution display

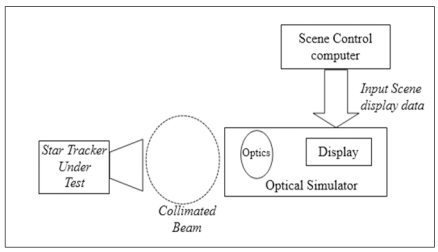
Summary of the proposed research and expected deliverables

The upcoming Space missions like ASTRIX L2 demands sub arcsec simulators to demonstrate the high pointing mission requirements.

The DMSS is a display system that generates a star field image from a star catalogue to simulate a real sky and projects it onto a star tracker of designated field of view. This simulator is used to verification and validation of star sensor for spacecraft application.

DMSS (Ref Fig) comprises of a PC driven high-resolution screen on which star pattern is generated and a collimating optics to project star pattern into a star tracker. The collimator produces star filed image from the diverging incident beam generated by the display. The output rays from the simulator enter Star tracker input and make images as if the light were coming from the real sky.

DMSS is expected to simulate up to 50 stars simultaneously in the given field of view up to a visual magnitude of 6.



Scope of the Work:

The proposed research should provide a solution for simulation stars on a high- resolution screen to achieve star simulation accuracies of 0.1 arcsecs or better.

The solution may comprise of:

- High resolution medical grade screen.
- Innovative Interpolation techniques for achieving sub-arcsec simulation accuracies.

Linkages to Space Programme:

The proposal has linkages to future On-orbit servicing missions and for on-orbit manufacturing & assembly in future.

Expected Deliverables:

- High resolution screen.
- Mechanical assembly to hold Screen.
- Interface software to drive screen with dynamically generated star data and does the required interpolation.
- before star display on the screen.
- Alignment of the system – star tracker to screen – within 1 arc sec or better.
- Demonstration of the developed solution for accuracies better than 0.1 arcsec or better.

RES-URSC-2023-039

Name of ISRO Centre/Unit

U R Rao Satellite Centre, Bengaluru

Title of the research proposal

Spacecraft Docking Soft Impact Dynamics Modelling and Simulation Using Two Ground Based Robotic Manipulators

Name of Co PI from ISRO Centre/Unit

Mr. Yajur Kumar

Contact Address of Co PI and e-mail id

yajur@ursc.gov.in

Area of Research

Aerospace and Robotics

Summary of the proposed research and expected deliverables

- The objective of this development is to emulate docking and proximity operations on-board of spacecraft for verification and validation.
- This shall include developing the mathematical model with high fidelity simulation system to enable soft-docking behavior under physical contact using force / torque measurement.
- When a physical contact happens between target and the docking vehicle the contact force and moment generated by the docking hardware will be feedback to the satellite simulator to emulate the equivalent motion.
- In this respect, two ground robotic manipulators are used to simulate satellite relative motion.
- Further, they provide data to the HILS (Hardware-in-loop simulation system) control command based on contact.
- When reacting over a physical contact during docking operation, the end-effector of the robots shall dynamically behave like the on-orbit satellite being simulated.
- This is equivalent to impendence matching.
- This simulator includes a real time controller interface linked to computer based numerical simulator of satellite orbital and attitude dynamics.
- The feedback loop is, hence, closed on the real force sensed at the docking interface during the contact.
- The feedback force is used as deriving input to satellites dynamics numerical simulation.
- The mathematical models shall include separate cases for:
  - Co-operative Docking Behavior.
  - Un-cooperative Docking Behavior.

Challenges:

- Hybrid contact dynamic model using contact force and torque (passive compliance control and virtual contact model).
- High bandwidth contacts dynamics at impact and very short duration of contract time duration

- Time of contacts are shorter than Inherent delays of robot controllers, Stability issues to be handled.
- Compensation of non-contact forces and torques (gravity effects).
- Analysis of system parameters mass, stiffness and damping of the contact parameters.

Scope of the Work:

- Space docking contact dynamics ground simulation.
- Verification/validation of soft docking and validation contact algorithm under various non- nominal conditions.

Linkages to Space Programme:

The project has linkages to future space science missions.

Expected Deliverables:

- Mathematical model for contact dynamics, with contact force for both co-operative and un-cooperative docking.
- Mathematical model for torque measurement equipment for robot system.
- Non-contact force and torque Compensation scheme.
- Stability analysis.
- Demonstration of all the developed mathematical models on the URSC RSL robotic platform.

NATIONAL REMOTE SENSING CENTRE
HYDERABAD

RES-NRSC-2023-001

Name of ISRO Centre/Unit
National Remote Sensing Centre, Hyderabad

Title of the research proposal
Liquid Neural Network (LNN) based deep learning approach for change detection of infrastructure & its prediction using satellite images

Name of Co PI from ISRO Centre/Unit
Mr. Subrat Kumar Acharya

Contact Address of Co PI and e-mail id
subrat_acharya@nrsc.gov.in

Area of Research
Satellite Image Processing, Pattern Recognition, Machine Learning, Deep Learning

Summary of the proposed research and expected deliverables
Change detection and prediction using satellite data have significant applications in various domains such as new build-up area detection, urban development analysis, disaster management, and agriculture. Traditional methods often struggle to handle the complexity and diversity of satellite data. Liquid Neural Networks (LNNs) provide a novel approach to address these challenges by offering dynamic and adaptive computation. This proposal outlines a research project focused on utilizing LNNs for change detection and prediction tasks using satellite imagery.

LNNs are more dynamic, adaptive, efficient, and robust than traditional neural networks and have many potential use cases for satellite image data analysis.

This research project aims to leverage the applicability of Liquid Neural Networks (LNNs) based deep learning method for change detection and prediction tasks using multi-temporal satellite data. The outcomes of this project have the potential to enhance our capabilities in understanding and managing various environmental and societal changes. By combining the adaptability of LNNs with analysis of satellite imagery, it is proposed to create more accurate and efficient tools for change analysis.

Scope of the Work:

Develop a Liquid Neural Network (LNN) Architecture: Design and implement an LNN architecture suitable for analyzing multi-temporal satellite imagery for change detection and prediction.

Dataset Collection and Preprocessing: Gather multi-temporal satellite datasets that encompass various types of changes, such as land cover changes, urban expansion, natural disasters, etc.

Pre-process the data to ensure consistency, alignment, and suitability for training LNNs.

Change Detection: Train the LNN model to identify changes between pairs of satellite images taken at different times. The model should be capable of highlighting regions with significant alterations.

Change Prediction: Extend the LNN's capabilities to predict potential changes in future satellite images based on historical data. This involves training the model to learn patterns and trends in changes over time.

Evaluation Metrics: Define appropriate evaluation metrics for both change detection and change prediction tasks. Common metrics like precision, recall, F1-score, and accuracy can be used.

Linkages to Space Programme:

LNN is an emerging technology for reducing the turnaround time to detect any changes in the spectral and temporal progression of biophysical and physical phenomena.

This work will enable us to address some of the existing gap areas of satellite data analysis using LNN architecture, its suitability, feature extraction, change detection and change prediction. It will be used for the detection of change in land, road, build-up area, de-forestation etc., and its change prediction.

Expected Deliverables:

- A novel Liquid Neural Network architecture optimized for change detection and prediction tasks using multi-temporal satellite data.
- Detailed Methodology & Algorithms/Techniques.
- Trained models capable of accurately detecting changes in satellite imagery and predicting potential changes in future images.
- Strengths in LNN approach for satellite data analysis and Inventory of dynamic change classes.

RES-NRSC-2023-002

Name of ISRO Centre/Unit

National Remote Sensing Centre, Hyderabad

Title of the research proposal

Groundwater regime impact and climate change towards sustainable development goal

Name of Co PI from ISRO Centre/Unit

Mr. Rajarshi Saha

Contact Address of Co PI and e-mail id

rajarshi_s@nrsc.gov.in

Area of Research

Remote Sensing & GIS

Summary of the proposed research and expected deliverables

Earth's climate change is subject to internal variability within the climate system itself and to external factors which may be natural or anthropogenic and it is no longer a hypothesis (IPCC, 2013). However, contemporary changes and warming trends have been attributed solely to anthropogenic influences.

Groundwater is a vital source of fresh water. In terms of human use of groundwater, 1.5–3 billion people rely on groundwater as their primary source of drinking water. The rapid increase in agricultural and industrial groundwater use in the last few decades, has created better livelihoods and food security

for the world's population. However, there are legitimate concerns and reports of over-exploitation of groundwater, driven by increasing water demand from rapid urban and industrial development, and expansion of irrigated lands. In many areas of the world, groundwater exploitation is carried out in an unsustainable way, with rates of withdrawal exceeding replenishment by recharge. Left unattended, this current trend of increasing societal dependence on non-renewable groundwater will undermine the resilience of human systems to water shortages and threaten ecological systems that depend on them.

Indian sub-continent and the Great Plains of the US, show significant depletion in groundwater.

The impact of groundwater systems on climate change and vice versa, through changes in groundwater abstraction on climate change through changes in land use/cover is of great concern. Studies of the potential impact of groundwater on climate change assume one of burning topics at present. Projections of climate change due to alterations of groundwater regime and vice versa change will require sophisticated reliable models.

However, many uncertainties still exist about specific microphysical processes and complex interactions that govern the climate system in terms of groundwater dependent ecosystems (GDEs).

Presently, climate change and groundwater have remained on the front burner of world leading scientific studies, and it remains topical at national and international levels because of its influence on policy and decision making in socioeconomic domains.

Scope of the Work:

India is the largest groundwater exploiter in the world and exploits more than 25% of the total world's exploited groundwater. More than 60% of irrigation in India is through groundwater, and around 90% of rural and 30% of the urban population's drinking/domestic need is fulfilled by it.

Groundwater is dynamic in terms of time and space which greatly depends on the recharge and exploitation conditions along with geological conditions. The overdependence of groundwater has resulted in indiscriminate abstraction of groundwater resources without considering the recharge capabilities. If measures are not adopted water shortages can threaten ecological systems that depend on it. Thus, it may affect the geo-environment and ultimately the climate. India is already impacted by this groundwater abstraction. Studies has already demonstrated, groundwater storage depletion in many hydrogeological provinces, which is further aggravated by population boom and increase in anthropogenic actions.

Similarly, climatic impact can also affect the groundwater. Moreover, many uncertainties still need to be answered and complex interactions that govern the climate system in terms of GDEs needs a detailed assessment. The temp rise of around 0.63 °C, with erratic rainfall pattern in India demonstrating a shift in climatic condition. Frequent drought, flood and other associated climatic condition showcase this phenomenon quite clearly with proper scientific databases of recent past.

Therefore, this needs to critical assessment of the groundwater regime in combination with underlying factors responsible for the climate change. In this regard, a scientific database/model is required to address the groundwater regime impact on climate change.

Linkages to Space Programme:

This proposal is linked with ISRO's 2030 vision of providing safe & sustainable drinking water to the country for water security management along with sustainable climate.

Expected Deliverables:

- To create an integrated framework model of GRICC on seasonal periodicity to showcase the specific physical processes along with complex interactions that govern the climate system in terms of GDEs and GDEs dependent climate change causative indices.
- To quantify the effect of anthropogenic change on the total water budget and average groundwater level.
- To assess the impact groundwater regime deviation on geo-environment and climate.
- To demonstrate climate change hotspot regions related to groundwater regime deviation.

RES-NRSC-2023-003

Name of ISRO Centre/Unit

National Remote Sensing Centre, Hyderabad

Title of the research proposal

Downscaling of Climate Datasets for Climate Change Impact Assessment

Name of Co PI from ISRO Centre/Unit

Mr. Anurag Mishra
Mr. Saksham Joshi

Contact Address of Co PI and e-mail id

anurag_mishra@nrsc.gov.in
saksham_joshi@nrsc.gov.in

Area of Research

Climate Change Impact Assessment

Summary of the proposed research and expected deliverables

The General Circulation Models (GCMs) provide projections of climate variables under different emission and socio-economic scenarios. GCMs are three dimensional numerical models that employ fundamental principles of conservation of energy, mass, momentum to mimic the land-surface, oceanic, atmospheric processes and their interaction.

Their development is necessary for understanding the response of earth's climate system to increasing concentration of greenhouse gases (see Taylor et al., 2012; Eyering et al., 2016). Since inception of their developments, GCMs have evolved in terms of incorporating more components of earth system, better representation of earth system processes, and better spatial resolution. Despite these advancements, the coarse spatial resolution severely limits the direct application of GCM output in regional and sub-regional analyses and decision-making (Wilby & Wigley, 1997). The direct application of GCM outputs is particularly challenging in areas with diverse topography, land cover and drainage patterns.

At present, under CMIP6, roughly 20 GCMs provide climate data for variables (precipitation, temperature, relative humidity, downwelling shortwave and long wave radiation) at 1 degree spatial resolution. Very few GCMs provide climate data projections at spatial resolution of <50 km.

Over India, IITM Pune provides high resolution climate simulations at ~35 km spatial resolution and products from COordinated Regional Downscaling EXperiment (CORDEX; Giorgi et al., 2015) are available at 0.44 degree (~50 km) spatial resolution.

NASA's Earth Exchange Global Daily Downscaled Products (NEXGDDP; Thrasher et al., 2022) are available at 0.25 degree spatial resolution for 6 climate variables, namely, precipitation, maximum temperature, minimum temperature, relative humidity, specific humidity, and surface wind speed for historical, ssp126, ssp245, ssp370, and ssp585 from 35 GCM models under CMIP6.

The downscaled climate data projections are required for assessment of likely impacts of climate change over small watersheds and administrative units (districts/ taluks/ blocks) in India which are not possible with existing coarse resolution datasets.

Scope of the Work:

The proposed study aims at generating downscaled projections of CMIP6 datasets for selected climate variables (precipitation, temperature etc.) under newly formulated shared socio-economic pathways at a spatial resolution <=25 km.

Linkages to Space Programme:

The proposed research will underpin the efforts towards climate change impact assessment and adaptation which aligns with the goals of National Water Mission of Govt. of India under National Action Plan on Climate Change.

Expected Deliverables:

- Methods to downscale climate datasets to a spatial resolution of <=25 km
- Downscaled projections of climate variables for climate change impact assessment studies.

RES-NRSC-2023-004

Name of ISRO Centre/Unit

National Remote Sensing Centre, Hyderabad

Title of the research proposal

Understanding the drivers and responses of flash droughts in Peninsular India

Name of Co PI from ISRO Centre/Unit

Ms. Nidhi Misra

Mr. Mohamed Ahamed J.

Contact Address of Co PI and e-mail id

nidhi_misra@nrsc.gov.in

mohammedahamed_j@nrsc.gov.in

Area of Research

Water Resources, RS & GIS

Summary of the proposed research and expected deliverables

Droughts have significant impacts on agriculture, and contribute to other extremes including enhanced heat extremes and declining water security.

Recent studies have identified that some droughts are associated with an unusually quick drying of the land system – called flash droughts.

Precipitation deficits combined with higher atmospheric evaporative demand dries the land surface faster during these events. Consequently, concurrent observations of the land- atmosphere system are required to characterise and understand these events.

With limited availability of fine scale observations, flash droughts in India have been primarily studied using modelled soil moisture datasets.

Current understanding indicates that flash droughts in India primarily occur during the summer monsoon season, except in Peninsular and Himalayan regions. The frequencies of these events are expected to show multi-fold increases in a warming climate which can have substantial impacts on agriculture and water security.

Scope of the Work:

This project will aim to

- Understand flash droughts by characterising events in Peninsular India using recently available regional observed datasets.
- To study the evolution of drought drivers and responses during recent historical events using flux tower observations, and draw in regional inferences from remote sensing datasets.
- A protocol for crop loss assessment due to drought has to be addressed integrating geospatial data products and crop models in such disaster events The results will help understand flash drought characteristics and contribute to enhancing our capability to monitor, predict and manage the impacts of these events.

Linkages to Space Programme:

This proposal is linked with future ISRO activities i.e. NISAR and TRISHNA missions , which primary aims to provide land surface observations like soil moisture, land surface temperature, actual evapotranspiration from satellite based observations. Remote sensing observations from these missions will be helpful to determine the flash drought conditions from space based input.

Also Under National Hydrology Project (NHP), National Evaporative Flux Monitoring System and National Hydrological Drought Information System are being developed across country.

Research in this area will help in the development of decision support system (irrigation advisory) for irrigation water management and early warning indicator of crop damage.

Expected Deliverables:

- Identification of flash droughts characteristics using remote sensing observations.
- Identification of flash drought drivers and response with flux tower data.
- Protocol for crop loss assessment.

RES-NRSC-2023-005

Name of ISRO Centre/Unit

National Remote Sensing Centre, Hyderabad

Title of the research proposal

Development of Hydrologic and Hydraulic Model for Early Warning of Glacial Lake Outburst Floods

Name of Co PI from ISRO Centre/Unit

Mr. B.Simhadri Rao

Contact Address of Co PI and e-mail id

simhadrirao_b@nrsc.gov.in

Area of Research

RS &GIS Applications Hydrologic Disasters

Summary of the proposed research and expected deliverables

Glacial Lake Outburst Floods (GLF) are increasing in trend over Himalayan region during past few decades. To mitigate the risk due to GLOFs it is important to have an early warning system for the glacial lakes. In this context it is proposed to develop a methodology and framework which provides prior information on impending floods caused by rainfall/GLOFs and the expected flood inundation extent.

The developed model must comprise of hydrological and hydraulic components. The hydrologic model must be able to generate discharge hydrograph at the specified location on the river on daily basis using globally available rainfall forecast data sets.

When the peak of discharge hydrograph crosses a threshold limit the hydraulic model must simulate the corresponding flood inundation extent and water level. The hydraulic model developed must use latest high resolution Digital Terrain Model as an input for simulating the flood extent.

The model should also be able to identify the infrastructure elements such as settlements, roads, etc, that will be affected by the flood event. The model should provide an alert to the system managers when the water level at the specified location on the stream crosses the identified threshold level.

Scope of the Work:

The Glaciers and associated glacial lakes are common in high altitude regions like Himalaya mountains. These glacial lakes at times cause sudden flash floods called Glacial Lake Outburst Floods resulting in loss of human lives and huge economic losses.

In order to minimize the losses due to GLOFs it is essential to have an Early Warning System (EWS). The EWS provides advance warning to the people living in the vicinity of lakes for move to safer places in case of impending floods from glacial lakes.

This area of research is in the beginning phase worldwide. Hence, it is proposed an EWS to be developed for selected glacial lake which later can be scaled up for multiple lakes.

Linkages to Space Programme:

NRSC has been involved in preparing inventory and monitoring of glacial lakes for the past decade. NRSC under National Hydrology Project also prepared glacial lake database for entire Indian Himalayas, prioritized critical glacial lakes and assessing GLOF risk for selected glacial lakes. In continuation of this activity, it proposed to develop EWS to mitigate risk due to GLOFs.

Expected Deliverables:

- A EWS model and framework for GLOFs.
- The calibrated & validated hydrologic and hydraulic components of EWS model.

RES-NRSC-2023-006

Name of ISRO Centre/Unit

National Remote Sensing Centre, Hyderabad

Title of the research proposal

Geobotanical indicators for targeting hydrocarbon, PGE and rare earth minerals

Name of Co PI from ISRO Centre/Unit

Dr. Arindam Guha

Contact Address of Co PI and e-mail id

Area of Research

Hyperspectral remote sensing and mineral exploration

Summary of the proposed research and expected deliverables

A plant is sensitive to the geologic environment in which it grows and may show characteristic variations in its form, size, color, and rate of growth based on the geological substrate on which it grows. Geobotany uses these environmental variations. It involves a visual survey of vegetation based on recognition of a specific plant population and the presence and absence of certain plant varieties associated with particular elements. Sometimes, proxy minerals related to the economic mineral may also influence the plant's growth pattern.

It is also recognized that some species are associated with abnormal mineral concentration Certain species such as Viola calaminaria spp. acts as an indicator plant for base metal prospecting. Prolific growth of Impatiens balsamina and Nyctanthes arbortristis (Seuli) in the rainy seasons are found to be associated with the outcrops of lead-zinc deposits at Zawar.

Similarly, Leucas aspera is found above the mine dump of Rajpura polymetallic deposits. Bryophyte moss has been a good indicator of U mineralization in the Siwalik sandstone of Himachal Pradesh, India.

Sometimes, specific plant species co-occur with certain mineral deposits across the geological terrain, while few species grow with particular mineral in specific location.

It has been also observed that the normal growth of certain plants is also affected by the excess presence of certain harmful toxic trace elements on or near the mineralization. Dwarfing of plants and total absence of certain species (eg. Sal (Shorea robusta) over the Kansa nickel deposit, Orissa) is also used as significant geobotanical indicator.

Therefore, research is required to identify the generalized and location-specific geobotanical anomalies associated hydrocarbon, PGE and rare earth minerals. These minerals are identified as strategic minerals for development of the country.

There is little work for identifying indirect clues from geobotany for these minerals and also establishing spectrogeochemical models associated with these anomalies. The spectrogechemical model would recognize spectral and geochemical contrast of these geobotanical elements concerning the corresponding parameters of associated species in each mineralized province.

Scope of the Work:

- Identify the site specific or invariant geobotanical anomalies for rare earth, hydrocarbon and PGE deposit.
- Identify the spectrogeochemical models associated the geobotanical anomalies.
- Utilize the spectrogeochemical models for processing hyperspectral data for identifying geobotanical anomalies.

Linkages to Space Programme:

It is important for utilizing EO data for supporting the exploration of ore beneath the cover program of Government of India.

Expected Deliverables:

- Detail record of geobotanical anomalies associated hydrocarbon,rare earth and PGE deposit.
- Spectrogeochemical models for each geobotanical anomaly for hydrocarbon, rare earth and PGE deposit.

RES-NRSC-2023-007

Name of ISRO Centre/Unit

National Remote Sensing Centre, Hyderabad

Title of the research proposal

Generation of high resolution cloud to ground lightning vulnerability maps using the ground and space borne data

Name of Co PI from ISRO Centre/Unit

Dr. Alok Taori

Contact Address of Co PI and e-mail id

alok_taori@nrsc.gov.in

Area of Research

Atmospheric Lightning, Climate Science, Remote Sensing, Risk Assessment, Map Generation, Mitigation

Summary of the proposed research and expected deliverables

Atmospheric lightning is an intriguing but least characterized phenomenon in the climate sciences. The array of ground based lightning detection sensors in combination with satellite data is important tool to monitor the lightning occurrences. Growing consensus in the climate science community is that the lightning occurrences show increasing trend with climate getting warmer. The changing patterns of ENSO are making the territorial patterns of lightning to change. To understand these changes, it is important to monitor the lightning occurrences from macro to the micro scales. A database mining of the lightning occurrences pertaining to the spatial characterization and diurnal variation from climate perspectives is required. For disaster support perspectives, it is important to identify the vulnerable zones. The vulnerable area needs further check with the help of ground reality. A reliable time- unbiased mapping of cloud to ground lightning flashes is important from this perspective. Using the NRSC-LDS network, and available space borne sensors the micro-level vulnerability maps can be generated which can be further utilized for the disaster management and public awareness.

Scope of the Work:

Generation of vulnerability maps state-wise, district and village level information. Ground-truth data collection for checking the vulnerability maps. Preparation of public awareness program by suggesting the precautionary steps.

Linkages to Space Programme:

NICES, Future Space Borne Lightning Imaging Sensor proposed by IMD.

Expected Deliverables:

High resolution lightning vulnerability maps for risk mitigation planning.

LIQUID PROPULSION SYSTEMS CENTRE
VALIAMALA

RES-LPSC-2023-001

Name of ISRO Centre/Unit
Liquid Propulsion Systems Centre, Valiamala

Title of the research proposal
Development of Combustion Instability Model for LOx-methane Engine

Name of Co PI from ISRO Centre/Unit
Mr. Abhishek Sharma

Dr. K.S Biju Kumar

Contact Address of Co PI and e-mail id
abhisheksharma@lpsc.gov.in

Area of Research
Reactive flow modelling, Large Eddy Simulations, Fluid flow and heat transfer simulations, Combustion experimentation, supercritical combustion analysis

Summary of the proposed research and expected deliverables
The coupling between unsteady heat release and pressure fluctuations leads to combustion instability in a rocket combustor. The high-fidelity simulations like reactive flow LES can provide deep insights into the physics of combustion instability but are limited by enormous compute power requirement for simulation of multiple injector element rocket engines. Currently, LES is restricted to single/few elements and its application to simplified geometries, but can be effectively utilized to extract highly realistic distributed time lag heat release at rocket operating conditions. It is difficult to extract distributed heat release through experimentation at actual operating conditions. The reduced order/acoustic modelling is a feasible option, which can be employed for prediction and analysis of instability in complex geometric and operating conditions. A reduced order model (Acoustic solver capable of handling unsteady heat release from LES) is required for prediction of instability characteristics in high pressure LOx-Methane engine. The reduced order model should be capable of incorporating the accurate combustion response from reactive flow LES. The reduced order model can be implemented in commercial or open-source platform, which can also be capable of incorporating the combustion response from in-house developed LES cases at LPSC/ISRO in ANSYS Fluent. A seamless algorithm to incorporate heat release response from LES into the Euler Equation/Acoustic solver (Commercial/Opensource) should be developed in this work. LES heat release should be incorporated into Acoustic/LEE code and the complex Eigen values should characterize the oscillation frequency and growth rate of the thermo-acoustic modes providing insight into the final state of the combustor. The acoustic model should include appropriate damping model. The acoustic equation solver should also be capable of incorporating the real gas effects of high-pressure combustion.

Scope of the Work:

The aim of the work is to develop a validated lower order tool/Acoustic solver which is computationally inexpensive, accurate and accounts for mean flow effects, complex boundary conditions and combustion

response for rocket scale applications suitable for the development of LOx-methane engine. This tool should be tested against benchmark experimental cases presenting longitudinal and transverse instabilities.

Linkages to Space Programme:

The proposal has linkages to the LME1100, SCE2000, CE20- both flight and ground engine applications.

Expected Deliverables:

Validated acoustic solver capable of handling heat release response, damping and real gas effects to predict stability at varied operating and geometric conditions. An algorithm to incorporate combustion response from LES into acoustic solver should be provided. Post processing tools to identify the instability characteristics in a full-scale engine.

Large eddy simulations on single element or few element configurations as per requirement of proposer, from which relevant heat release response can be extracted. Instantaneous pressure-time probe or spatial data can be provided to extract time-lag and heat release features for acoustic model.

RES-LPSC-2023-002

Name of ISRO Centre/Unit

Liquid Propulsion Systems Centre, Valiamala

Title of the research proposal

Providing coating on SS321 conduits & flexible hoses for transporting high pressure (100 bar), high temperature (650 to 750 K) oxygen gas at 50 m/sec velocity

Name of Co PI from ISRO Centre/Unit

Mr. B Suresh Babu

Contact Address of Co PI and e-mail id

balabhadrasureshbabu@lpsc.gov.in

Area of Research

Materials/coating

Summary of the proposed research and expected deliverables

Selection of materials for oxygen gas transportation depends on temperature, pressure and flow velocity. High nickel alloys like Inconel and Monel can be used, without coating, upto limited operating conditions. Coatings (metallic/ceramic) on base material enhances oxidation resistance and makes it acceptable for wider range of operating conditions.

Research proposal is to study the effectiveness of coating on stainless steel pipes and convoluted flexible hoses (with SS321 material, Ø32 ID) for transportation of oxygen gas at specified temperature (650 to 750 K), pressure (100 bar)and velocity (50 m/sec) conditions. The coating shall withstand operating conditions of the pipe/flexible hose and shall be free from surface defects (discoloration, blisters etc).

Scope of the Work:

Technical proposal based on theory and published research. Selection of coating materials. Parametric

studies to find out the effectiveness of different coating materials on SS for specified pressure, temperature and velocity combinations.

Coating on specimens of pipes and corrugated tubes and ensure the effectiveness (SS321 material, Ø32 ID). Develop NDT techniques to ensure defect free coating.

Demonstration of coating effectiveness by testing with hot oxygen gas at specified temperature, pressure and velocity on conduits (pipes) and metallic convoluted flexible hoses (SS321 material, Ø32 ID).

Linkages to Space Programme:

Developed technology can be implemented in Oxidizer rich gas circuits of the SemiCryo Engine and future LOX-Methane Engine.

Expected Deliverables:

- Demonstrated specimens of pipes and corrugated inside surfaces.
- Detailed process plan and procedure document. Qualified NDT plan for evaluation of coating.
- Test results compiled.

RES-LPSC-2023-003

Name of ISRO Centre/Unit

Liquid Propulsion Systems Centre, Valiamala

Title of the research proposal

Studies, characterisation and generation of optimized welding parameters for similar and dissimilar joining Monel 400 and Monel K 500

Name of Co PI from ISRO Centre/Unit

Mr. Debasis Tripathy

Contact Address of Co PI and e-mail id

debasis_tripathy@lpsc.gov.in

Area of Research

Material joining technique development and characterisation

Summary of the proposed research and expected deliverables

Monel grades (Monel 400 and Monel K 500) are a group of Ni-Cu alloys containing 65 to 70 % of Ni and 30-35 % Cu.

These materials possess very good ignition resistance in presence of Oxygen rich environment. These grades also show very good resistance to acidic corrosion. Because of the ignition resistance, these are used in GO_2 lines and subsystems for human rated space systems. These GO_2 feed lines need to be joined with other sub-systems which contain other grades of materials like steels and super alloys through both TIG and EBW processes.

This proposed research is for the joining of similar and dissimilar Monel 400 / K 500 with austenitic steels (SS 321) and Super alloy (IN 718).

Scope of the Work:

- Joining of Monel 400 and Monel K 500 by both TIG and EBW.
- Joining of Monel 400 / K 500 with SS 321 and IN 718 by both TIG & EBW.
- Post weld HT to obtain desired mechanical properties.
- Microstructure and Mechanical properties of different weld joints.
- All materials required for the studies shall be supplied by LPSC.

Linkages to Space Programme:

Monel 400 is used GO_2 lines (welded lines) and Monel K500 is used in GO_2 lines (non-welded) in Gaganyaan Crew module. It is essential to study the welding characteristics of these Monel 400 & Monel K500 with different materials.

Expected Deliverables:

- Optimisation of joining method for best post weld properties.
- Development of WPS and PQR for joining methods.
- Detailed characterisation results with interpretation.

RES-LPSC-2023-004

Name of ISRO Centre/Unit

Liquid Propulsion Systems Centre, Valiamala

Title of the research proposal

Study of Fracture toughness (K_{IC}/J_{IC}) of additively manufactured IN718, IN625 and XH67 components in temperatures range of 77K- 950K

Name of Co PI from ISRO Centre/Unit

Mr. Shubham Kumar

Contact Address of Co PI and e-mail id

shubham_kumar@lpsc.gov.in

Area of Research

Additive manufactured material Characterisation

Summary of the proposed research and expected deliverables

For futuristic engines of ISRO, additively manufactured Inconel 718, Inconel 625 and XH67 superalloys are proposed to be used extensively. Engine components undergo different types of loading at different temperature ranges during its operating cycles. Additively manufactured materials are expected to have microscopic defects and orientation dependent mechanical properties.

In order to have complete understanding on the behaviour of additively manufactured materials under service conditions, it is essential to generate the data for fracture toughness and characterise the fracture behaviour of these materials under operating conditions in the range of 77-950K in the final heat treated condition in which thecomponents are actually used.

Scope of the Work:

- Preparation of additively manufactured samples for Fracture toughness corresponding to different directions.
- Fracture toughness testing of additive manufactured samples at different temperatures (77K-950K) in different built orientations.
- Fractographic characterization of tested samples after testing.
- All materials required for the studies shall be supplied by LPSC.

Linkages to Space Programme:

Inconel 625, Inconel 718 & XH67 superalloy materials are proposed to be used in LOX–LCH_4 engine development through AM route. It is essential to generate fracture toughness data at different operating temperature and loadings for materials realized through AM route.

Expected Deliverables:

- Generation of fracture toughness data with respect to different directions and temperatures in final heat treated condition.
- SEM studies for fractured surface for evaluation of failure mode.

RES-LPSC-2023-005

Name of ISRO Centre/Unit

Liquid Propulsion Systems Centre, Valiamala

Title of the research proposal

Compatibility of materials with liquid methane

Name of Co PI from ISRO Centre/Unit

Mr. Ajit Kumar

Contact Address of Co PI and e-mail id

ajitkumar@lpsc.gov.in

Area of Research

Material characterisation

Summary of the proposed research and expected deliverables

For futuristic engines of ISRO compatibility of materials with Liquid Methane needs to be studied. Further, it is proposed to manufacture most of the parts through additive manufacturing which will lead to considerable time saving and flexibility in manufacturing.

Therefore, it is essential to study the compatibility of different materials with liquid methane for appropriate selection of materials and design of the components. The materials being considered for compatibility tests are SS 12-10PH, SS321, Inconel 718, Inconel 625, Cu-Cr-Zr-Ti, Cu-Cr-Zr, GRcop-42, Ti-6Al-4V, Ti-5Al-2.5Sn, SS316L & AA2219.

Scope of the Work:

- The scope for compatibility tests will include the following.

  - Chemical compatibility.
  - Material degradation with time, if any.
  - Study on change in weight with time.
  - Chemical analysis of reaction products, through analysis of specimen and fluid.
- Design & realization of test setup and conducting experiments.
- Sample preparation for different types of tests.
- Generation of reports on compatibility.
- All required materials for study will be supplied by LPSC.

Linkages to Space Programme:

Compatibility data of Methane with various grades of materials realized in conventional & additively manufactured routes will be useful in selection and validation of materials in LOX-Methane engine.

Expected Deliverables:

Comprehensive study report on compatibility of various grades of materials realized in conventional & additively manufactured routes with liquid methane.

RES-LPSC-2023-006

Name of ISRO Centre/Unit

Liquid Propulsion Systems Centre, Valiamala

Title of the research proposal

Characterisation of sub-structures and precipitate morphology for advanced Nickel based superalloys manufactured through additive manufacturing in liquid engines

Name of Co PI from ISRO Centre/Unit

Mr. R. Santhoshkumar

Contact Address of Co PI and e-mail id

r_santhoshkumar@lpsc.gov.in

Area of Research

Superalloys for high temperature applications, Materials

Summary of the proposed research and expected deliverables

LPSC uses various grades of Nickel and Cobalt based superalloys for high temperature applications in LOX-Methane engine, cryogenic, semi-cryogenic engines and PS4 engine. Presently, several grades of these superalloys have been proposed to be manufactured through additive manufacturing route including LOX-Methane engine. These superalloys are procured in mill annealed condition and are heat treated to impart strength to the fabricated component. These superalloys are welded and subjected brazing operations and are often heat treated multiple times, which changes the microstructures and directly affects the mechanical properties of the materials. The changes in the microstructure are at sub-microscopic level and need extensive transmission electron microscopy and atom probe investigations. The advent of additive manufacturing of superalloys has completely changed the microstructural characteristics of conventional materials due to the high cooling rates involved. In order to effectively

and successfully use the additively manufactured products in liquid engines, a detailed understanding of the microstructure-property correlation is essential. Explaining the mechanical properties from microstructures of materials processed under different conditions is expected from this study.

Therefore, the purpose of this proposal is to study the effect of heat treatment and process variables on the sub-microscopic microstructures, precipitate size and volume fraction and their correlation to the mechanical properties of superalloys (IN718, IN625, XH55, XH67 and Haynes 230) in additively manufactured materials under different processing conditions. Also, establish and compare the results with conventionally processed (ingot metallurgy) materials.

Scope of the Work:

- Detailed transmission electron microscopy of IN718, IN625, Haynes 230, XH55, XH67 alloys under different processing conditions in additively manufactured and conventionally processed (ingot metallurgy) materials.
- 3D Atom probe tomography of precipitate characteristics and correlation to the processing conditions.
- Detailed interpretation and analysis of results obtained.
- All required materials for studies will be supplied by LPSC.

Linkages to Space Programme:

Detailed microscopic characterisation of additively manufactured superalloys will be useful for selecting / upgrading materials for elevated temperature application in LOX-Methane engine, cryogenic and semi-cryogenic engines.

Expected Deliverables:

- Detailed electron microscopic characterisation of superalloys through transmission electron microscopy and 3D atom probe tomography.
- Chemical characterisation of precipitates in superalloys.

RES-LPSC-2023-007

Name of ISRO Centre/Unit

Liquid Propulsion Systems Centre, Valiamala

Title of the research proposal

Generation of physical properties data for additively manufactured materials

Name of Co PI from ISRO Centre/Unit

Ms. Varsha Florist

Contact Address of Co PI and e-mail id

varsha_florist@lpsc.gov.in

Area of Research

Material characterization

Summary of the proposed research and expected deliverables

It is proposed to manufacture most of the parts of futuristic LOX LCH_4 engine through additive

manufacturing. Additively manufactured (AM) materials are being increasingly used in aerospace applications considering the advantages in design optimization and flexibility. There is limited availability of data on physical properties of super alloys as well as other Ti & Al alloys manufactured through AM route. As LPSC is planning to use different types of AM products in different grades of materials, it is necessary to have data on physical properties of these materials. Hence, it is proposed to evaluate and generate data on physical properties (CTE, Cp & k) in the range of 90K to 1100K for additively manufactured materials in IN718, IN625, AlSi10Mg, AISI316L, Ti-6Al-4V & Cu-Cr-Zr.

Scope of the Work:

- To generate data on the following (in the range of 90K-1100K).
  - Coefficient of thermal expansion.
  - Specific heat.
  - Thermal conductivity.
- Realization of test setup & consumables for conducting experiments.
- Sample preparation for different types of test.
- Generation of reports.
- All materials required for the studies shall be supplied by LPSC.

Linkages to Space Programme:

Physical properties of additively manufactured materials at operating temperature (90K to 1100K) will be useful for appropriate selection of material and design of components in current on-going programme (Earth storable, Cryo) and futuristic missions like LOx-Methane and Semicryo engine.

Expected Deliverables:

Data on physical properties (CTE, Cp & TC) in the range of 90K to 1100K for additively manufactured materials in IN718, IN625, AlSi10Mg, AISI316L, Ti- 6Al-4V & Cu-Cr-Zr-Ti.

RES-LPSC-2023-008

Name of ISRO Centre/Unit

Liquid Propulsion Systems Centre, Valiamala

Title of the research proposal

Development of novel Non-Destructive Procedure for detection and quantification of de-bonds in the dissimilar metallic interfaces of explosive bonded plates and diffusion bonded rings

Name of Co PI from ISRO Centre/Unit

Mr. Syamkumar S,
Mr. Manu Joseph,
Mr. Anver Ali,
Mr. Roykuttan K K

Contact Address of Co PI and e-mail id

s_syamkumar@lpsc.gov.in
manu_joseph@lpsc.gov.in

Area of Research

Non-destructive Evaluation

Summary of the proposed research and expected deliverables

Aluminium Alloy Stainless Steel Bi-metallic Adapters (BMAs) are used for the joining between AA2219 propellant tanks to SS321 pipes & valves in launch vehicle stages. BMAs are realized through one of the following routes followed by machining,

- Explosive bonding of AA2219 T87 and ICSS-1218-321 with a sandwiched pure aluminium interlayer in thebutt configuration.
- Diffusion bonding of AA2219 T87 and ICSS-1218-321 rings in lap configuration.

As the bond integrity of the dissimilar metal interface decides the quality of the final BMA, detection of de-bond/ discontinuity, if any, at the intermetallic interfaces is of paramount importance. Presently, conventional Ultrasonic testing is carried out to assess the bond integrity of the metal to metal interfaces of explosive bonded plates at 3mm Flat bottomed Hole level. The higher acoustic impedance mismatch between SS and AA2219 produces an inherent high amplitude echo which affects detection capability. It is observed that this difficulty in distinguishing de-bond indications has subsequently led to failure at product level. Other volumetric NDE like Radiography and Computed Tomography also did not yield promising results. The aim is to develop a Non-destructive Evaluation technique and procedure for reliable detection of de-bonds in the dissimilar metallic interfaces in the butt and lap joints of the BMAs (i.e. SS to pure Al and AA2219 to pure Al composite butt joints in explosion bonded plates and; SS to AA2219 lap joints in diffusion bonded rings) with minimum area of 3.14mm2 (equivalent to 2mm Flat Bottomed Hole) or lesser.

Scope of the Work:

Bi-metallic adaptors for CUS and C-25.

Linkages to Space Programme:

Non-Destructive Evaluation of Metal to Metal interfaces of Bi-metallic Adaptor plates used in Cryogenic Upper stages of ISRO launch vehicles.

Expected Deliverables:

NDE technique and procedure for the above application.

ISRO PROPULSION COMPLEX
MAHENDRAGIRI

RES-IPRC-2023-001

Name of ISRO Centre/Unit
ISRO Propulsion Complex, Mahendragiri

Title of the research proposal
Development of Ignition resistance coating for Semi-cryo main turbine application

Name of Co PI from ISRO Centre/Unit
Dr. SGK. Manikandan

Contact Address of Co PI and e-mail id
manikandan.sgk@iprc.gov.in

Area of Research
Materials

Summary of the proposed research and expected deliverables
Semi-Cryo Engine operates on Oxidizer Rich Staged Combustion Cycle (ORSCC). Some of the parts of Semi-cryo Main Turbine are exposed to high pressure, high temperature oxidizer rich environment. As the application requires high strength at elevated temperature and creep resistance, Nickel based super-alloy materials (XH67 and Inconel 718) are selected for these components. The presence of Oxygen at high temperature and high pressure can cause metal ignition and to survive under such a not so conducive environment, the parts are coated with a Nickel-based protective coating named "Metal Ceramic Coating" (MCC). The semi-cryo engine main turbine parts/ sub-assemblies are to be coated.

Scope of the Work:

The primary objective of the project is to develop a suitable high entropy alloy or any other alloy system coating with the ignition resistance. The refectory high entropy alloys (RHEAs) are one of the probable candidates for the high temperature applications. Equimolar VNbMoTa exhibits the superior yield strength of at elevated temperature that is superior to most RHEAs reported so far. Any other suitable system also shall be chosen subject to the final clearance from IPRC. The coated substrate before and after coating is to be subjected to various characterizations to test the high temperature resistance capacity. The tests are to be conducted in a motive to quantify the thermal barrier efficiency and the high temperature oxidation and ignition resistance of the coating.

- To investigate the following types, but not limited to, of high temperature oxidation and ignition resistant HEAs using CALPHAD (NiCoYHfSix, NiCoZrTaAlx, NiCoCeWAlx, NiCoNbBAlx, NiCoMoVAlx) coating on Superalloy X750 or 718 substrates using APS or other technique.
- One system will be converged based on the CALPHAD analysis.
- To investigate the improvement in high temperature oxidation resistance at 540m/s high velocity hot gas and thermal barrier capacity of HEA coatings.

- Characterize the changes in phase, microstructure, mechanical properties, and temperature resistance of the deposited coating.
- Demonstration of test conditions catering the operating conditions mentioned as follows: Pressure: 11 to 44 MPa Temperature: 470 to 840K Hot gas velocity: 540 m/s Shear stress: 0.137MPa Strain: 1.7%.
- To check the percentage of improvement in the Temperature, oxidation and ignition resistance of the substrates to counter the failure.
- Demonstration of exposure to oxidizer rich environment and simulating the pressure and shear stress levels.

Linkages to Space Programme:

The proposal has linkages to Ignition resistance coating for Semi-cryo engine components.

Expected Deliverables:

- Development of new coating system for ignition resistance.
- Demonstration of operating environments described above.
- Technology transfer of the coating system and coating method developed.
- Coated samples on the sample substrate.
- Demonstration of exposure to oxidizer rich environment and simulating the pressure and shear stress levels.

RES-IPRC-2023-002

Name of ISRO Centre/Unit

ISRO Propulsion Complex, Mahendragiri

Title of the research proposal

Development of Automatic Deluge System using Image based Hydrogen Leak Detection Technique for Cryogenic Test Facilities

Name of Co PI from ISRO Centre/Unit

Mr. Poofa Gopalan

Contact Address of Co PI and e-mail id

poofa.gopalan@iprc.gov.in

Area of Research

AI, Image processing based Hydrogen detection

Summary of the proposed research and expected deliverables

In cryogenic test facilities, presently, hydrogen gas leakage is being detected by using catalytic sensors and deluge system to quench fire. The response of catalytic sensors is slow. The response time needs to be improved. Leakage detection comprises of four major steps namely Image acquisition, Pre-processing and segmentation, Feature extraction and Interpretation. The image shall be acquired by a conventional camera. It shall be noted that hydrogen gas is not infrared active. The image acquired shall be pre-processed using suitable algorithm to identify the presence of hydrogen. Feature extraction

involves the process of selecting and extracting suitable features that may lead to efficient classification. Interpretation focuses on making accurate decisions based on the test and analysis done on the image.

Based on the decision, the controller shall generate a digital output for triggering the deluge system.

Scope of the Work:

Leakage of hydrogen in Cryogenic test facilities at IPRC needs to be detected immediately to avoid further fire and safeguard the engine, stage and the test facility. Hence, this system can be used in all cryogenic test facilities at IPRC, Mahendragiri.

Linkages to Space Programme:

The proposal has linkages to Cryogenic Engine and Stage testing for LVM3 missions.

Expected Deliverables:

Cameras, workstations, intelligent controller, control circuit.

RES-IPRC-2023-003

Name of ISRO Centre/Unit

ISRO Propulsion Complex, Mahendragiri

Title of the research proposal

Development and studies on tailoring hydrodynamic instabilities in fluid systems

Name of Co PI from ISRO Centre/Unit

Mr. Karthikeyanathan S

Contact Address of Co PI and e-mail id

sk.nathan@iprc.gov.in; sk.nathan@iprc.dos.gov.in

Area of Research

Diffusive combustion, concentration distribution mapping, Hydro-dynamic instability, High frequency thermo-acoustic combustion instability

Summary of the proposed research and expected deliverables

Co-axial atomizers of shear/ swirl types plays critical role in delivering and preparing combustible fuel-oxidizer mixtures uniformly inside combustors. Total kinetic energy available from pressure budget for fluids will be partitioned to bulk fluid disintegration based on hierarchical instability mechanisms possessing the highest growth rates. Relative motion between fluids by its very existence originates and amplifies Hydro-dynamic instabilities that undergo either absolute or convective growth depending on Weber number, Bond Number of resulting liquid sheet in primary disintegration zones. Configuring geometry of atomizing systems becomes essential to tailor different instabilities with varying temporal and spatial growth rates will essentially help in delivering promising droplet size and velocity distribution to combustion zones.

It is aimed to systematically configure the atomizers and investigate the energy budget of R-T over K-H instability interaction under various flow field conditions simultaneously, that helps in reducing length

and time scales of disintegration of fluid bulk. We aim at partitioning 90% of total available energy towards R-T type instability over K-H instability in liquid sheet fixed Gallelian reference frame to trigger optimal instability of liquid sheet thereby reducing instability wavelength to lowest minimal possible in reconstructed phase-space for generating finest droplets in lowest length and time scales possible.

It is proposed to study,

- Dynamics of Hydro-dynamic instabilities of different origins under different initial conditions by varying the flow geometry. (RT type, KH type, RP type).
- Associated rate of growth or decay in these instabilities using non-linear dimensionality reducing decomposition techniques.
- Coupling mechanics of these instabilities with external fluctuations like turbulence, vortices and acoustic excitation.
- Role of these mechanisms on secondary atomization zone which finally sets up the droplet distribution pattern inside combustor.

Final outcome of project will be novel geometry of atomizers tailored with R-T Preceding K-H type instability to meet promising atomization properties like particle size, velocity distribution, temporal evolution of species, and spatio-temporal stationality of species under Gallelian invariance condition.

This involves evaluation of

- Penetration depth. (in terms of L*).
- Time averaged species concentration map at identified spatial location.
- Spatial species concentration distribution.
- Size-velocity correlation of spray field and establishing spray stationality.

Scope of the Work:

These kind of high strain rate-tailored hydrodynamic instabilities originated prompt atomizer are state–of the-art technologies that will find wide application in rocket systems ranging from multi-propellant capability, wider thrust augmentation capability by de-coupling thermo-acoustic oscillation delivering stable C* characteristics. Tailoring hydro-dynamic instabilities using geometry is novel research field and it aims at delivering promising particle sizes at varying operating conditions.

Linkages to Space Programme:

Key deliverables of this research program are canonical flow geometries that help rapid interaction between density stratified fluids under varying co-moving velocity ratio conditions. This helps in finalizing feed line configuration that helps improving heat transfer, fluid mixing and disintegration of bulk fluids.

Expected Deliverables:

- Different atomizer geometry with total energy partitioning functions to R-T vs K-H type instabilities.
- Experimental results obtained as described in section 6 together with linear spray measurement parameters like size and velocity field, divergence field, dispersion, penetration etc.

RES-IPRC-2023-004

Name of ISRO Centre/Unit

ISRO Propulsion Complex, Mahendragiri

Title of the research proposal

Automation of Dynamic Balancing of Rotors

Name of Co PI from ISRO Centre/Unit

Mr. Keshavakrishnan S

Contact Address of Co PI and e-mail id

keshavakrishnans@iprc.gov.in

Area of Research

Industrial Automation

Summary of the proposed research and expected deliverables

Balancing operations commences with setting up of balancing machine for the intended rotor. Rotor specific calibration is done initially with mass addition to calibrate the balancing setup. The automation controller will be fed with desired unbalance as input. The controller shall be interfaced with main drive unit of the balancing machine and shall start and stop the machine when desired. Initial balancing run will provide residual unbalance available in the rotor. The controller shall rotate the rotor at slow speed to align the material removal position in line with grinding tool. The grinding tool shall remove material for calculated time period from the desired location. The balancing runs followed by material removal are repeated until the unbalance meets the specification. Once the unbalance values meet the specification, balancing operations are stopped and repeatability trials are carried out. Balanced rotor can be taken from the balancing machine post material removal.

Scope of the Work:

The scope of the proposed research is to automate material removal in balancing. Automation system shall consist of following

- A controller to obtain unbalance data and location of unbalance from the balancing machine.
- A grinding tool to remove material from the required location to desired unbalance values.
- The grinding machine shall have provision for changing of wide range of tools to suit with desired rotor.
- A computer interfaced with automation controller shall be provided to provide inputs for balancing.
- The grinding tool shall have provision for linear travel along the balancing machine bed (for material removal from two planes) and radial movement (for removal of material from rotors of varying diameters).

Linkages to Space Programme:

Rotor balancing is done prior to integration of Fuel and Oxidiser turbo pumps of liquid rocket engines. A balancing machine with automated operations can be incorporated for rotor balancing activities related to CUS, CE20, SCE and Vikas Engine.

Expected Deliverables:

A controller with a grinding tool setup interlinked with the balancing machine. The controller fetches the unbalance mass and the phase angle of the unbalance mass and commands the grinding tool setup to remove the material at the identified location by grinding. The grinding tool is retracted and the rotor is run to find the unbalance. The grinding operation is continued till the unbalance levels are achieved.

PHYSICAL RESEARCH LABORATORY
AHMEDABAD

RES-PRL-2023-001

Name of ISRO Centre/Unit
Physical Research Laboratory, Ahmedabad

Title of the research proposal
UV photostability of molecular ions in the interstellar medium

Name of Co PI from ISRO Centre/Unit
Dr. Rajesh Kumar Kushawaha

Contact Address of Co PI and e-mail id
kushawaha@prl.res.in

Area of Research
Spectroscopy and Laboratory astrophysics

Summary of the proposed research and expected deliverables
The abundance of various molecular species in space relies on a synergistic approach involving activities such as astronomical observations, laboratory measurements, and accurate modeling. The modeling requires parameters such as the absolute cross sections of photodestruction of molecular species, rate coefficients of ion-molecule reactions of relevance, etc., since these processes govern the abundance of molecular species in space. This project aims to develop a storage ion source to generate gas-phase molecular ions of astrophysical interest and measure the absolute photodetachment/ photodissociation cross-sections of molecular ions of astrophysical interest using a unique experimental technique featuring ion traps. The initial experiments will focus on the measurements of cross-sections of C_5N^- and $HCOO^-$ at 266 nm (4.66 eV). C_5N^- has already been detected in the interstellar medium (ISM), and $HCOO^-$ is likely to be found in the ISM. One primary mechanism determining the abundance of these molecular ions in the ISM is their photodestruction. Since the molecules of our interest have relatively high electron affinity (4.45 eV and 3.50 eV, respectively, for C_5N and HCO_2), photodetachment occurs only at photon energies in the UV region. In this project, the laboratory measurement of absolute photodetachment and photodissociation cross-sections of molecular ions of astrophysical relevance will be performed, and results will be used to understand the underlying gas phase chemistry in the Interstellar Medium.

Scope of the Work:

Estimating the abundance of molecular species making up the ISM is an active field of research in laboratory astrophysics. In the ISM and circumstellar envelopes, about 300 molecular species have been detected. Out of these, only six anions have been identified so far (C_nH^-, where n = 4,6, and 8, and C_nN^-, where n = 1,3, and 5). CN^-, C_3N^-, and C_5N^- are nitrogen- based anions, which have a high potential for the formation of several complex molecular species in the ISM. The abundance of CN^- and C_3N^- has been shown to be severely affected by their UV photodetachment, since they have been found to yield high absolute photodetachment cross-sections. So far, there have been no measurements on the absolute photodetachment cross- section of C_5N^-. Furthermore, $HCOO^-$has not been observed so far

in the ISM, most likely due to the limited availability of the spectroscopy data. It is essential to measure how stable $HCOO^-$ is against photodetachment to conclude whether this molecule could be found in the ISM with significant abundance. The proposed measurement will allow us to understand the underlying gas phase chemistry in the Interstellar Medium.

Linkages to Space Programme:

The project aims to study one of the elementary mechanisms by which molecular ions are destroyed in interstellar medium / circumstellar envelopes. This study constitutes one of the major objectives of laboratory astrophysics, which is aligned quite well with ISRO's objectives. The data obtained from these measurements can be used as an input to the models employed to determine the abundance of molecular ions in space.

Expected Deliverables:

The project aims to generate benchmark data for absolute photodetachment and photodissociation cross-sections of molecular ions of astrophysical relevance. It is proposed to carry out measurements on C_5N^- and $HCOO^-$. These data will be used to precisely model the abundance of these molecular ions and other species that could emerge within interstellar clouds through reactions involving these anions and various atomic and molecular constituents present in the ISM. It is also expected to generate data for absolute photodetachment and photodissociation cross-sections of various molecular species relevant to laboratory astrophysics.

RES-PRL-2023-002

Name of ISRO Centre/Unit

Physical Research Laboratory, Ahmedabad

Title of the research proposal

Exploring the role of waves and small-scale transients in the heating of solar chromosphere and corona

Name of Co PI from ISRO Centre/Unit

Dr. Girjesh R. Gupta

Contact Address of Co PI and e-mail id

girjesh@prl.res.in

Area of Research

Solar Physics, MHD waves, Magnetic reconnection, Emission line spectroscopy

Summary of the proposed research and expected deliverables

The tenuous outer atmosphere of the Sun, commonly known as the 'corona', is significantly hotter (>1 MK) than the solar surface (<6000 K), while the chromosphere is at around 20000 K. It is now widely accepted that the magnetic field plays a crucial role in heating the solar corona and chromosphere.

Magnetohydrodynamic (MHD) waves as well as small-scale magnetic reconnection events (transients) like microflares, spicules, and jets observed at different atmospheric heights, are proposed to provide the necessary energy to sustain the elevated temperatures of the corona and chromosphere.

Despite the abundance of observations regarding wave propagation and small-scale transients in the solar atmosphere, the precise physical processes and mechanisms responsible for their dissipation and their contributions to plasma heating remain unclear and not yet fully quantified.

Therefore, a comprehensive assessment of the role of each of these proposed mechanisms is necessary.

For the purposes of our study, we will employ spectroscopic and imaging data from ground-based MAST/USO, as well as space- based SUIT and VELC both onboard Aditya-L1. Additionally, we may utilize complementary data from XSM onboard Chandrayaan-2 and X-ray spectrometers onboard Aditya-L1.

Information from other missions such as SDO, IRIS, and Solar Orbiter could also be vital for these studies. It is proposed to conduct detailed multi-wavelength investigations of MHD waves and small-scale transients occurring in the solar atmosphere. This study aims to provide a comprehensive understanding of the heating processes in the solar upper atmosphere and to elucidate the coupling throughout the entire solar atmosphere.

Scope of the Work:

- Quantifying the energy content of various types of MHD waves and small-scale transients at different heights in the solar atmosphere.
- To Investigate whether waves can induce small- scale magnetic transients, and vice-versa.
- Establishing a unified three- dimensional picture of small-scale transients observed at varying heights in the solar atmosphere.

Linkages to Space Programme:

High-resolution spectroscopic and imaging data required to accomplish the project's scientific objectives will be obtained from the Multi Application Solar Telescope (MAST) located in Udaipur and operated by the Physical Research Laboratory. The project will greatly benefit from data acquired through ISRO's space mission, Aditya-L1. We will promptly utilize data from the Solar Ultraviolet Imaging Telescope (SUIT) and the Visible Emission Line Coronagraph (VELC), both on-board Aditya-L1, as soon as it becomes available.

Additionally, the work will also incorporate X-ray data from the Solar X-ray Monitor (XSM) on- board Chandrayaan-2 and the X- ray spectrometers on-board Aditya-L1 into the research purposes.

Expected Deliverables:

The proposed research is expected to yield the following outcomes, aligning with the science goals of the various ISRO missions mentioned above.

- Insights into whether MHD waves carry enough energy to heat and sustain the solar atmosphere, and identifying any specific types of MHD waves that may contribute to radiation losses in the solar atmosphere.
- Insights into whether a significant number of small- scale transients exist in the solar atmosphere to maintain its high temperature at both small- and large-scales.
- Details on any potential interplay between MHD waves and transients in the transport of energy across different layers of the solar atmosphere.

RES-PRL-2023-003

Name of ISRO Centre/Unit
Physical Research Laboratory, Ahmedabad

Title of the research proposal
FPGA based control system for Adaptive Optics: Image stabilization System

Name of Co PI from ISRO Centre/Unit
Shri A Raja Bayanna

Contact Address of Co PI and e-mail id
bayanna@prl.res.in

Area of Research
Adaptive Optics

Summary of the proposed research and expected deliverables
The resolution of any ground-based telescope is limited by the atmospheric turbulence. To enhance the resolution of a seeing limited telescope to its diffraction limit, it is necessary to employ image restoration techniques. Adaptive Optics (AO) is one such technique that corrects the distorted wavefront in real-time. Image motion correction due to telescope tracking and global tilt of the distorted wavefront is the first step towards the high- resolution imaging. At Udaipur Solar Observatory a image stabilization system is employed for 50 cm Multi-Application Solar Telescope for (global) image motion correction. The system includes a software based (feedback) control system. It is more useful to include a hardware based control system based on FPGA and any other methods to sense the global tilt of the wavefront and correcting the image motion in real-time.

Scope of the Work:

The proposed work will help to develop an image stabilization system that uses hardware based control system for better performance (speed and correction). Also, similar methods/techniques can be used for correcting the local tilts of the distorted wavefront in real-time.

Linkages to Space Programme:

This will be helpful in implementing a tip-tilt mirror or adaptive optics system for future space telescopes, particularly correcting the first order terms.

Expected Deliverables:

Hardward based control system that can be integrated with existing global tilt sensor and corrector.

RES-PRL-2023-004

Name of ISRO Centre/Unit
Physical Research Laboratory, Ahmedabad

Title of the research proposal
Waves, Instabilities, and Turbulence of the Heliosphere

Name of Co PI from ISRO Centre/Unit

Mr. Aveek Sarkar

Contact Address of Co PI and e-mail id

aveeks@prl.res.in

Area of Research

Solar Physics, Space Weather

Summary of the proposed research and expected deliverables

Even 60 years since its discovery, the physics of the solar wind remains elusive. Multiple spacecraft continuously sample various solar wind parameters at different heliospheric distances. This data reveals that the magnetic plasma of the solar wind is turbulent in nature. However, the generation and dissipation mechanisms of this turbulence remain unsolved problems. In-situ data further reveal that the collisionless nature of the magnetic plasma gives rise to several waves and instabilities in the heliosphere, which, in turn, interact with the solar wind plasma. Elemental abundances of the solar wind also change in a non-trivial way. Many of these problems are thought to be interlinked. They are also supposed to be connected to the lower corona.

A comprehensive understanding of turbulence, wave-particle interactions, and elemental abundances within the heliosphere may reveal crucial insights into various aspects of the heliosphere, such as the acceleration mechanisms of the fast solar wind, the energy exchange between the lower corona and heliosphere, and more. Such an understanding can be attained through sophisticated numerical simulations or the analysis of existing spacecraft data.

Data analysis from instruments like the Parker Solar Probe (PSP), the Advanced Composition Explorer (ACE), WIND, STEREO, and others can provide valuable insights for a detailed understanding of the heliosphere.

Additionally, it is anticipated that these numerical simulations and data analysis techniques will assist in comprehending the data from in-situ instruments (e.g., ASPEX, PAPA, Magnetometer) onboard Aditya-L1.

Scope of the Work:

- The three in-situ payloads of Aditya-L1 are poised to yield a wealth of data. To extract meaningful insights from this data, it becomes essential to comprehend the diverse physics at work within the heliosphere. The proposed research will either develop numerical models to explain the various physical phenomena occurring in the heliosphere or generate data analysis tools that facilitate a deeper understanding of the underlying physics.
- Since the project primarily focuses on various observational signatures of different physical phenomena, its outcome will prove valuable in determining the precise requirements for future in-situ experiments in the heliosphere.
- In the era of burgeoning space-based experiments, the community needs to cultivate a trained workforce capable of analyzing and comprehending data. One of the main aims of the project is to foster this trained community manpower for heliospheric physics.

Linkages to Space Programme:

The project will assist in understanding and interpreting data from Aditya-L1's in-situ payloads, including ASPEX, PAPA, and the magnetometer. The numerical simulations will be conducted with the aim of producing results that are valuable not only for analyzing real data from these payloads but also for guiding the design of future in- situ payloads.

Expected Deliverables:

- Comprehensive understanding of heliospheric turbulence, waves, and instabilities.
- Numerical framework to validate heliospheric observations.
- Data analysis tools that can be utilized to analyze data from Aditya-L1's in-situ payloads and identify the impact of errors in the data on specific physical p henomena.

RES-PRL-2023-005

Name of ISRO Centre/Unit

Physical Research Laboratory, Ahmedabad

Title of the research proposal

Effect of Space Weather on the Climate of Venus

Name of Co PI from ISRO Centre/Unit

Professor. Varun Sheel

Contact Address of Co PI and e-mail id

varun@prl.res.in

Area of Research

Planetary Atmospheres

Summary of the proposed research and expected deliverables

One of the fascinating phenomena in Astronomy and Space Science, is the effect of space weather on the Venus atmosphere. These include both average variations in solar radiation and solar wind, as well as extreme conditions such as interplanetary Coronal Mass Ejections (CMEs), Solar Energetic Particles (SEPs) and solar flares. Such space weather events can cause changes in the ionospheric structure, the electrical properties and even atmospheric chemistry of Venus.

For example, the atmospheric escape on Venus is the effect of the planetary space weather conditions near its neighbourhood. Auroral emissions have been observed on Venus, believed to be associated with solar flares. In terms of the plasma environment or ionosphere, atmospheric ionization by galactic cosmic rays (GCRs) is another effect of planetary space weather. GCR ionization (<100km) in Venus atmosphere, have a strong influence on electrical conductivity, atmospheric chemistry and charging of cloud particles leading to possible lightning.

Therefore changes to ionization rates due to GCR variability may affect the occurrence of electrical phenomena, relating space weather to meteorological phenomena. It is therefore important to quantify the effect of planetary space weather on Venus atmosphere, based on satellite observations and modelling.

Scope of the Work:

This study will evaluate the change in Venus climate over various solar cycles, due to space weather events. Such a study is important to prepare us for ISRO's future Venus mission which has many instruments that will observe various properties of space weather events. It will provide a comprehensive overview of what we understand, and based on the opne questions, what we should look for with our instruments being developed for the Indian Venus mission.

Linkages to Space Programme:

This work has direct link to ISRO's future Venus mission. For the mission to be successful, Indian scientists need to develop a deeper understanding of the science behind the interaction of space weather events with the Venusian atmosphere. This will directly help in the development of many of the instruments that will observe, and even encounter such events.

Expected Deliverables:

This work will result in development of models within India, to address the science from India's Venus mission.

RES-PRL-2023-006

Name of ISRO Centre/Unit

Physical Research Laboratory, Ahmedabad

Title of the research proposal

Characterization of micrometeorites, interplanetary dust particles and returned samples

Name of Co PI from ISRO Centre/Unit

Mr. Ramakant R. Mahajan

Contact Address of Co PI and e-mail id

ramakant@prl.res.in

Area of Research

Planetary Science, dust, returned samples

Summary of the proposed research and expected deliverables

Compared to the modern Sun's flare emissions a young Sun was expected to have emitted significantly higher (~104- 105) and more energetic particle flux and this evidenced in observations of young stellar objects in the Orion nebula. The return samples from asteroids Ryugu and Bennu provide an excellent opportunity to understand exposure to energetic particles. Characterizing the signatures/ features of interaction with energetic particles will help to answer questions about the extent of exposure of asteroid material (e.g. Ryugu / Bennu) material exposed to irradiation from early active Sun, burial depths, we working of material and excavation due to impact. Asteroid return samples give us an opportunity to ground truth and test for signatures of normal cosmic ray spectrum as well the highly intense solar flares through characterization of sample mineral grains or their aggregates through track density documentation and subsequently followed by 21Ne noble gas in irradiated grains vis- à-vis the signatures in unirradiated grains.

Such analyses have been conducted on meteorites and lunar samples but not on return samples from asteroids, in that sense this is unique opportunity. The asteroid return samples that are anticipated to be available are similar to carbonaceous chondrites in their chemical and isotopic composition. While characterizing these samples for track and noble gas signatures so it is equally important to characterise their elemental and isotopic composition with other microanalytical techniques.

This will help to understand the nature and composition of minerals which bear record to early active Sun different from others that have not been irradiated.

Fortunately apart from CI meteorite samples which are similar to return samples and are in short supply we also have micrometeorites /IDPs compositionally similar to many carbonaceous chondrites, such as CI and CM chondrites. The extra-terrestrial flux that enters the Earth's surface is dominated by micrometeorites / interplanetary dust particles (IDPs), which contribute nearly 100 tonnes of material daily, it is the largest extra-terrestrial debris captured by Earth.

Micrometeorites/IDPs are small-sized extraterrestrial materials, sizes that are in the range of a few tens of microns to a few hundred microns, rarely in the mm size range. A small group of micrometeorites have escaped damage and alteration (chemical and/or isotopic) from heating.

We anticipate noble gas and chemical composition studies of Antarctica micrometeorites collected from Maitri station, India, as well as dust collected in stratosphere will provide valuable constraints on the particle origin and history and their genetic linkages as different meteorite groups have diagnostic compositions. Most of the returned samples are of single grain type in nature.

As samples are precious the development of specific protocols and methods, and its testing and validations at various stages is an important prerequisite for returned sample analyses and success in sample allocation request. The dust characterization will provide a platform towards the small sample analysis.

Scope of the Work:

This study will help to develop the necessary protocols for single grain and grain aggregate track and noble gas analyses; and chemical and isotopic characterization techniques using micro analytical methods. The experimental work includes measurement of track signatures, noble gas composition, and chemical characteristics of dust falling on Earth and meteorite analogues of asteroid return samples. This will help to understand the type of dust, e.g., silicate or metal, and environment around Earth and interplanetary space.

Linkages to Space Programme:

This work is related to 'planetary exploration', 'IDP flux and characterization' program, 'in-situ measurement of soil and rock composition of Moon, Mars and planets'.

Expected Deliverables:

Exposure history of meteorites and their regolith environment and constrain the nature and accretion of parent bodies of carbonaceous chondrites. Composition of dust around the Earth and the type of flux roaming in the interplanetary space near Earth. This work will help to constrain whether the dust origin is from asteroids or comets. It is to be understood that spacecrafts are subjected to bombardment by

dust. This project will help to understand the type of dust around Earth that will contribute towards mitigating any potential hazards to spacecraft / instrumentation and this contribute to space program of ISRO.

RES-PRL-2023-007

Name of ISRO Centre/Unit

Physical Research Laboratory, Ahmedabad

Title of the research proposal

Analysis of samples analog to Mars for decoding scientific processes that shaped it throughout its evolution

Name of Co PI from ISRO Centre/Unit

Dr. Amit Basu Sarbadhikari

Contact Address of Co PI and e-mail id

amitbs@prl.res.in

Area of Research

Planetary Geochemistry on Moon, Mars, Vesta

Summary of the proposed research and expected deliverables

It is needed to advance the current consensus on the role of secondary mineralization in the evolution of the Martian crust and soils. With the emerging interest in the missions to Mars, the importance of its soil has risen as an in-situ resource. Weathering and aqueous alteration of samples from Mars are capable to provide information of rock-water-atmosphere interactions and climatic conditions at different geologic ages. In this project, geological field work of Earth analog sites of Mars will be carried out. Analog samples will be collected and analyzed for their compositions. The examination of these samples, coupled with comparative analysis of the similar deposits on Mars, contributes to our understanding of Mars-related contexts. This research sets the stage for future endeavors aimed at conducting more analogous studies. By expanding our investigations to diverse locations, we anticipate gaining valuable insights into the Martian environment and its geological processes.

Scope of the Work:

Field relation of different primary and secondary assemblages and geochemical study of the samples along with comparison with other secondary deposits will be aligned to the context of Mars. This will set up the future goal of similar analog study including field work of the secondary rock/soil deposits in India.

Linkages to Space Programme:

The examination of these samples, coupled with comparative analysis of other similar deposits, contributes to our understanding of Mars-related contexts.

This study will advance the current consensus on the role of secondary mineralization in the evolution of the martian crust and soils. Martian soil is the repository of processes at the crust- atmosphere interface over geologic time, compositional trends in the soil provide clues not only of the geologic past, but also

to the general habitability of Mars. With the emerging interest in the missions to Mars, the importance of its soil has risen as an in-situ resource to extract H2O for a sustained human presence.

Expected Deliverables:

The preliminary findings of this research shed light on the approximate mineralogy and geothermal conditions that resemble those of Martian counterparts. This research sets the stage for future endeavors aimed at conducting analogous studies, including fieldwork in different parts of India. By expanding our investigations to diverse locations, we anticipate gaining valuable insights into the Martian environment and its geological processes.

RES-PRL-2023-008

Name of ISRO Centre/Unit

Physical Research Laboratory, Ahmedabad

Title of the research proposal

Modelling or experimental work related to interplanetary/planetary dust

Name of Co PI from ISRO Centre/Unit

Dr. Jayesh P. Pabari

Contact Address of Co PI and e-mail id

jayesh@prl.res.in

Area of Research

Interplanetary Dust Science

Summary of the proposed research and expected deliverables

The Interplanetary Dust Particles (IDPs) are originated from asteroid belt and other sources. These IDPs sometimes are trapped between two planets and create a resonance dust ring. Also, planetary dust like dust storms/devils is of scientific interest. The properties of the dust at a planet and its effect may be understood using the instrument on future planetary missions/modelling. The work may involve aspects related to IDP.

Scope of the Work:

The scope of research can cover new design concepts, laboratory model of the instrument, data analysis of the past observations, modelling and related ideas. It can also involve refinement of existing model from recent observations, new technique of observation with instrumentation and related aspects.

Linkages to Space Programme:

The research related to planetary lightning or interplanetary dust are directly linked to the future planetary missions to Venus/Mars. The work could be in line with the present activities of PRL in the respective fields.

Expected Deliverables:

The expected deliverables could be a new instrument model/technique of observations, a laboratory model of the instrument, modelling results, scientific outcomes from the data analysis etc.

RES-PRL-2023-009

Name of ISRO Centre/Unit

Physical Research Laboratory, Ahmedabad

Title of the research proposal

Polar cold traps of Moon and Mercury as a scientific resource

Name of Co PI from ISRO Centre/Unit

Dr. Megha U. Bhatt

Contact Address of Co PI and e-mail id

megha@prl.res.in

Area of Research

Infrared spectroscopic analysis/Remote Sensing

Summary of the proposed research and expected deliverables

PSRs are a scientific resource to understand volatile transport system on airless planetary bodies because they act as a key sink in this transport system. Volatiles have been reported at Moon and Mercury poles but the time history of volatiles within the PSRs and nature is still not understood in detail. With Chandrayaan-2 in orbit to Moon and BepiColombo on its way to Mercury a detailed mapping of poles is expected. A new set of high resolution data will provide an opportunity to understand origin and volatile distributions. Such a comparative study will address to the question; why the nature of volatiles different at the Moon and Mercury?

Scope of the Work:

The planned work is first step towards comparative planetology we intent to pursue. The work will have implications towards understanding how water-ice environment evolved in the inner solar system.

Linkages to Space Programme:

ISRO has planned Lupex mission to lunar pole with the main objective of quantification of water ice. This proposal will provide context to Lupex and all other future high latitude in situ explorations.

Expected Deliverables:

- A better understanding of why the nature of volatiles different at the Moon and Mercury?
- Better resolution polar maps.

RES-PRL-2023-010

Name of ISRO Centre/Unit

Physical Research Laboratory, Ahmedabad

Title of the research proposal

Ionospheric density characterization over low latitudes through observations and Modelling

Name of Co PI from ISRO Centre/Unit

Dr. K. Venkatesh

Contact Address of Co PI and e-mail id

venkateshk@prl.res.in

Area of Research

- Equatorial ionospheric dynamics
- Space weather Effects on low and equatorial latitudes
- Ionospheric Empirical modelling

Summary of the proposed research and expected deliverables

The equatorial and low latitude ionosphere exhibits high degree of variability being characterized with electrodynamical processes namely the Equatorial Electrojet (EEJ), Equatorial Ionization Anomaly (EIA) and Equatorial Spread-F (ESF). Spatio temporal distribution of ionospheric plasma in the equatorial and low latitudes is dominantly controlled by these electrodynamic processes, especially by the extremely variable EIA phenomena. Consequently, the day-to-day variability of various parameters to characterize the structure and dynamics of ionospheric plasma remains as an enigma.

Also, geomagnetic storm induced disturbances like the Prompt Penetration and Disturbance Dynamo Electric Fields (PPEF & DDEF) can severely modify the equatorial zonal electric field and in turn disturb the electrodynamic processes. Understanding the interplay of storm induced disturbances from different sources is crucial to comprehend the space weather impacts on ionospheric dynamics and subsequent modifications in the plasma distribution.

A broad range of user applications are crucially reliant or affected by the state of the ionosphere. For instance, highly variable electron density governed by the electrodynamic processes leads to ambiguous range delays threatening the failsafe performance of satellite based technologies.

Irregular structures in the night time ionosphere cause loss-of-locks in trans-ionospheric signals effecting the reliability of satellite based communication systems. As such, modeling and correction of these impacts is subsequently highly sensitive to the choice of ionospheric representation.

Scope of the Work:

Space weather processes have severe effects on the Global Navigational Satellite Systems (GNSS) leading to several anomalies in position, velocity and timing applications.

These effects are intense during disturbed space weather conditions such as geomagnetic storms, solar flares etc., due to their impacts on the coupled ionosphere thermosphere system.

The GNSS position accuracy is limited by several error sources, among which, the ionospheric delays are predominant. It is important to characterize the ionospheric features in horizontal and vertical scales, their short and long term variations and response during different space weather conditions.

Employing advanced machine learning tools is worthwhile for the comprehensive validation of ionospheric models.

Linkages to Space Programme:

These studies have significant relevance with the activities of ISRO. Characterizing the ionospheric density and other parameters in different spatial and temporal scales is essential to understand the upper atmospheric effects on the GNSS systems, including NaVIC. Studies on the space weather processes and their linkage to magnetosphere-thermosphere- ionosphere system has significant relevance with the science focus of the Aditya-L1 mission and future missions of ISRO.

Expected Deliverables:

Deliverables include the quantitative understanding of physical processes governing the variability of ionospheric structure and dynamics; evaluation and improvements in the prediction capabilities, AI/ML codes, algorithms to estimate ionospheric parameters over the equatorial and low latitudes.

RES-PRL-2023-011

Name of ISRO Centre/Unit

Physical Research Laboratory, Ahmedabad

Title of the research proposal

Small scale and transient features in the Mesosphere Lower Thermosphere (MLT) region using airglow technique

Name of Co PI from ISRO Centre/Unit

Dr. Ravindra Pratap Singh

Contact Address of Co PI and e-mail id

ravindra@prl.res.in

Area of Research

- MLT dynamics
- Optical Aeronomy
- Spectral image analysis
- Optical Instrumentation

Summary of the proposed research and expected deliverables

Upward propagating waves (tides and gravity waves) from lower atmosphere affect the mesosphere lower thermosphere (MLT) dynamics.

Imaging and spectral techniques are used to measure naturally occurring airglow emissions that respond to the neutral density and temperatures perturbations due to these upward propagating waves. Upward propagating waves having large amplitudes produces large wind shears and steep negative temperature gradients in the MLT region.

These make the atmosphere unstable and produces a dynamical unstable region due to the interaction of waves and the background atmosphere and convective instability (super adiabatic lapse rate).

Due to the presence of these unstable regions transient features named as ripples are generated in the MLT region which are less explored. OH(3-1) band airglow emission intensities are measure from which the rotational temperatures are derived corresponding to 87 km altitude using PRL airglow infrared

spectrograph (PAIRS). In addition, a high spatial and temporal resolution airglow imager is developed to observe these ripples using OH airglow measurement in the short wave infrared (SWIR) region. These small scale features will be investigated using ground- and satellite-based data sets to understand the MLT dynamics during convective and dynamical instability.

Scope of the Work:

- This study will help to investigate the reasons behind generation of the ripple like structures seen in the imager data.
- Analyze satellite based data sets e.g., Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) and TIMED Doppler Interferometer (TIDI) to identify the instability features in the MLT region.
- Use PAIRS and SWIR imager data to investigate the perturbations in the airglow emission intensities and temperatures due to the dynamical and convective instability in the MLT region.
- Field operation of PAIRS and SWIR imager from suitable locations.

Linkages to Space Programme:

Investigation MLT dynamics is important to understand the forcing due to the upward propagating waves and its interaction in the upper atmosphere. These activities will complement the science objective of the proposed ISRO's DISHA (Disturbed and quiet time Ionosphere- thermosphere System at High Altitudes) mission.

Expected Deliverables:

- Explore the small-scale transient features in the MLT region to understand the energy input.
- The expected outcome will enhance the understanding of the MLT dynamics duringunstable atmospheric conditions.

RES-PRL-2023-012

Name of ISRO Centre/Unit

Physical Research Laboratory, Ahmedabad

Title of the research proposal

Astronomical transients: Early classification and multi-wavelength follow-up

Name of Co PI from ISRO Centre/Unit

Dr. Vishal Joshi

Contact Address of Co PI and e-mail id

vjoshi@prl.res.in

Area of Research

Astronomical data analysis

Summary of the proposed research and expected deliverables

All-sky survey programs such as the Palomar Transient Factory (PTF), the All-Sky Automated Survey for Supernovae (ASAS- SN), and the Zwicky Transient Facility (ZTF) have discovered several brilliant

explosions known as astronomical transients. These explosions have changed our understanding of cosmic fireworks.

In the new era of time-domain astronomy, the rate of transient discovery has increased enormously, almost exponentially. The commissioning of the Large Synoptic Survey Telescope (LSST, also known as the Vera Rubin Observatory) in the coming years will allow us to scan the optical sky every night further increasing the rate of the transient discovery. The timescales of astronomical transients range from a few hours to a few years. Their progenitor channels, physical environments, and the processes involved are presumably different for different transients. The study of these cosmic catastrophes requires early classification, multi-wavelength observations, and follow-up observations of newly discovered transients. Spectroscopic classification of a large number of newly discovered transients is a challenging task. This has led to a significant gap between the number of discovered transients and classified transients. So far, transient classification programs have been conducted by a few dedicated facilities and individual groups around the world. However, these facilities are inadequate. In India There is no astronomical spectroscopic facility available for robotic observations and real-time transient classification. The newly commissioned 2.5m telescope at Mount Abu observatory along with upcoming low-resolution spectrograph can be used to acquire optical observations of newly discovered transients in a semi-automated manner. The acquired observations can be used to classify the transient and plan follow-up multi-wavelength observations from the Mount Abu Observatory as well as other ground- and space-based observatories.

Scope of the Work:

The scope of the work may include tasks related to the classification of astronomical transients and their multiwavelength follow-up. Some possible tasks include: Selecting astronomical transients of interest, Conducting optical observations from the Mount Abu Observatory, Reducing and analyzing the observed data, Classifying the astronomical transients, Planning and coordinating follow-up observations, Interpreting the derived results etc.

The development of procedures/logic and associated Python codes is also expected as part of the proposed work for some of the following tasks:

- Automated identification of potentially interesting transients using discovery data, availability in the Mount Abu sky, brightness of the transients, etc.
- Automated basic analysis of the spectroscopic data acquired from the Mount Abu Observatory.
- Classification of astronomical transients using traditional techniques such as feature extraction and template matching, as well as artificial intelligence techniques.
- Searching for archived data of transients from various astronomical archives. The work also involves planning follow-up multiwavelength observations of interesting transients from other Indian (e.g., ASTROSAT, GMRT) and international observatories, and analyzing the acquired data.

Linkages to Space Programme:

The codes developed under the proposed project will help to analyze the spectra and classify the transients in an efficient manner.

Expected Deliverables:

- Various python codes as listed in the above as per the Scope of the work.

RES-PRL-2023-013

Name of ISRO Centre/Unit

Physical Research Laboratory, Ahmedabad

Title of the research proposal

Development of large-area, radiation tolerant Silicon Carbide X-ray detectors for Planetary Exploration

Name of Co PI from ISRO Centre/Unit

Dr. M. Shanmugam

Contact Address of Co PI and e-mail id

shansm@prl.res.in

Area of Research

Detector Development and Space Instrumentation

Summary of the proposed research and expected deliverables

Remote sensing of planetary objects using X-ray wavelengths for obtaining the elemental composition is considered as necessary for the scientific study of planetary bodies. Silicon based detectors integrated to custom developed electronics are being used in Ch-2/Ch-3 missions such as Solar X-ray Monitors (XSM) and Alpha Particle X-ray Spectrometers (APXS) and also in other space missions. Planetary exploration, however, presents some of the harshest operating environments, which places high demands on Instrumentation, including extreme thermal conditions, low mass, stringent power constraints and high-radiation tolerance. In particular, radiation-harsh environments are typical to some critical space-based missions. To maximise the science returns, the detectors must have high detection efficiency, good spectral resolution, good dynamic range, capable of operating at high temperatures compared to today's cooled devices and able to withstand harsh space radiation environments found around planets in our solar system. Though conventional Si detectors are currently used in high resolution X-ray spectroscopy, their application is limited due to their low radiation tolerance. Wide bandgap semiconductors such as Silicon Carbide, diamond have the potential to overcome the temperature and radiation limits of commercial silicon.

Scope of the Work:

The research work focusses primarily on fabrication and characterization of large-area, SiC X-ray detectors operating at room temperature/elevated temperatures meeting the requirements of planetary exploration and testing the performance under space-like radiations. On the other hand, detailed material characterization, device fabrication/ characterization, packaging, integration with the existing electronics and the space-radiation tolerance compares to Si detectors are most pivotal issues that requires more research efforts.

Linkages to Space Programme:

As ISRO is gearing up for the series of planetary missions for the planets such as Venus, Mars and other planets, it is essential to have such high temperature and radiation tolerant detectors for its survival for the longer periods to have measurements in the X-ray and high energy regime.

Expected Deliverables:

Packaged, Large-area SiC X-ray detectors.

SATISH DHAWAN SPACE CENTRE
SRIHARIKOTA

RES-SDSC-2023-001

Name of ISRO Centre/Unit
Satish Dhawan Space Centre, Sriharikota

Title of the research proposal
Numerical simulation of propellant slurry casting

Name of Co PI from ISRO Centre/Unit
Mr. Srinivas Yara,
Mr. Chandra Prakash Kotwal

Contact Address of Co PI and e-mail id
srinivas.yara@shar.gov.in,
chandraprakash.kotwal@shar.gov.in

Area of Research
Simulation of non-Newtonian slurry flow

Summary of the proposed research and expected deliverables
Solid motors are being used of boosters for launch vehicles. Solid motor processing involves raw material preparation, mixing, casting, curing and finishing operations. After propellant mixing, propellant slurry will be cast into the rocket case by maintaining vacuum and slurry feed rate. Slurry flows from the mixer bowl/hopper to rocket case through the feedline and falls into the rocket case. Propellant slurry is consisting of 68% oxidiser, 18% fuel, 10% binder and 0.8% curator. Slurry viscosity increases from 600 Pa-s (end of mix) to 1600 Pa-s in 4 hours on account of curing reaction. This propellant slurry is considered as non-Newtonian fluid.

For processing the large rocket case, casting is being carried out with vertical feed line and for small rocket cases, multi feed (inclined feedline) is being used. Any bubble formed/present during propellant casting, rises through propellant slurry with varying viscosity regions.

Now, it is proposed to carry out numerical simulation of propellant casting using ANSYS Fluent and bubble rise phenomenon in slurry.

Scope of the Work:

- Develop a methodology for steady state numerical analysis of propellant slurry casting for a given vertical feedline and multi feed.
- Unsteady bubbles rise phenomenon in propellant slurry with varying viscosity regions.

Linkages to Space Programme:

The proposal has linkages to the study on the propellant slurry casting of solid rocket motors.

Expected Deliverables:

- Finalize parameters like mesh size, time step, residuals, algorithm selected, boundary conditions parameters for numerical simulation.
- Submission of ANSYS Fluent files in DVD/portable storage format.
- A detailed report of methodology evolved for numerical simulation and results.

RES-SDSC-2023-002

Name of ISRO Centre/Unit

Satish Dhawan Space Centre, Sriharikota

Title of the research proposal

Real time JPDA & MHT based Data Association in dense multi target tracking environment

Name of Co PI from ISRO Centre/Unit

Mr A.Vaidhyanathan

Contact Address of Co PI and e-mail id

vaidhyanathan.a@shar.gov.in

Area of Research

Radar Data Processing

Summary of the proposed research and expected deliverables

Multi Object Tracking Radar (MOTR) is an L-Band Active Phased Array Radar designed to track multiple targets. It is a long range skin mode tracking radar capable of tracking 0.25m2 RCS target up to a range of 1000km. MOTR can track more than 10 simultaneous targets using single agile beam.

MOTR has implemented Linear Kalman filter (LKF) and Extended Kalman filter (EKF) for tracking multiple targets simultaneously and Simple Nearest neighborhood (SNN) based data association algorithm to associate target returns with the target being tracked. SNN data association algorithm gives a better result in tracking multiple targets when the targets being tracked are spatially separated. When multiple targets are very closer SNN algorithm gives poor result. It also fails in situation like targets cross over and co traveling of two targets.

To overcome this situation probability based data association (PDA) methods like Joint Probability data association (JPDA) and Multiple Hypothesis Tracking (MHT) algorithms are used. Since these algorithms uses probability based algorithms these are complex incorporated to SNN. Hence these algorithms are mostly used in offline analysis.

Scope of the Work:

To implement JPDA in Real time and MHT in near real time application of MOTR for tracking multiple targets.

Linkages to Space Programme:

This proposal has linkages to the Near real time application of MOTR for tracking multiple targets.

Expected Deliverables:

Expected deliverables are the detailed study and simulation of PDA, JPDA and MHT algorithms in MATLAB, simulation results of above algorithms with MOTR radar data and implantation of these in C code.

RES-SDSC-2023-003

Name of ISRO Centre/Unit

Satish Dhawan Space Centre, Sriharikota

Title of the research proposal

Space Debris RCS Estimation and dynamics Characterisation from MOTR Space Debris tracked data

Name of Co PI from ISRO Centre/Unit

Mr. A.Vaidhyanathan

Contact Address of Co PI and e-mail id

vaidhyanathan.a@shar.gov.in

Area of Research

Radar Data Processing

Summary of the proposed research and expected deliverables

Multi Object Tracking Radar (MOTR) is an L-Band Active Phased Array Radar designed to track multiple targets. It is a long range skin mode tracking radar capable of tracking 0.25m2 RCS target up to a range of 1000km. MOTR can track more than 10 simultaneous targets using single agile beam.

MOTR is the first sensor in India capable of tracking space debris up to an altitude of 800 km. MOTR has tracked and catalogued nearly 54 different space objects from an altitude of 400 to 900km which includes spent down stages of launch vehicles, debris, space station like ISS, Tiangong and live satellites. MOTR tracked the space objects in skin mode.

Studying the received signal from the target gives us the information of the target like its dynamics spin, its size and RCS. These characteristics of the debris need to be catalogued, to compute its drag coefficient, and its life time assessment.

Scope of the Work:

To study on the Dynamic characteristics and RCS estimation of Space debris from MOTR tracked data.

Linkages to Space Programme:

The deliverables from this project may be helpful in RCS Estimation and dynamics Characterisation of Space Debris from MOTR tracked data.

Expected Deliverables:

Expected deliverables are the detailed study and simulation of the required algorithms to be implemented in MATLAB, simulation results and implantation of the algorithms in C code.

ISRO INERTIAL SYSTEMS UNIT
THIRUVANANTHAPURAM

RES-IISU-2023-001

Name of ISRO Centre/Unit
ISRO Inertial Systems Unit, Thiruvananthapuram

Title of the research proposal
Development of coating recipes using Atomic Layer thin film Deposition (ALD) for coating on Ball bearing components

Name of Co PI from ISRO Centre/Unit
Mr. R. Sivakumaran

Contact Address of Co PI and e-mail id
r_sivakumaran@vssc.gov.in

Area of Research
Thin films, Atomic layer deposition and surface characterizations

Summary of the proposed research and expected deliverables
To develop a various coating recipes such as Carbides, Sulfides and Nitrides using Atomic layer thin film deposition (ALD) to coat on Bearing components made of AISI 440C such as Spherical balls and Bearing Inner and Outer races. The above said Recipes will be used for coating of Titanium carbide, Molybdenum sulfide and Titanium Nitride on the above said substrates.

Scope of the Work:

Research & Development : Using suitable precursors and its chemistry to develop a various ALD coating recipes and deposit Uniform, Conformal coating, High aspect ratios, and repeatability on substrate materials of Bearing components such as Spherical balls (Dia < 7mm) and Bearing Races Dia 20 x 42 mm and 10 x 26 mm. Optimize the anti-wear coatings with respect to coating thickness, coating adhesion, surface roughness (< 0.045µ), Plasma treatments on the wetability of coated surfaces. Demonstrating the above requirements/specifications shall be developed.

Linkages to Space Programme:

The proposal has linkages to Sensors, spacecraft actuators like Reaction wheel, Momentum wheel, SADA and scan Mechanisms etc.

Expected Deliverables:

Demonstrating the above requirements/ specifications on Bearing components as well as sample coupons.

Sample coupon level coating evaluations such as Coating thickness, Surface roughness, Substrate Hardness, Coating Adhesion, Nanoindentation and Nano scratch test, Morphology and coating compositions.

RES-IISU-2023-002

Name of ISRO Centre/Unit

ISRO Inertial Systems Unit, Thiruvananthapuram

Title of the research proposal

Mitigation of surface distress in bearing steel

Name of Co PI from ISRO Centre/Unit

Mr. Rejith. R

Contact Address of Co PI and e-mail id

rejith_ramkumar@vssc.gov.in

Area of Research

Surface distress and Rolling contact life assessment of bearing steel under distress condition

Summary of the proposed research and expected deliverables

Rolling bearings can undergo a loss of material (wear/contact fatigue) due to inadequate lubrication, entry of abrasive particles and other causes. Surface distress refers to the surface degradation in bearing contact surfaces triggered by surface asperity interactions. Even though bearing performance is not affected in the early phase of surface distress, surface degradation can accelerate lubricant degradation and cause bearing failure in initial phase of design life itself. Hence it is critical for long life bearing applications.

The current proposal will focus on the main mechanisms of the potential wear-fatigue combination damage modes under surface distress conditions. The study will aim to analyse the role of steel microstructure in surface distress and evaluation of newer grades of bearing steels under operating conditions prone to surface damage. Modeling and experiments needs to be carried out to gain a better understanding on surface distress initiating mechanisms and role of bearing steel in this phenomenon.

Scope of the Work:

The scope of the proposal is to establish a correlation between bearing steel microstructure and surface distress so that newer material grades can be used to mitigate this failure mode and improve bearing life and reliability for long life applications such as spacecraft mechanisms.

Linkages to Space Programme:

The proposal has linkages to Space Tribology - Bearings for L/V and S/C programmes.

Expected Deliverables:

- Role of steel microstructure in surface distress.
- Protocols for surface profiling, optimum thermal treatments in bearing steels to address surface distress.
- Evaluation of alternate bearing steel grades in RCF tests under test conditions triggering surface distress.

RES-IISU-2023-003

Name of ISRO Centre/Unit

ISRO Inertial Systems Unit, Thiruvananthapuram

Title of the research proposal

Ultra low damping conductive thin film coating development for hemispherical resonator of HRG

Name of Co PI from ISRO Centre/Unit

Mr. Arun George

Contact Address of Co PI and e-mail id

k_arungeorge@vssc.gov.in

Area of Research

Sensors

Summary of the proposed research and expected deliverables

HRG is a classical Coriolis vibratory gyroscope made of only three components viz. Hemispherical Shell Resonator, Forcer and Housing. The reduced number of components increases the reliability, robustness and producibility of the sensor. The performance of HRG is dependent mainly on the Quality factor of the resonator which is typically of the order of 7 million prior to any conductive coating. Hence the hemispherical shell resonator is realized in high purity fused silica which is having the minimum internal damping. The forcing and sensing of the sensor is capacitive based and hence an ultrathin layer of conductive coating is required over the resonator shell. The inner hemispherical surface of the shell and the forcer forms electrodes of the capacitor. Addition of thin metallic coating on the resonator surface reduce the Q factor of the shell drastically. Hence the coating thickness has to be less than 500 armstrong. Also the electrical requirements such as continuity, conductivity, capacitance etc to be met with the coating. The proposed research is aimed at development of an ultra-low damping thin film coating process development on a hemispherical surface. The method of coating can be either DC/RF sputtering or Ion beam sputter coating. The study shall include the various damping mechanisms of thin film coating and how each of the damping mechanisms are minimized.

Scope of the Work:

IISU is developing Hemispherical resonator gyroscope which is next generation ultra precision gyroscope based on Coriolis effect. The ultra-high Q fused silica resonator the heart of the sensor. Since the sensor forcing and pick off is capacitive based, an ultra thin film conductive layer (300 to 500 armstrong) is required on the inner surface of the resonator shell. A thin film coting process has to be developed with minimum effect on the Q factor. The scope also include:-

- Main coating Material selection and its thickness.
- Undercoat material selection if required and its thickness.
- The coating process can be DC/RF sputtering, Ion beam sputter coating, e-beam coating or any other suitable.
- Coating parameters like temperature, rate of deposition, vacuum level etc..
- Post processing like thermal ageing, annealing etc..
- Modelling of various thin film based damping mechanisms.

- Coating adhesion qualification and coating characterisation for mechanical and electrical requirements.

The experimental trials may be conducted on high Q specimen and the Q factor deterioration can be assessed by Laser doppler vibrometer or any other similar setups. The coating thickness and material for coating can be finalised based on thermoelastic damping studies using FE or analytical tools.

Linkages to Space Programme:

Space craft and launch vehicle inertial navigation system.

Expected Deliverables:

Qualification of ultrathin film coating process, evaluation of study report and process documents for DC/RF sputtering, e-beam or ion beam coating system.

RES-IISU-2023-004

Name of ISRO Centre/Unit

ISRO Inertial Systems Unit, Thiruvananthapuram

Title of the research proposal

Optical Phase Locked Loop for Phase stabilization of Raman Beams

Name of Co PI from ISRO Centre/Unit

Mr. Sasikumar K K

Dr. Radhika V N

Contact Address of Co PI and e-mail id

sasikumar_kk@vssc.gov.in

vn_radhika@vssc.gov.in

Area of Research

Optics, Opto-electronics, Physics, Electronics and Control

Summary of the proposed research and expected deliverables

For Cold Atom interferometry based gravimeter setup, coherent interaction of light with matter is carried out using Raman lasers. It requires two separate light fields (one master and one slave) whose frequency difference should be precisely maintained at 6.834682610 GHz and it's phase difference should be locked and can be varied as and when required. General approach is that beat frequency from master and a slave laser is compared with a stable reference signal and OPLL circuit generates the error signal for the slave laser correction through the feedback loop. In atom interferometry, phase between Raman beams are to be varied and Acceleration or Rotation measurements are derived using suitable algorithms.

The present proposal is to design and development of an Optical Phase Lock Loop which gives two spatially separated laser beams (generated from Toptica DLC pro laser sources – master and slave) with a frequency difference of 6.834682610 GHz and are phase locked. Phase Variance $(\Delta\varphi)^2$ should be less than 1µrad/√Hz. Master laser source will be frequency locked to the desired atomic transition (780.2 nm regime) and slave laser to be controlled in close loop with master laser for maintaining frequency separation and phase stability.

Scope of the Work:

Proposed research is to design compact system for generating phase locked laser beams at a frequency difference 6.834682610 GHz having provision to vary phase offset from 0 to 2π in steps of 1 mrad is expected. OPLL Circuit shall take input laser beams from external cavity diode lasers of Toptica DL Pro, measure the frequency difference, phase difference and generate the feedback signals for closed loop control of slave laser (as per the mentioned specifications). In addition, the phase offset between the laser beams have to be controlled based on an external input.

Linkages to Space Programme:

The project has linkages to Cold Atom Sensor Development.

Expected Deliverables:

- Compact module of OPLL with necessary interfaces for powering as well as passing master and slave laser beams.
- Detailed design documentation and test results.

RES-IISU-2023-005

Name of ISRO Centre/Unit

ISRO Inertial Systems Unit, Thiruvananthapuram

Title of the research proposal

Energy Harvesting from Martian Environment using Triboelectric Effect for Powering Smart Sensor Nodes

Name of Co PI from ISRO Centre/Unit

Dr. Anjitha Viswanath

Contact Address of Co PI and e-mail id

anjitha_viswanath@vssc.gov.in

Area of Research

Energy harvesting, self powered sensors

Summary of the proposed research and expected deliverables

A consistent and reliable power source is critical for any Mars exploration missions. Current energy supply for Mars mission relies on solar cell and radioisotope thermal generator, but they suffer from sunlight decline by dusty air and potential risk of contamination, respectively. Abundant wind, strong dust storms and surface vibrations on Mars are attractive mechanical sources to convert into electrical energy. Conventional electromagnetic generators are unsuitable for planetary exploration due to the heavy weight of permanent magnets and metal coils and high launch costs. The alternative to electromagnetive generators could be the triboelectric harvesters which yields high output power per mass.

The triboelectric nanogenerator (TENG) uses contact electrification and electrostatic induction as energy harvesting principle. TENG converts high entropy mechanical energy such as wind, vibrations etc. into electricity by collecting charges generated through materials in contact, which are placed apart in the triboelectric series. These nanogenerators are the applications of Maxwell's displacement current

in energy and sensors. TENG is a paradigm shift technology with an output power density of up to 500 W/m^2 and an instantaneous conversion efficiency of ~70 %. TENG uses neither magnets nor coils; it is light in mass, low in density, low in cost, and can be fabricated using most of the materials.

The highly insulating layer of unconsolidated material covering the Martian bed rock in extremely dry conditions at low temperatures and low pressures is favorable in building up of electrostatic charge. The triboelectric properties of martian environment can be effectively utilised for generating electricity through TENG technology. In addition, in the era of IoT and sensor networks, self-powered electronics is of great interest, especially for space exploration. Energy autonomous smart sensor modules for Mars exploration can be realized using TENGs, which can supply adequate and uninterrupted electric power to sensor nodes through energy management circuits.

Scope of the Work:

To design and fabricate an efficient triboelectric nanogenerators suitable for Martian environment harvesting high entropy mechanical energy from wind, vibration and triboelectric charges in Mars for powering smart sensor nodes and other payloads.

Research involves:

Identification of the generator architecture, mechanism and the tribo-pair material selection suitable for Mars environment.

Simulation validating the geometry and dimensions of the generator and the output voltage that can be generated.

Development of the scalable working prototype that can be used to capture the mechanical energy from the working environment to sustainably power electronic sensors.

Method to couple and store the energy harvested.

Identify the fabrication methodology and tools.

Linkages to Space Programme:

Mars Lander Mission involves the development and deployment of ISRO smart sensor nodes to study about the Martian environment. These energy harvesters can be used to power these sensor nodes making them self powered.

Not only in Martian environment this can also find application in other planetary missions wherein the payloads can be powered using this TENG technology.

Expected Deliverables:

Simulation studies and experimental validation of the electrical output of the developed TENG.

Scalable working prototype of triboelectric nanogenerators suitable for Martian environment for self-powered sensors.

INDIAN INSTITUTE OF REMOTE SENSING
DEHRADUN

RES-IIRS-2023-001

Name of ISRO Centre/Unit
Indian Institute of Remote Sensing, Dehradun

Title of the research proposal
Phenology monitoring for high and medium biomass crops (C4 and C3) using multispectral (optical) and Synthetic Aperture Radar data with changing climate variables

Name of Co PI from ISRO Centre/Unit
Dr. Dipanwita Haldar

Contact Address of Co PI and e-mail id
dipanwita@iirs.gov.in

Area of Research
RS and GIS-Agricultural applications using Microwave Remote sensing data and other RS data

Summary of the proposed research and expected deliverables
Among the dominant tropical crops in India, many of them have heavy foliage growth and high biomass in both C3 and C4 categories. They require long and warm growing season. In the monsoon season availability of the optical data is a critical issue and coincides with the fast growth so multitemporal dual-polarised/ fully polarimetric data of moderate swath and resolution seem viable. Use of various frequency SAR data for different crops has been demonstrated globally (Chakraborty et al., 2005 Inoue et al, 2002, Haldar et al. 2012, 2014, 2018, Maity et al.2004, McNairn et al.,2002, Dave, Haldar et al., 2017, Chauhan et al., 2018) condition assessment in paddy, cotton, jute, and groundnut in the past. But the high biomass crops eg. sugarcane need to be addressed with higher wavelength facilitating better penetration for crop parameter study. Land preparation, sowing, tillering/vegetative phase, grand growth and maturity phase in sugarcane/ vegetative crops are the main stages to affect the specific synergistic response from SAR and optical multispectral data. For the freshly sown crops, the reflectance/backscatter is mainly from the soil surface in the field. As the plant develops, the radar response increases due to volume scattering.

These details will be captured by the various frequency SAR operating presently. Therefore, in this project, it is proposed for utilization of lower frequency satellite data (C/S and L band) and evaluation of its response to crop biophysical parameter and yield monitoring.

Additional response information in the lower frequency domain is expected. Both C3 and C4 crops will be addressed with respect to difference in their water use and rate of photosynthetic assimilation. The extremes in climate variables are expected to modify/ delay the onset of phenophases in one of the above category as compared to the other. The rate of assimilation is expected to be different.

Scope of the Work:

The studies with X- and C band report saturation beyond 5 kg/m2 of fresh biomass and entails difficulty in discrimination and biophysical parameter retrieval and yield. Also in the initial growth period

multispectral optical data will provide detailed crop growth information. The scope is retrieval of the parameters beyond C-band particularly in its saturation zone (also saturation zone for multispectral remote sensing).

The high biomass crops like sugarcane and few others where yield is from vegetative part, this effort has multidimensional scope not only for vegetation monitoring but also predicting phenology wise crop condition and crop yield as affected by changing climate.

In the past effort has gone in monitoring Jute and cotton crop where encouraging results were obtained for crop condition and biomass monitoring though conjuctive use of SAR and optical data (Haldar et al., 2012, 2014, 2020). Similar efforts with improved instrumentation will address both C3 and C4 group of crops, their biomass assimilation differs, these will be captured with RS data. Photosynthetic assimilation will be assessed in terms of biomass and canopy water with phenology under the changing climatic variables.

Linkages to Space Programme:

The biomass and the biophysical parameters retrieved will be used for assessing the crop condition and also to predict crop yield. These parameters will act as yield indicators.

This will link to the NISAR data utilization and RISAT- constellation mission, also other EO satellite missions from high orbits.

Expected Deliverables:

Biomass map, crop height map, crop condition. phenology map and their differences over time.

RES-IIRS-2023-002

Name of ISRO Centre/Unit

Indian Institute of Remote Sensing, Dehradun

Title of the research proposal

Automating information extraction of objects of interest using development of advanced methods and algorithms for online/offline processing and analysis of multi-source data/ from High & medium resolution satellite images

Name of Co PI from ISRO Centre/Unit

Dr. Vandita Srivastava

Contact Address of Co PI and e-mail id

vandita@iirs.gov.in

Area of Research

Automating Information Extraction; Image Processing & Analysis

Summary of the proposed research and expected deliverables

Extraction of important information, from a satellite image or a set of satellite images/multi source data, (such as 2D & 3D building parameters and individual tree boundaries, number, height, canopy shape etc., water bodies, roads and their width, road types, tree plantations, parks, play grounds, built up area, in a

habituated (urban or rural) area, in-land water bodies, information on cultural heritage and tourism sites, etc.) is important for various purposes (inventorisation, planning, management and decision making) at various levels. Availability of multi & hyper-spectral (optical/microwave), multiresolution/ sensor, multitemporal from multiple platforms (space based aerial/ ground based/ UAV/ LiDAR) coupled with appropriate automated methods could fulfil the requirement of information extraction from satellite images. Several potential methods such as neural networks & deep learning, natural intelligence based methods, object based methods considering spatial spectral classification analysis, contextual methods, appropriate fusion (at pixel/ feature level and information) of multisource data, need to be explored for effective utilization of the huge amount of multi-source data available from remote sensing satellites.

Scope of the Work:

Conception, development and implementation of algorithm/s and model of (semi/) automatic object extraction, data collection and pre-processing for specific objects chosen for study and demonstration of working of the model with set and appropriate outcomes, from high and/or medium resolution satellite images, and other multi source data.

Linkages to Space Programme:

The proposal has linkages to ISRO's High Resolution Imaging programme.

Expected Deliverables:

Working model on important information extracted from satellite images or a set of satellite images on chosen objects/ information such as 2D & 3D building parameters and tree canopy boundaries, number, height, canopy shape etc., water bodies, roads and their width, road types, tree plantations, parks, play grounds, built up area, in a habituated (urban or rural) area, inland water bodies, information on cultural heritage tourism sites, etc.).

RES-IIRS-2023-003

Name of ISRO Centre/Unit

Indian Institute of Remote Sensing, Dehradun

Title of the research proposal

Assessing Building Vulnerability to Multiple Hazards in Hilly Urban Environments: An InSAR and Geotechnical Data Approach

Name of Co PI from ISRO Centre/Unit

Dr. Sandeep Maithani

Contact Address of Co PI and e-mail id

maithani@iirs.gov.in

Area of Research

Geospatial Technology for urban studies

Summary of the proposed research and expected deliverables

Buildings and infrastructures in mountainous regions are inherently vulnerable, often resulting in human casualties. They face an array of natural hazards whose cumulative risks and their impact on populations remain insufficiently explored. Due to the distinctive topography, geological dynamics, and

hydrology of mountainous areas, residents and settlements in urban areas become highly susceptible to multiple concurrent natural threats, including landslides, earthquakes, cloud bursts, flash floods, and wildfire. To enhance urban safety, it's crucial to identify high-risk zones proactively, thereby reducing urban vulnerability. In this context, satellite radar interferometry (InSAR), emerges as a valuable tool which provides precise, non- invasive monitoring of land surface deformations across extensive areas.

By integrating InSAR data with geotechnical information, we gain a holistic view of urban infrastructure vulnerability, evaluating building deformations comprehensively. This can also involves intricate analysis, considering factors such as building types, historical landslide data, and geological conditions within a GIS framework. This approach enhances our understanding of how multi-hazards affect buildings in mountainous regions, facilitating more effective vulnerability assessment and mapping.

Scope of the Work:

This project can enhance disaster preparedness in mountainous regions by identifying high-risk zones and facilitating more effective mitigation strategies. Also, by evaluating building deformations and vulnerability comprehensively, this project contributes to enhancing the safety of urban areas in mountainous regions.

The use of advanced technologies like interferometric SAR combined with geo physical and geotechnical investigations expands the scientific understanding of multi-hazard interactions in mountainous terrains, potentially leading to broader applications beyond this context.

Linkages to Space Programme:

Evaluate multi-hazard risks in urban environments through the use of InSAR and geotechnical data, addressing challenges arising from diverse hazard events at varying scales.

Combine InSAR data, geotechnical information, and damage surveys to detect, map, and assess landslides, contributing to comprehensive urban planning and risk mitigation.

Expected Deliverables:

- Detailed GIS maps showcasing vulnerability hotspots in mountainous regions, highlighting areas at the highest risk of multi-hazard impacts such as landslides, earthquakes, and flash floods.
- A comprehensive assessment of urban safety, including evaluations of building deformations, structural vulnerabilities, and infrastructure resilience in response to multi-hazards.
- A comprehensive document detailing the multi-hazard risk evaluation, including analysis of InSAR and geotechnical data, spatial risk distribution, and identification of vulnerable areas.
- A plan outlining recommended strategies to reduce urban vulnerability based on the identified risk distribution, aiding urban planners and authorities in hazard mitigation.

RES-IIRS-2023-004

Name of ISRO Centre/Unit

Indian Institute of Remote Sensing, Dehradun

Title of the research proposal

Design and Development of Astroculture system to study crops growth under space environment

Name of Co PI from ISRO Centre/Unit

Mr. Ashutosh Kumar Jha

Contact Address of Co PI and e-mail id

akjha@iirs.gov.in

Area of Research

Human Space Program

Summary of the proposed research and expected deliverables

The focus of this project is to closely monitor the health and growth of edible high reproducible plants under the space environment. A prototype of close vegetation module that can support robust root and shoot systems for plant cultivation in space should be built. By studying plant growth in controlled environment, the astroculture system, practices and protocols for ensuring a sustainable food supply during extended space missions will be established.

The proposal aims to gain insights into what are the optimal environmental conditions affecting its growth in space environment and how crops growth is affected.

Objective:

To design and construct a plant growth system based on hydroponics or rockwool culture-based root and shoot systems with plant growth and various physiological parameters monitoring system for establish the relationship between different environmental factors and plant health indicators.

The closed environmental system should offer continuous monitoring capabilities using sensors to analyze factors such as atmospheric composition,

- Photosynthetically Active Radiation (PAR), and the chemical composition of the aqueous solution.

Develop a plant growth module that includes:

- Reliable root/shoot zones with moisture and nutrient delivery control system for microgravity-environment.
- An illuminating system with adjustable lighting conditions and schedule to deliver
- UV-VIS-NIR radiation (300-800nm).
- An atmosphere management system capable of controlling temperature and humidity, especially under conditions of low gravity and elevated carbon dioxide and oxygen concentrations.
- A process control and 3D observation unit for plant growth monitoring, along with periodic data recording with integrated hyperspectral and depth cameras.

Scope of the Work:

The design should be gravity agnostic as far as possible and capable of handling various inflight shocks and deployment.

The unit of 2 root shoot zones with growth volume of 10 cmX10 cmX10 cm should be built.

Linkages to Space Programme:

The proposal has linkages to ISRO's Space Science Program.

Expected Deliverables:

- Environmental control system with design and build of material.
- Two modules each:
  - First phase on ground module.
  - Second phase inflight delivery.
- Document and published papers having reference of above design.
- Software system interface.

RES-IIRS-2023-005

Name of ISRO Centre/Unit

Indian Institute of Remote Sensing, Dehradun

Title of the research proposal

Synergistic study and modeling of urban heating, urban fluxes and landscape pattern in an urban purlieu

Name of Co PI from ISRO Centre/Unit

Dr. Asfa Siddiqui

Contact Address of Co PI and e-mail id

Area of Research

RS and GIS-Geospatial Technology for urban studies

Summary of the proposed research and expected deliverables

Assessment of energy fluxes and surface-atmosphere energy balance is considered an important study for urban environment. The arrangement of manmade impervious surfaces (building and roads), their geometry and orientation, material composition, albedo/emissivity, topography, natural and delineated spaces of vegetation, and the concurrent atmospheric profiles together play a pivotal role in defining the urban morphological thermal environment. All the above together help in determining the surface temperature and related boundary layer parameters. Scale and spatial resolution can also alter the scenario of conclusive recommendations based on the interrelationships between urban landscape structure and urban heating through their respective indicators. Luan, et al. analysed some urban green land in Beijing with Landsat TM5 data with 90 m spatial resolution and showed that urban green land patches' perimeter, area, shape index, and fractional vegetation cover had no significant correlation with their cooling range on their surroundings; Gao et al. obtained completely different conclusions by aerial photos with 0.25 m spatial resolution. Additionally, deterministic models such as building energy models (BEM) developed based on the interactions of building volume with the surrounding environment and other computational fluid dynamics (CFD) based models (like ENVIMET) can be efficiently used for modelling the heat flux and urban heating phenomenon holistically. These models can simulate the micro-scale thermal interactions to investigate the effects of urban form and landscaping efficiently

as suggested by various studies. Also, the model can help in exploring the relationship between Near Surface Urban Pollution (NSUP) and Surface Urban Heating (SUH) using high resolution drone data.

Scope of the Work:

The scope of the research is limited to using satellite and ground based observations for urban environment simulations in deterministic models like ENVIMET (for micro-level analysis) and WRF (for regional and meso scale analysis). The scope also covers scenario generations w.r.t. roof material change/ albedo change/reduction in vegetation, etc.

Linkages to Space Programme:

ISRO has been working mainly for societal benefits in varied fields. The field of urban planning is greatly benefitted through geospatial inputs enabled through medium to high spatial resolution satellites. The work is an important indicator for take away by policy planners willing to regulate urban environment for the betterment of the society.

Expected Deliverables:

The project provides an interrelationship between bio-physical, climatic and anthropogenic parameters altering the urban heating environment. It further simulates the micro and macro scale urban thermal environment and generates scenarios under situations of altered parameters under consideration. It paves ways for policy planners by providing recommendations.

RES-IIRS-2023-006

Name of ISRO Centre/Unit

Indian Institute of Remote Sensing, Dehradun

Title of the research proposal

Micro- and Meso-Scale Urban Climate Modelling and research for improved weather prediction and disaster risk reduction over urban areas

Name of Co PI from ISRO Centre/Unit

Dr. Kshama Gupta

Contact Address of Co PI and e-mail id

Area of Research

Geospatial Technology for Urban Studies Sub-area: Urban micro-climate modeling

Summary of the proposed research and expected deliverables

Study of urban climate is important at local and global scale, which is influenced by several factors such as urban morphology and density, properties of urban surfaces, vegetation cover, etc.

The urban built-form is highly heterogeneous and due to its dense development and high-rise character, and the increase in impervious and absorptive surfaces are responsible for the trapping of heat and reduction in evaporative cooling due to decrease in vegetated, soft, pervious surfaces in urban areas. It is imperative to represent urban surfaces in high–resolution models accurately in detail to integrate urban energy exchange processes for improved weather forecast and disaster management in urban areas.

It is more significant in the scenario of climate change. Technology development is desirable for the generation of 3D urban database, urban parameterization in numerical weather models, urban canopy parameters estimation and understanding the micro- and meso-scale urban climate phenomena using space based observations. Such studies shall be useful for improved weather prediction over urban areas which shall be useful and shall assist in disaster risk reduction in urban areas.

Scope of the Work:

The study will focus on geospatial driven methods and approaches for urban canopy parameter estimation and their integration in high-resolution urban climate models for improved weather and climatological modeling in urban areas for disaster risk reduction.

Linkages to Space Programme:

The study can be linked with utilization of Indian EO program and sustainable built environment.

Expected Deliverables:

Spatially variable urban canopy parameters as an input to high-resolution weather prediction models for improved weather prediction.

RES-IIRS-2023-007

Name of ISRO Centre/Unit

Indian Institute of Remote Sensing, Dehradun

Title of the research proposal

Hydrological cycle and water ice dynamics assessment of Solar system and water cycle of exoplanets using orbiting satellites, astronomical observations and simulation models

Name of Co PI from ISRO Centre/Unit

Dr. Praveen K Thakur

Contact Address of Co PI and e-mail id

praveen@iirs.gov.in

Area of Research

Water cycle and ice dynamics

Summary of the proposed research and expected deliverables

There are several celestial bodies in our Solar System, where water is known to exist in its various forms. Most of the terrestrial planets (Mercury, Venus, Earth, and Mars), shows some presence of water ice, at their poles, except for Earth, where water is found in all three phases (solid, liquid and vapor) and at all places. Similarly Earth's Moon, Moons of Jovian Planets or Giant Planets such as Europa, Ganymede Enceladus, Titan, Triton etc., and near-Earth asteroid 'Ceres' have shown strong presence of water ice and possibility of liquid water or "oceans worlds" below thick ice curst.

The projects under this theme would attempt to characterize, quantify and monitor such water of Solar system celestial bodies using data form existing Indian and international space missions, as well as using theoretical mathematical models.

Scope of the Work:

The main scope of this work would be further the understanding of water dynamics of some of the celestial bodies of our Solar system. This will also help in developing the understanding of water dynamics, origin and evolution of life in our Solar system.

Linkages to Space Programme:

The project will help in identification and quantification of water ice and water cycle of solar system objects using current and future ISRO's space science and planetary missions, such as Chandrayaan 1/2/3; Mangalyaan 1; Mangalyaan 2; etc. It will also lead future development of ISRO's space exploration missions to Earth's Moon, Mars, Moons of Jupiter, Saturn and selected asteroids..

Expected Deliverables:

The main deliverables would be maps and quantification of water ice for the selected Solar system objects and water cycle dynamics as observed by historical, present day and future space missions.

RES-IIRS-2023-008

Name of ISRO Centre/Unit

Indian Institute of Remote Sensing, Dehradun

Title of the research proposal

Satellite data and numerical simulations based studies of intra-seasonal variability of South-West monsoon system

Name of Co PI from ISRO Centre/Unit

Dr. Charu Singh

Contact Address of Co PI and e-mail id

charu@iirs.gov.in

Area of Research

Earth, weather and Climate Sciences/ Atmosphere and Climate Sciences

Summary of the proposed research and expected deliverables

Rainfall during the summer monsoon season is one of the most important factors in deciding the fate of the economy in tropical region. Livelihood of people specifically in Indian subcontinent region largely depends on agriculture yield, which is considerable modulated by amount of rainfall within a monsoon season. Prediction of the seasonal total rainfall have notably been improved in recent years based on the present set of global circulation models (GCMs), however still there is a substantial scope to improve our present understanding of intra-seasonal variability of the Indian summer monsoon. Intra-seasonal variability is observed across various elements of the monsoon system e.g. pressure of monsoon trough, cross-equatorial flow, monsoon clouds and rainfall etc. which consist of periodicities at similar temporal scales and propagation. Such periodicities are connected with the active and break periods during the principal rainy season and are found to be largely affected by the land-atmosphere feedback mechanism (local and regional), aerosols (both anthropogenic and natural) as well as the large-scale forcing. In a country like India where major agriculture practices are based on rain fed agriculture, the development of suitable methods and analysis for improved understanding of the mechanism of active

and break spells formation are of utmost importance. Satellite based data sets have been proved to be useful in delineating the active and break rainfall spells in several previous studies (Hoyos et al., 2007; Singh et al., 2016; Singh et al, 2017; Singh and Dasgupta, 2017). It is proposed to study the intra-seasonal variability of Indian summer monsoon system parameters based on synergistic use of satellite, reanalysis data sets and numerical simulations which will be helpful in developing the understanding of physical mechanism behind this variability. Such a study would be a value addition to the ongoing research in this context and may prove to be helpful in developing a method for identification of active and break rain spells and their spatial-temporal characteristics in association with local, regional and remote factors.

Scope of the Work:

In proposed research, synergistic use of the observational data sets, satellite based estimates, reanalysis products and numerical simulations will be carried out to address variability of Indian summer monsoon across the scales in more comprehensive way to incorporate high frequency to low frequency fluctuations, land-surface feedback mechanism, ocean-atmosphere feedback mechanism, aerosol-cloud-precipitation interaction and remote teleconnections.

Linkages to Space Programme:

The deliverables of this project will be useful for the Atmospheric Science Program of ISRO. The project will also make use of the data from existing and future meteorological satellites of ISRO/NASA/JAXA/ESA etc.

Expected Deliverables:

- Improved understanding of intraseasonal variability of South-West monsoon in association with regional and remote teleconnections.
- Understanding of physics of aerosol-cloud- precipitation interaction and its role in delineating depth and duration of active and break rainfall spells during monsoon.
- Comprehensive understanding of various feedback mechanism in controlling the precipitation distribution during South-West monsoon.

RES-IIRS-2023-009

Name of ISRO Centre/Unit

Indian Institute of Remote Sensing, Dehradun

Title of the research proposal

Inter-annual variability of Indian Ocean carbon cycle using satellite and numerical ocean modelling

Name of Co PI from ISRO Centre/Unit

Dr. Sachiko Mohanty

Contact Address of Co PI and e-mail id

sachiko@iirs.gov.in

Area of Research

Earth, Ocean, Atmosphere, Planetary Sciences and Applications/ Ocean and Climate Sciences

Summary of the proposed research and expected deliverables

Oceans play a significant role in maintaining the balance of the global carbon cycle. As a consequence of anthropogenic activities, the carbon dioxide (CO_2) in the atmosphere is steadily increasing. It is estimated that the ocean absorbs one-third of the CO_2 present in the global atmosphere. However, the studies on the seasonal and inter-annual variability of carbon and the relative importance of various underlying physical and dynamic processes are still in their early stage, especially over the Indian Ocean. In the current global warming scenario induced by climate change, an accurate estimation of the local and basin-wide distribution of carbon absorbed and released over the Indian Ocean is of primary significance. The recent advances in satellite-remote sensing in conjunction with the usage of 3D coupled physical and biogeochemical modeling can facilitate the better understanding of the current spatiotemporal variability and estimation of future conditions.

Scope of the Work:

In the present study, the primary objective will be to investigate the interannual variability of partial pressure of CO_2 using the multi-year Oceansat data in conjunction with a basin scale configuration of three dimensional coupled physical-biogeochemical numerical model. The potential causative factors governing the year-to-year variability will also be investigated. The spatiotemporal distribution of surface oceanic carbon over the Indian Ocean will be studied by utilizing the satellite-derived estimates. The observed variability in the carbon distribution will be investigated by the using numerical model simulations to discern the relative role of physical and dynamical processes in governing the carbon cycle over the various sectors of the Indian Ocean.

Linkages to Space Programme:

The proposal will use Oceansat 3 data for the proposed study.

Expected Deliverables:

- Quantitative estimates of interannual variability of surface carbon distribution over the Indian Ocean.
- Disentangling the potential factors governing the observed year-to-year variability of surface carbon distribution over the Indian Ocean.
- Improved scientific insights on the response of carbon cycle under the climate change induced basin-wide warming of the Indian Ocean.

NATIONAL ATMOSPHERIC RESEARCH LABORATORY

GADANKI

RES-NARL-2023-001

Name of ISRO Centre/Unit

National Atmospheric Research Laboratory, Gadanki

Title of the research proposal

Scattering simulations of electromagnetic radiation by raindrops

Name of Co PI from ISRO Centre/Unit

Dr. T. Narayana Rao

Contact Address of Co PI and e-mail id

tnrao@narl.gov.in

Area of Research

Radar meteorology, Retrieval of geophysical parameters, rain attenuation, communication

Summary of the proposed research and expected deliverables

Interaction of electromagnetic radiation with raindrops is quite complex and depends on several factors, phase and shape of hydrometeor, frequency of EM radiation, temperature, etc. These simulations are highly essential for variety of applications, including retrieval of geophysical parameters from satellite data, link budget estimations related to rain attenuation, and accurate quantitative precipitation estimation with polarimetric Doppler weather radars. Traditionally, T-matrix scattering simulations are being used to estimate polarimetric products from measured raindrop size distributions.

Other scattering simulations, like lattice Boltzmann code, can be developed to better understand the dependence of scattering on size and shape of raindrops, which improves quantification of rainfall.

Scope of the Work:

In addition to advancing scientific understanding of EM wave scattering by raindrops, the work will help improve QPE by Doppler Weather radars and space-borne radars, in retrieving geophysical parameters and in link budget estimations related to rain attenuation.

Linkages to Space Programme:

The scientific understanding of EM wave scattering by raindrops and the code will help in link budget estimations related to rain attenuation.

Specifically, quantification of rain attenuation of Ku, Ka and Q-band signals at different rain rates and also by different drop sizes.

Expected Deliverables:

- Lattice Boltzmann code.

- Relations between polarimetric products for improved estimations of rainfall, raindrop size distribution, quantification of rain attenuation of Ku, Ka and Q-band signals at different rain rates and also by different drop sizes.

RES-NARL-2023-002

Name of ISRO Centre/Unit

National Atmospheric Research Laboratory, Gadanki

Title of the research proposal

Retrieval of Temperature and Trace gases from Middle Atmospheric Radiometric satellites

Name of Co PI from ISRO Centre/Unit

Dr. M. Venkat Ratnam

Contact Address of Co PI and e-mail id

vratnam@narl.gov.in

Area of Research

Atmospheric Science/Middle and Upper atmosphere/Retrieval techniques

Summary of the proposed research and expected deliverables

In light of the increasing realization of the impact of solar variability and associated space weather processes on the terrestrial system, as well as on sophisticated space missions, coupled with the growing dependence of the modern world on space-based communication and navigation needs on one hand, and anthropogenic perturbations on the geosphere and its feedback to higher regions of the atmosphere on the other, the need for satellites covering the complete middle and upper atmosphere is paramount.

A limb-scanning satellite with an infrared radiometer covering the spectral range from 1 μm to 17 μm can be used to retrieve the vertical profiles of kinetic temperature and trace gases. Given that the middle atmosphere is distant from Local Thermodynamic Equilibrium (LTE), one must consider non-LTE above 60-70 km for these retrievals.

Earth's lower atmosphere is in LTE because of frequent collisions under which the populations of the energy levels within a molecule are given by the Boltzmann law at the local kinetic temperature. However, non-LTE arises when the `internal' temperature of a representative molecule, becomes different from the `local' temperature. The difference depends on mean rate of collision (which is lesser) which in turn depends on number density and pressure which dominates upper atmosphere.

Due to involved work and complexities, currently, India does not have expertise in developing retrieval techniques for extracting temperature and trace gases from middle atmospheric radiometric satellites.

Scope of the Work:

Main objective of this proposal is to obtain solutions for non-LTE conditions. Currently two solutions exist i.e., (i) Total Escape to Space (TES) which is the simplest approximate solution for non-LTE assuming that all photons emitted are lost and none are reabsorbed and (ii) Cool to Space (CTS) which introduces the concept of the 'escape probability' function that gives the probability that a photon, emitted at

an altitude z, escape to space in any direction in the upper atmosphere. These solutions need to be implemented that will help in developing the retrieval algorithms for middle atmospheric radiometric satellites for obtaining profiles of temperature and trace gases.

Linkages to Space Programme:

The proposed research will be highly valuable in the future when India launches middle atmospheric radiometric satellites. These developed algorithms, can then be used to investigate the structure and dynamics of the middle atmosphere more preciously for understanding several middle atmospheric processes and its impact on weather and climate.

For the time being the developed algorithms will be applied for the raw data being obtained from the existing NASA satellite like SABER onboard TIMED mission.

Expected Deliverables:

Algorithm(s) for the retrieval of kinetic temperatures and trace gases above 60-70 km up to 120 km with highest precision and accuracy from middle atmosphere Limb viewing satellites.

Non-LTE retrieval techniques that are useful in the estimation of thermal cooling and solar heating rates.

RES-NARL-2023-003

Name of ISRO Centre/Unit

National Atmospheric Research Laboratory, Gadanki

Title of the research proposal

Software Defined Radio (SDR) based multi-channel receiver and signal processing system for atmospheric radar

Name of Co PI from ISRO Centre/Unit

Ms. P Yasodha

Contact Address of Co PI and e-mail id

pyasoda@narl.gov.in

Area of Research

Atmospheric Radar remote sensing

Summary of the proposed research and expected deliverables

Atmospheric radars employ techniques like spaced antenna, imaging, post beam steering, digital beam forming etc., which require multiple receive channels to process the atmospheric back scatter collected by the independent sub-arrays of the radar antenna. A multi-channel receiver and signal processing system is essential to process the radar multiple receive channel data. Each channel data has to undergo through a sequence of signal processing steps, which include, digitization, range gating, filtering, decoding, decimation, coherent integration, DC/clutter removal etc., before subjecting to the specific data analysis technique. Finally the atmospheric products will be derived from the multi-channel data. Data analysis techniques include Full correlation Analysis (FCA) for spaced antenna application, Capon/ Fourier imaging for imaging application etc.

Software defined radio (SDR) is becoming popular, owing to its reconfigurability, flexibility and cost-efficiency. SDR boards are available commercially with multiple transmit and receive channels, which make them suitable to be used as multi- channel receiver for the atmospheric radar application. All the signal processing steps mentioned above can be implemented in the SDR board with multiple receive channels. Open source software is available to program the SDR boards. The board takes a reference timing pulse from the radar and then starts to receive and digitize the signals at the multiple channels.

The data is then processed and transferred to PC where it is further processed and stored. The software also contains a GUI to program the board for the radar parameters and to store the processed data and derived products with date and time stamp.

Scope of the Work:

Development of SDR based multi-channel receiver and signal processing system for atmospheric radar.

Linkages to Space Programme:

The atmospheric data products derived can be used as initial parameters for weather and climate modelling which can in turn be used for rocket launch support.

Expected Deliverables:

Multi-channel SDR based receiver and signal processing system with GUI, atmospheric data products (U, V, W, turbulence etc.)

NORTH EASTERN SPACE APPLICATIONS CENTRE
SHILLONG

RES-NESAC-2023-001

Name of ISRO Centre/Unit
North Eastern Space Applications Centre, Shillong

Title of the research proposal
Development of unsupervised domain adaptive deep learning models for aerial and satellite imagery

Name of Co PI from ISRO Centre/Unit
Mr. Avinash Kumar Chouhan

Contact Address of Co PI and e-mail id
avinash.chouhan@nesac.gov.in

Area of Research
Artificial Intelligence, Deep Learning

Summary of the proposed research and expected deliverables
Unsupervised Domain Adaptation (UDA) in the context of remote sensing data involves adapting a model trained on labeled data from a source domain (such as one geographic area or sensor) to perform effectively on an unlabeled target domain (a different geographic area or sensor) without the need for target domain labels. In remote sensing, the challenges of varying lighting conditions, sensor characteristics, and environmental factors can hinder model generalization across diverse geographical locations. UDA techniques bridge this gap by leveraging shared features between domains, utilizing transferable knowledge, and reducing domain shift. By aligning feature distributions between the source and target domains, UDA enhances the model's ability to accurately classify land cover, detect objects, and perform other tasks in the target domain, thereby improving the practicality and applicability of remote sensing models across varying operational contexts.

The main objective of this work is to develop UDA techniques so that the deep learning models trained on one domain can be enhanced to work on new target domain.

Scope of the Work:

- Develop UDA techniques for deep models and demonstrate the domain adaptation for atleast three vision tasks (Semantic segmentation, Change detection, Object detection, etc.) using benchmark datasets.
- Atleast two multi-modal test cases (UAV– Satellite/ Multispectral – SAR/ RGB – Point Cloud/ etc.) to be included in this work.
- Create a user interface that will be used to produce target domain labels using developed UDA techniques and provide a mechanism to update the labels.

Linkages to Space Programme:

The amount of multi modal earth observation data generated is increasing at a large pace each year. UDA based model development is very important as it provide ability to create generalized deep

learning based solutions. In the remote sensing domain, UDA is more relevant due to variations in sensors, flying conditions, and other changing parameters. UDA also provides a platform to refine the foundation models for the earth observation domain that will be very useful for various downstream image analysis tasks. UDA can also be used to augment the manual annotation task, which requires huge human efforts. UDA can significantly improve the utility of deep learning models developed for earth observation data analysis.

Expected Deliverables:

- UDA techniques and deep learning models.
- Task specific UDA datasets created using benchmark datasets.

RES-NESAC-2023-002

Name of ISRO Centre/Unit

North Eastern Space Applications Centre (NESAC), Shillong

Title of the research proposal

Performance Evaluation of MSW Incinerated ash Based Capillary Barrier System for Stabilizing Rainfall Induced Landslides: An Experimental and Numerical Study

Name of Co PI from ISRO Centre/Unit

Dr. Kuntala Bhusan

Contact Address of Co PI and e-mail id

Kuntala.bhusan@nesac.gov.in

Area of Research

Disaster Management, RS & GIS, and Materials

Summary of the proposed research and expected deliverables

Rainfall-induced slope failures are common in the North Eastern Region (NER) of India. In recent days, the capillary barrier system (CBS) has been found to be an effective method for stabilizing the slope under rainfall conditions. This study proposes a sustainable CBS (SCBS) to stabilize rainfall-triggered slope failures/active landslides. SCBS reduces rainwater infiltration into slopes. A SCBS is a two-layer man-made system with varying hydraulic properties between the fine-grained (drainage) and coarse-grained (capillary break) layers of soils.

India generates approximately 68 million metric tons of Municipal Solid Waste (MSW) annually, and this number is expected to be continuously increasing. Hence the utilization of MSW incinerated ash is of utmost importance. Effective utilization of ash not only will address the critical issue of waste management, but also provide numerous environmental, economic, and social advantages. By recycling and repurposing materials from municipal solid waste, it is possible to reduce the strain on natural resources and the environmental impact of waste disposal.

MSW incinerated bottom ash and fly ash is proposed to be used as a material for SCBS combined with vegetation. Further to simulate the response of the SCBS and vegetation under actual rainfall conditions using numerical studies. Finally, the performance of the SCBS should be evaluated under northeast climatic conditions through a pilot lab and in-situ field study.

Scope of the Work:

The current study aims to conduct a thorough examination of the efficacy of utilizing Municipal Solid Waste (MSW) incinerated ash in capillary barrier systems as a means of mitigating landslides triggered by rainfall. Study includes the execution of laboratory tests to evaluate the performance of the system in controlled conditions as well as for the actual field condition. Moreover, the study will employ numerical models to simulate its response in different rainfall scenarios and analyze the resulting data to arrive at conclusions regarding its effectiveness. The key objective of this study is to offer practical suggestions for the design and implementation of the sustainable capillary barrier system (SCBS). Additionally, it seeks to provide insights into the potential environmental consequences and cost- effectiveness of the proposed measures. The primary aim is to provide significant insights and recommendations for the implementation of this unique methodology in areas susceptible to landslides. Finally, this study is in line with the "Waste to Energy" concept to mitigate consequences of rainfall-triggered landslides.

Linkages to Space Programme:

The proposed study explores the potential utilization of satellite imagery and derived thematic information, landslide susceptibility maps prepared under ISRO DMSP in order to establish connections with the space program. Further space-based technologies have the potential to monitor and evaluation of areas that are susceptible to landslides, analysis of rainfall patterns and terrain characteristics. Satellite image will be also used to identify the MSW dump sites in the northeast regions. The utilization of satellite data offers significant contributions to the understanding of the environmental and geographical elements that contribute to landslides. This facilitates the identification of appropriate locations for research and the verification of computational models. Furthermore, the collaboration within the space program might potentially contribute to the incorporation of sophisticated geospatial data into the analysis and recommendations of the study. This integration would result in improved accuracy and relevance of the research findings, particularly in the context of efforts to mitigate consequences of landslides.

Expected Deliverables:

- The expected deliverables are as follows:
  - The current study set out to investigate the long-term effect of vegetation on the slopes protected with an MSW incinerated ash-based capillary barrier system under heavy rainfall conditions.
- The key outcomes of the present study are as follows:
  - A sustainable capillary barrier system (SCBS) for stabilizing the slopes under heavy rainfall conditions.
  - Assessment report on long-term effect of vegetation & influence of rainfall condition/intensity on the performance of the SCBS.
  - The performance report of vegetated SCBS through numerical and laboratory studies, which will be investigated based on the in-situ field conditions.

RES-NESAC-2023-003

Name of ISRO Centre/Unit

North Eastern Space Applications Centre, Shillong

Title of the research proposal

Crustal deformation analysis in the tectonically active regions of NER using SAR and GNSS data

Name of Co PI from ISRO Centre/Unit

Dr. Gopal Sharma

Contact Address of Co PI and e-mail id

gopal.sharma@nesac.gov.in

Area of Research

RS & GIS Applications: Geoscience

Summary of the proposed research and expected deliverables

The projects shall involve

- Methodology development for SAR and GNSS data integration to study crustal deformation.
- SAR based Seismotectonic analysis of the region.
- Time series analysis for crustal convergence estimation in the region.
- Identification of pre seismic deformation pattern.

Scope of the Work:

With the launch of many SAR sensors including the NASA – ISRO Synthetic Aperture Radar (NISAR), Indian Earth Observation Satellite – 04 (EOS-04), Sentinel 1 etc., SAR Interferometry technique is emerging for tectonic and deformation study thereby reducing the dependability of dense GNSS network. Additionally Survey of India (SoI) initiative to establishment of Continuously Operating Reference Stations (CORS) in NER shall provide continuous flow of ground data. The current need is the integration of GNSS observations and SAR interferometry. This integrated study shall help immensely in understanding the spatial distribution of crustal deformation and strain in the region with limited GNSS observation data.

Linkages to Space Programme:

EOAM project of ISRO: Geodynamics and Seismicity Investigation, NISAR data utilization and EOS-04 data utilization.

Expected Deliverables:

- Deformation pattern in selected region of NER.
- Understanding of seismic potential of the region.

RES-NESAC-2023-004

Name of ISRO Centre/Unit

North Eastern Space Applications Centre, Shillong

Title of the research proposal

Experiment to find suitability of ionospheric seismotectonic precursors for North Eastern Region through a network of low cost GNSS receivers

Name of Co PI from ISRO Centre/Unit

Mr. Anjan Debnath

Contact Address of Co PI and e-mail id

anjan.debnath@nesac.gov.in

Area of Research

Navigation

Summary of the proposed research and expected deliverables

Ionospheric seismotectonic precursors are believed to be observable 3-5 days before large magnitude shallow earthquakes. Considering the vulnerable situation of the NER for earthquakes and co-induced natural disasters, a comprehensive study needs to be done to examine the potential of ionospheric precursors of seismotectonic activity for the NER especially.

A brief study conducted under ISRO STIC (NIT-Agartala) TDP (S-TIC-NE-0124), it was found that for South East Asian (SEA) region, ionospheric Vertical Total Electron Content (VTEC) based earthquake precursor study gave promising results when the actual observations from International GNSS Services (IGS) network stations' data were fed to a Artificial Neural Network (ANN) based machine learning (ML) model. The model could predict location, time and magnitude of impending earthquakes with varying degrees of accuracy based on earthquake magnitude and other parameters.

Accordingly, based on the results, a GNSS based experimental study is proposed in the NER by setting up a distributed low cost GNSS receiver network to monitor the performance of such precursors when used with similar ML models. The project will develop the necessary receivers, place them in chosen locations in the field and see the performance of the receivers during a 5- year period.

Scope of the Work:

The project will aim to create a ground based network of high precision low cost GNSS receivers throughout NER, especially the most vulnerable locations to earthquake in NER. Through the network, ionospheric observables (VTEC, foF2, hmF2) would be registered and archived on a continuous basis and fed to a ML model which can predict impending earthquakes (time, magnitude, location) based on anomalies observed in the values of ionospheric observables. The process would be done in automated manner to see the performance of multiple candidate ML models to select the best performing model in a long term scenario.

Linkages to Space Programme:

The project is directly related to application of GNSS, namely, NaVIC and GAGAN of ISRO and other GNSS (GPS of US, GALILEO of EU, GLONASS of Russia and augmentation systems of other regions/countries), especially for Space Based inputs for Disaster Mitigation, management & Early Warning System.

Expected Deliverables:

- An Earthquake Early Warning System (EEWS) based on ionospheric seismotectonic precursors.
- A Machine Learning Model trained for the NER with scope for expansion for prediction of earthquake magnitude, location and time.
- Actionable input for DM authorities at Central/State level for necessary Disaster Risk Reduction (DRR) exercise.

RES-NESAC-2023-005

Name of ISRO Centre/Unit

North Eastern Space Applications Centre, Shillong

Title of the research proposal

ISM band voice communication transceiver system design with Repeater for Disaster scenario with NAVIC positioning feature

Name of Co PI from ISRO Centre/Unit

Mr. Himangshu Jyoti Das

Contact Address of Co PI and e-mail id

himangshu.das@nesac.gov.in

Area of Research

Communication

Summary of the proposed research and expected deliverables

Most of the traditional communications means are failed during disaster. Satellite communication is a valuable tool for such emergency communication during disasters. However a second line of communication infrastructure will always plays an important role in disaster management. As NER comes in a disaster prone area, the availability of such infrastructure will definitely help the disaster management much more efficient.

Based on this theme, a transceiver system working on ISM band with repeater and equipped with NAVIC positioning features may enhance the disaster communication with more reliability. As ISM band is license free, the license acquiring complexities will be avoided in the project.

The communication between the transmitter and receiver will further carry the location information of the transceiver system provided by a NAVIC receiver attached with the device.

Scope of the Work:

A transceiver system working in ISM band and a NAVIC receiver module attached may be designed and investigated under this project. The limitation in ISM band communication is the range of communication between two nodes. However the communication range can be enhanced by introducing a repeater in between the transmitter and repeater. During actual disaster scenario, the repeater can be placed by means of a High Altitude Platform (HAP) e.g. atmospheric balloon, high rise tower etc. to cover larger area.

The larger area coverage by such system is in the scope of research.

Linkages to Space Programme:

The deliverables of the project will be used in the standard positioning services of NAVIC/ IRNSS.

Expected Deliverables:

- A transceiver system prototype for voice data communication in ISM band (2.4 GHz).
- A repeater system to amplify the incoming voice signal.
- Integration of a NAVIC receiver into the transceiver module for location information.

ISRO TELEMETRY TRACKING AND COMMAND NETWORK

BENGALURU

RES-ISTRAC-2023-001

Name of ISRO Centre/Unit

ISRO Telemetry Tracking and Command Network, Bengaluru

Title of the research proposal

Development of algorithm for Interference Monitoring of NavIC signals

Name of Co PI from ISRO Centre/Unit

Mr. Prem Ranjan Dubey

Contact Address of Co PI and e-mail id

prem@istrac.gov.in

Area of Research

Satellite Navigation Technology

Summary of the proposed research and expected deliverables

NavIC services are critical infrastructure which are prone to intentional and non-intentional interferences. In order to mitigate the interference, it is necessary to first detect the interference, identify the type and then localize using suitable signal processing algorithms. Identification of interference involves identifying whether it is spoofed interference or blanket interference (CW or Pulsed interference; Narrow band and Wide band Interference). There are different localization techniques such as Angle of Arrival (AOA), Time Difference of Arrival (TDOA), Frequency Difference of Arrival (FDOA) and Received Signal Strength which can be used alone or in combination for further optimization.

Scope of the Work:

The proposed research includes

- Design and implementation of Interference Detection algorithms.
- Design and implementation of Interference Source direction estimation algorithms.
- Design and implementation of Interference Source.
- Localization and tracking algorithms.
- **Software of the processing module to be preferably written in HDL language**

Linkages to Space Programme:

Design will be used to improve the interference mitigation performance of NavIC Receivers deployed at critical infrastructures.

Expected Deliverables:

- Functionality tested Software modules for above mentioned algorithms, HDL design files, simulation model including test benches and netlist for the complete design.

- Design Documents, Algorithms in the soft copy (CD/DVD) and hard copy (print) format and intellectual property.
- Simulation results of the implemented methods.
- Receiver implementation on suitable evaluation boards with the Interference detection and mitigation algorithms and test results.
- Project Report.

RES-ISTRAC-2023-002

Name of ISRO Centre/Unit

ISRO Telemetry Tracking and Command Network, Bengaluru

Title of the research proposal

Design and development of tracking and multipath mitigation system for NavIC signals using RF-signal characterization through advanced Correlator technology

Name of Co PI from ISRO Centre/Unit

Ms. Neelu Kasat

Contact Address of Co PI and e-mail id

neelurathi@istrac.gov.in

Area of Research

Satellite Navigation Technology

Summary of the proposed research and expected deliverables

Advanced correlation based tracking shall be a method of measuring the RF characteristics in the time domain of the phase transitions of the modulated signal. This method shall provide a very robust tracking of the NavIC signals in the multipath environment. It also provides a very accurate measurement of code range and carrier phase even in the multipath environment.

Scope of the Work:

The proposed research includes

- Design and realization of correlation hardware circuitry for measuring the Radio Frequency properties of the chip transition in fine detail.
- Hardware for filtering the noise and forming an average chip transition shape by super imposing successive chip transitions.
- Formation of reference shape of the chip transition by collecting the data from the NavIC simulator and from the live signal.
- Development of an algorithm for decomposing the received average chip transition shape in to a direct path signal and multiple multipath signals by comparing with the reference chip transition shape. Identifying the amplitude, phase and delay of the direct signal and multipath signal.
- Generation of the corrections for the tracking signals.
- Design and realization of the receiver acquiring, tracking with advanced correlator and measurement generation for L1, L5 and S band NavIC signals on a suitable FPGA+SoC platform.
- The software of the receiver to be preferably written in C/C++ and HDL Language.

Linkages to Space Programme:

The developed algorithms and the prototype design will be used to improve the range measurement accuracy obtained from the receiver. These measurements are used to determine the orbit and clock characteristics of the NavIC satellite constellation which in turn improves the position accuracy of the NavIC user.

Expected Deliverables:

- Software: Functionally tested NavIC receiver Script/High-level source code HDL design files, simulation models and netlists, for complete design and executable.
- Algorithm for identifying the Amplitude, phase and delay of direct and indirect signal in the soft copy (CD/DVD) and hard copy (print) format.
- Design documents, algorithms and other intellectual property.
- Receiver implementation on evaluation boards with the multipath mitigation algorithm and test results.
- Project Report.

RES-ISTRAC-2023-003

Name of ISRO Centre/Unit

ISRO Telemetry Tracking and Command Network, Bengaluru

Title of the research proposal

Development of algorithm for pulsed interference detection and mitigation technique for NavIC L-band signals

Name of Co PI from ISRO Centre/Unit

Ms. Aakanksha Avnish Bhardwajan

Contact Address of Co PI and e-mail id

aakanksha_bhardwajan@istrac.gov.in

Area of Research

Satellite Navigation Technology

Summary of the proposed research and expected deliverables

Pulse Blanking is a technique to suppress pulsed interference by having Analog to digital converter output zeros when pulse is detected. Strong pulse will saturate the A/D performance which will suppress the desired signal, weak pulses will add to the noise. The degradation of receiver depends on the power spectral density of the pulsed signal.

Pulse blanking shall be selected for its reduced computational requirements. Pulse blanking significantly extends the receiver capabilities and allows it to maintain lock even in the proximity of the jammer. Pulse blanking significantly improves the receiver performance and a gain of about 6 dB on the Carrier-to-Noise power spectral density ratio (C/N0) values of the signals tracked.

Scope of the Work:

The proposed research includes

- Design and realization of antenna, antenna subsystem, RF frontend with variable gain, analog to digital samples and sample processing module.
- Development of optimal algorithm to detect the pulse interference in the NavIC signal frequency band and also to detect the start, width and frequency of repetition of the interfering pulse.
- Implementation of processing module consisting of detection of the interference and blanking of the samples for the configured period.
- Software of the processing module to be preferably written in HDL language.

Linkages to Space Programme:

Design will be used to improve the performance and gain of the tracked NavIC signals.

Expected Deliverables:

- Functionality tested NavIC sample processing module HDL design files, simulation model and netlist for the complete design.
- Algorithm for detection pulse interference and method of blanking of the samples in the soft copy (CD/DVD) and hard copy (print) format.
- Simulation results of the implemented methods.
- Fabricated prototype consisting of antenna, antenna subsystem, RF/IF frontend with variable gain and digital processing board with implementation of pulsed interference detection and blanking.

RES-ISTRAC-2023-004

Name of ISRO Centre/Unit

ISRO Telemetry Tracking and Command Network, Bengaluru

Title of the research proposal

Algorithm development for detection of spoofing signals in NavIC receivers

Name of Co PI from ISRO Centre/Unit

Mr. Prem Ranjan Dubey

Contact Address of Co PI and e-mail id

prem@istrac.gov.in

Area of Research

Navigation Systems

Summary of the proposed research and expected deliverables

All civilian GNSS signals are vulnerable to spoofing due to the extremely weak signals received at the receivers. Spoofing allows an adversary to mimic the navigation satellite signals and present the receiver with data that can lead to incorrect position/time solutions. This can be easily implemented with COTS SDR platforms and is a growing concern for the security of signals received by civilian GNSS application.

This proposal is for the development of system that can detect spoofing in the NavIC signals. NavIC being the Indian regional navigation constellation with both civilian and strategic objective, is just as vulnerable to spoofing.

This proposal aims to develop the algorithms for detection of spoofing in the NavIC signals. This proposal looks for a comprehensive solution that can detect spoofed signals at various stages of the navigation signal processing.

Scope of the Work:

The proposed research includes

- Development of algorithms for detection of spoofing in NavIC signals.
- Design and realization of receiver hardware with the implemented algorithms.
- The software of the receiver to be preferably written in C/C++ and HDL Language.

Linkages to Space Programme:

The developed systems can be used by the NavIC user segment in the detection of malicious signals under adverse conditions.

The receiver can also be used by the NavIC ground segment to identify such sources in the vicinity of its ranging or monitoring stations.

Expected Deliverables:

- Software: Functionally tested NavIC receiver Script/High-level source code.
- HDL design files, simulation models and netlists, for complete design and executable.
- Algorithm for detection and mitigation of various spoofing attacks with respect to NavIC signals in the soft copy (CD/DVD) and hard copy (print) format.
- Generation of the spoofing signals and demonstration of the detection of the spoofing attacks.
- Receiver with the implementation of spoofing detection and mitigation mechanism on suitable evaluation boards and test results.
- Project report.

RES-ISTRAC-2023-005

Name of ISRO Centre/Unit

ISRO Telemetry Tracking and Command Network, Bengaluru

Title of the research proposal

Space object characterisation using Remote Sensing data mining

Name of Co PI from ISRO Centre/Unit

Mr. Sowmitra CVSS

Contact Address of Co PI and e-mail id

sowmitra@istrac.gov.in

Area of Research

Remote Sensing

Summary of the proposed research and expected deliverables

Remote Sensing satellites collect data of Earth from orbit that includes any space object passing through the Field-of- View (FOV). This information is usually filtered out for remote sensing applications. The research is towards understanding and developing an automated software to ingest the remote sensing (RS) satellite images and process the image to identify for presence of any space object.

Scope of the Work:

The objective is to extract the dimensions and shape of the space object through existing RS images. The shape data of space objects thus captured might be crucial for space object catalogue maintenance and other SSA applications. Initially, the study may be focused towards RS optical image processing and later may be extended to other frequency domain observations.

Linkages to Space Programme:

The proposal has linkages to the Safe and Sustainable Space Operations Management.

Expected Deliverables:

Software to detect presence of specific space object in remote sensing data.

RES-ISTRAC-2023-006

Name of ISRO Centre/Unit

ISRO Telemetry Tracking and Command Network, Bengaluru

Title of the research proposal

To develop LLM based Expert AI agent for mission operation management

Name of Co PI from ISRO Centre/Unit

Mr. Amit Kumar Singh

Contact Address of Co PI and e-mail id

amit@istrac.gov.in

Area of Research

Artificial Intelligence

Summary of the proposed research and expected deliverables

Mission operation management involves analysis of telemetry data of satellite to assess the health of all the subsystems of the satellite, planning of payload operations and report generation with statistical information about the overall health of the satellite based on the data available through all the internal documents. In this regard, AI assistant which perform multiple tasks like providing statistical analysis in forms of chart and graph, helps in planning and generation of payload operations and providing document summarization and searching with report generation capability to ease referring all the available documents. Recently, large language models have shown capability to perform the above proposed tasks and hence looking for a standalone offline large language model that can perform all the above proposed tasks.

An NLP and LLM based AI assistant that perform the following task:

- Analysis of data for patterns with output in terms of statistical parameters in forms of graph and charts.
- Planning and generation of required operations plan.
- Document searching based on prompt and summarization with capability to generate in all available document formats like PDF, etc. All the answers to prompt should have source information location reference.

Scope of the Work:

- RL based expert system for Mission Operation management.
- NLP model for understanding language and replying in text and voice – Design model for data analysis on the telemetry data.
- Operational guidelines based on voice input and technical information provided them in required format.
- LLM Model should be designed to accept text/voice query and provide required documents and answer for the query.

Linkages to Space Programme:

The project has linkages to Mission Operation management of Existing IRS satellites and Interplanetary mission.

Expected Deliverables:

Package:

- Model that can be deployed and operate without access to internet.
- input: Text/Voice
- Output: Text/voice/word report/PPT/PDF Document.

Features required:

- Data analysis tool with plots.
- Provide statistical information.
- Operational guidelines preparation in required format.
- Document search and summarization with links to actual source of information.
- Project report, Implementation and process documentation.

MASTER CONTROL FACILITY

HASSAN

RES-MCF-2023-001

Name of ISRO Centre/Unit

Master Control Facility, Hassan

Title of the research proposal

IF Switch Matrix (Combining and Distributive)-32x32 matrix

Name of Co PI from ISRO Centre/Unit

Mr. Jitendra Kumar Kapse

Contact Address of Co PI and e-mail id

jitenkapse@mcf.gov.in

Area of Research

Solid state relay circuit design and simulation

Summary of the proposed research and expected deliverables

In Satellite ground segment, in order to utilize the baseband resources effectively combining/ distributive switch matrixes are utilized for the routing of baseband signal from various ground terminals to baseband equipment and vice-versa.

Scope of the Work:

As a part of the project a combining and a distributive switch matrix has to be developed as per technical specifications mentioned below:

Technical Specifications: 32x32 IF-band Fan-in/Combining Switch Matrix

Parameter	Specification
Capacity	32 inputs x 32 outputs
Routing	Combining, DC blocking, Individual card for each input and output. Full Fan-in Matrix (or fully combining matrix): any input can be routed to any output. Many inputs can be routed to each output. Each input can only be routed to one output.
Frequency Range	70±20 MHz (IF)
Gain Flatness 50-90 MHz	±1 dB or better
Gain	0 dB ± 1 dB nominal
Input Return Loss	18 dB or better
Output Return Loss	18 dB or better
1 dB Compression	+5 dBm or better
Noise Figure	22 dB or better
OIP3	+15 dBm or better

Port-Port Isolation	I/P – O/P: 65 dB or better I/P – I/P: 75 dB or better O/P – O/P: 75 dB or better
Local Control	HMI Touchscreen display (8" or more) on front panel
Remote Control	Ethernet (RJ45), SNMP and web browser interface. Individual Ethernet monitoring for each CPU must be possible. Remote Monitoring & Control software should be provided.
Operating temperature	0 to 45˚C or better
Humidity	20 to 90% non-condensing
Matrix Cards	Single (one per input and one per output), Hot-swap. Failure in one card should result in loss of only one output
CPU	Dual redundant, Hot-swap
PSU	Dual redundant, Hot-swap
AC Power	Dual Input AC Sockets 85-264 VAC 50Hz
Power failure	In case of power failure in both AC sources, and shutting down of the matrix, on turning it back–the matrix should retain the same settings as earlier, i.e. prior to the power shutdown.
Alarms	Continuous monitoring of amplifiers, CPU and PSUs must be possible and any faults should result in an alarm on front panel and remotely. Alarm should report the fault down to the component level.
Dimensions	19" Rack type, not more than 6U
Connectors and impedance	BNC-F, 50 ohms

Technical Specification: 32X32 Switch Matrix Full Fan out/Distributive Switch Matrix:

Parameter	**Specification**
Capacity	32 Inputs x 32 Outputs
Routing	Individual card for each input and output. Distributive, Non-blocking Any input can be routed to any output. Many outputs can be connected to one input. Each output can only be routed to one input.
Frequency Range	70 MHz +20MHz (IF)
Flatness 50-90 MHz	+1 dB or Better
Gain	0dB + ldB
Input Return Loss	18 dB or Better
Output Return Loss	18 dB or Better
1 dB Compression point	+ 5 dBm or better
Noise Figure	18 dB or Better
Input Signal level	0 d Bm to -70 dBm
Port-Port Isolation	I/P - O/P : 80 dB or Better

	I/P - O/P : 80 dB or Better
	I/P - I/P : 80 d B or Better
	O/P - O/P: 80 d B or Better
Local Control	HMITouchscreen display (8" or more) on Front panel
Remote Control	Ethernet (RJ45), SNMP and web browser interface. Individual Ethernet monitoring for each CPU must be possible. Remote Monitoring & Control software should be provided.
Operating temperature	0 to 45°C or Better
Humidity	20 to 90% non-condensing
CPU	Dual redundant, Hot-swap
PSU	Dual redundant, Hot-swap
AC Power	Dual Input AC Sockets, 85-264 VAC 50Hz
Power failure	In case of power failure in both AC sources, and shutting down of the matrix, on turning it back-the matrix should retain the same settings like routing path, IP Address etc. as earlier, i.e. prior to the power shutdown.
Alarms	Continuous monitoring of amplifiers, CPU and PSUs must be possible and any faults should result in an alarm on front panel and remotely. Alarm should report the fault down to the component level.
RF Path 1/0 Cards	Failure in one card should Result in loss of only one path
Dimensions	19" Rack type, not more than 6U
Connectors and impedance	BNC-F, 50 ohms

Linkages to Space Programme:

Full-Fan Out and Full-Fan-In IF switch matrices are key elements in the satellite ground station. They enable us to route the IF signal dynamically to the required destinations. This allows us to re-configure any earth station and Baseband system in case of any contingency. These systems also reduces the total downtime of the operation in case of any uplink and downlink chain failure. Till date IF Switch Matrixes are procured through foreign Vendors like ETL etc. Hence, in order to meet total indigenization of TTC Ground Systems IF Uplink / Downlink Chains, this indigenous realization of IF Switch Matrixes (Full-Fan-In & Full-Fan-Out) will be an important milestone towards 'AtmaNirbhar Bharat' goal in Space Ground Baseband Chain Elements.

Expected Deliverables:

- Circuit schematic, design files and simulation files/results.
- Prototype design and test results.
- Source Code of the firmware developed.
- Remote interface features.

RES-MCF-2023-002

Name of ISRO Centre/Unit

Master Control Facility, Hassan

Title of the research proposal

Realization of C-Band Down-converter towards GEO/GSO Spacecraft Telemetry Signal Acquisition

Name of Co PI from ISRO Centre/Unit

Shri Rajeev Mulugu

Contact Address of Co PI and e-mail id

rajeevmulugu@mcf.gov.in

Area of Research

Communication

Summary of the proposed research and expected deliverables

Down converters are used in SATCOM downlink chains after the Low Noise Amplifiers (LNAs) towards frequency conversion of Space originated telemetry RF signals (typically ranging in freq. between 3700 to 4200 MHz) from RF to intermediate frequency which is typically centered at 70 MHz for further processing of the telemetry signal through suitable Baseband Unit.

A C-Band Down-converter is envisaged to be designed & developed through academia, preferably using super- heterodyne principle along with associated band-pass filters so as to reject the unwanted spurious products generated during the heterodyning/mixing processes in RF/IF Mixers.

Scope of the Work:

A C-Band (3700 to 4200 MHz) Downconverter is envisaged to be designed & developed through Academia ensuring following minimum guideline specifications. The major Technical Specifications of C- Band Down-converter are as follows:

Detailed Specifications of C-Band Down-converter

Parameter	Specification
Frequency Range (CF)	3700 to 4200 MHz
Output Frequency	52 - 88 MHz
Freq. Step-Size	125 kHz (1kHz desirable)
Conversion	Dual
Input Power Range	0 dBm Max
Small Signal Gain	40 dB Min.
Gain Stability	± 0.25 dB/day
Freq. Stability (time)	± 1 X 10^{-7}/Day
P1 dB	+10 dBm
Output Phase Noise	-75dBc @ 1KHz or better
Image Rejection	> 80 dB (in-Band)

Carrier Related Spurious	> 60dBc
Non-related Spurious	Better than -75dBm
Input & Output VSWR	1.35:1 or better
RF Input Connector	N-Type Female
IF Output Connector	BNC (f)
Remote Control Interface	RJ-45 LAN Interface
Operating Temperature Range	0 to 50 Deg. C
Electrical Supply	AC 230V, 50Hz

Linkages to Space Programme:

TTC Earth-Station Ground Segment C-Band Down-converter is a major element in TTC Earth-Station Downlink Chain along with LNA. Till date C-Band Downconverters are procured through foreign Vendors like Comtech, Work Microwave, Miteq etc. Hence, in order to meet total indigenization of TTC Ground Systems RF Uplink / Downlink Chains, this indigenous realization of C-Band Down-converter will be an important milestone towards 'AtmaNirbhar Bharat' goal in Space Ground RF Chain Elements.

Expected Deliverables:

Proto-type Down-converter to be demonstrated and delivered to MCF along with complete RF Circuit design details comprising RF & Control circuit detailed layouts with MIC / lumped Electronic component details.

RES-MCF-2023-003

Name of ISRO Centre/Unit

Master Control Facility, Hassan

Title of the research proposal

Realization of C-Band 200W SSPA towards TTC Earth-Station Uplink Chain

Name of Co PI from ISRO Centre/Unit

Mr. Amit Kumar Vishwakarma

Contact Address of Co PI and e-mail id

amitkvk575@mcf.gov.in

Area of Research

Communication

Summary of the proposed research and expected deliverables

Solid State Power Amplifier is used as final amplifier in the SATCOM Uplink to boost the RF signal levels for transmission of information carriers at the required power levels in order to overcome various link losses encountered along a SATCOM Link to ensure a reliable link performance.

A C-Band SSPA with rated RF Output of 200W (400W desirable) is envisaged to be designed & developed through academia, preferably using GaAs or GaN based SSPA Technology. This SSPA will be used to replace existing Outdoor TWT based Power Amplifiers, which have higher CAPEX & OPEX compared to SSPA's and are currently imported through foreign OEM's.

Scope of the Work:

A Solid-State Amplifier with rated Output Power of 200W in C/Ext. C-Band (preferably 400W) is envisaged to be designed, developed and fabricated through Academia/industry ensuring following minimum guideline specifications. The major technical specifications of C-Band SSPA are as follows:

Detailed Specifications of C-Band SSPA

Parameter	Specification
Frequency Range	5850 to 6450
Rated RF Power (P1)	200W (53 dBm) (Remarks: 400W (56dBm) desirable)
Linear RF	100W (50 dBm) (Remarks: 200W (53-dBm) desirable)
Gain at P1 (dB) minimum	70-dB
Gain Adjustability (dB)	20-dB min. with 1-dB Step
Gain Flatness (dB)	3-dB Pk.-to-Pk. Max (Remarks: Over Full Band)
Gain Slope	0.6-dB over any 40 MHz
RF Power Stability	± 0.25 Pk-to-Pk at any set RF Power
Max. Input Power w/o damage	+10-dBm
3rd Order Intermodulation	25-dBc Max. at 3-dB Back-off
AM/PM Conversion Coeff.	3 Deg./dB Max. at P1
Spurious / Harmonics	-60-dBc at P1
Noise Output	Transmit Band: -85dBm/Hz Receive Band: -145 dBm/Hz
Group Delay	Linear: 0.03 ns/MHz Parabolic: 0.003 ns/MHz^2 Ripple: 1ns Peak-to-Peak
Input / Output VSWR	1.3:1 Max.
RF Input Connector	N-type (f)
Output Interface	WR-137
Remote Control Interface	TCP/IP LAN Interface (HTTP, Telnet, SNMP)
Operating Temperature Range	0 to 50 Deg. C
Electrical Supply	230 Volts, 50 Hz Single Phase
Power Consumption	1300 VA Max.
Chassis / Construction	Suitable Chassis for Outdoor Application

Linkages to Space Programme:

The proposal has linkages to the TTC Earth-Station Ground Segment.

Expected Deliverables:

Proto-type SSPA to be demonstrated and delivered to MCF along with complete RF Circuit design details comprising RF & Control circuit & Power Supply detailed layouts with respective MIC / lumped Electronic component details.

RES-MCF-2023-004

Name of ISRO Centre/Unit

Master Control Facility, Hassan

Title of the research proposal

Development of Motion Controller for Full Motion Antenna

Name of Co PI from ISRO Centre/Unit

Mr. Vipin Agrawal

Mr. Javed SAR Qureishi

Contact Address of Co PI and e-mail id

vipin@mcf.gov.in

jsarq@mcf.gov.in

Area of Research

Digital Control System

Summary of the proposed research and expected deliverables

Motion controller based Antenna Control System (ACS) for 11 mt Full Coverage Antenna (FMA) shall be used to drive the antenna for tracking Geostationary as well as Inclined Geo-Synchronous Satellites. The ACS can be used to position the antenna in all axes of movement for the purpose of locating and tracking the satellite of interest. The pointing modes include, Command Position, Preset Position and Manual Rate. The Tracking Modes include Step Track, Program Track & monopulse auto track.

Motion controller provide compact digital control system specially designed for industrial use. It is highly reliable system running on real time operating system and specially designed for precise position and velocity controls.

Servo loop has 3 cascade PID controllers for closed loop control. Position loop is the outermost loop, where PID controller minimizes the error between desired position which is the commanded value and antenna actual position read by absolute optical encoder. Position loop has lowest bandwidth in all loops. Velocity loop which is a faster loop is cascaded inside position loop and the controller ensures the correct velocities to reach desired position with minimum overshoot / undershoot. The inner most and the fastest is current loop which regulate motor current for optimum control.

Here position loop and velocity loops utilizes PID software that shall be implemented in the Motion Controller at fast sampling rate (typically less than 1ms) whereas current loop is implemented in servo drive amplifiers.

Scope of the Work:

To develop and deliver the motion controller as per technical specifications given below:

Motion Controller Technical Specifications

Feature	Description
No. of axis	• Minimum TWO independent axis with each axis having three cascaded PID loops. • Motion controller should have feature for implementing dual drive counter torque scheme for each axis to avoid backlash.
Digital Input Channels	Minimum 48
Digital Output Channels	Minimum 48
High speed Analog Input Channels	Minimum 4
High speed Analog output Channels	Minimum 4
SSI / EnDat / EtherCAT encoder channel	Minimum 3
ADC / DAC Resolution	16 bits
Feedback sensor	• Single turn Absolute optical encoder with configurable resolution up to 26 bits for position feedback. Support SSI / EtherCAT / EnDat communication. • Resolver / incremental encoder / tacho inputs for motor velocity feedback.
Timing Control	support IRIG-B
System Communication	TWO Ethernet ports; TWO serial ports for RS 422/485; ONE CAN port.
Operating Temperature	0 to +50 ˚C
Input supply	220-240 VAC Single Phase, 50 Hz
DC Power Supply	Dual power supply with auto changeover feature.
Control Software	Motion controller IDE & Simulation Software
System configuration	Stand alone with RTOS
Memory	Flash memory for user programs, parameters, miscellaneous storage

Linkages to Space Programme:

The deliverables will help in supporting the launch & early orbit phase operations, ranging and TTC operations in any kind of contingency.

Expected Deliverables:

- Motion Controller with all specified features for precise full motion antenna control.
- Proper ICDs and IDE to develop system software & application software.
- Source code and hardware designs.

HUMAN SPACE FLIGHT CENTRE
BENGALURU

RES-HSFC-2023-001

Name of ISRO Centre/Unit
Human Space Flight Centre, Bengaluru

Title of the research proposal
Microgravity effects on human physiology

Name of Co PI from ISRO Centre/Unit
Mr. Anurag Kumar Sinha

Contact Address of Co PI and e-mail id
aksinha-hsfc@isro.gov.in

Area of Research
Human physiology

Summary of the proposed research and expected deliverables
Bed rest studies involving a 6-degree head-down tilt are conducted to simulate the physiological effects of spaceflight, particularly microgravity conditions, on the human body.

Scope of the Work:

- Cardiovascular Adaptations: Prolonged bed rest can result in cardiovascular deconditioning, including orthostatic intolerance when returning to an upright position. Research in this area helps develop strategies to maintain cardiovascular health during space missions and upon re-entry to Earth's gravity.
- Fluid Redistribution: Microgravity leads to a redistribution of bodily fluids, which can affect various physiological systems. Bed rest studies allow scientists to investigate fluid shifts and their impact on astronaut health, helping in the development of fluid management strategies for space travelers.
- Endocrine and Metabolic Changes: Researchers can study the endocrine system's response during bed rest, including alterations in hormones like insulin and cortisol. Understanding these changes can aid in optimizing nutrition and hormonal regulation for astronauts.
- Neurological Effects: The head- down tilt position can simulate some of the changes in intracranial pressure experienced in space. This is relevant for studying conditions like space motion sickness and intracranial hypertension.

Linkages to Space Programme:

The project has linkages to Human space programme.

Expected Deliverables:

Study report on Bed rest studies.

RES-HSFC-2023-002

Name of ISRO Centre/Unit
Human Space Flight Centre, Bengaluru

Title of the research proposal
Controllability studies of a typical Crew module during Mission phases

Name of Co PI from ISRO Centre/Unit
Mr. Sreejith Sreekumar

Contact Address of Co PI and e-mail id
sreejith-hsfc@isro.gov.in

Area of Research
NGC systems

Summary of the proposed research and expected deliverables
Crew Module is typically an autonomous controlled body with on-board avionics. For taking care of unknown failures, provisions are planned in various modules such as Soyuz and Apollo for the Crew to control the module NGC systems and carry out maneuvers during the mission.

Scope of the Work:

Based on the module parameters and human model, an integrated simulation model has to be designed for typical operations in the mission to study the impact of crew operation. The model shall highlight the impact of delay of crew operation, requirements in guidance and control design to take care of crew operation etc. A typical module such as Apollo can be taken as case study and can be adapted for Gaganyaan Crew Module.

Linkages to Space Programme:

For future human space program involving Rendezvous and docking.

Expected Deliverables:

A detailed document addressing the study outcome as well as design files and simulation models as part of the study.

RES-HSFC-2023-003

Name of ISRO Centre/Unit
Human Space Flight Centre, Bengaluru

Title of the research proposal
Hand gesture based activities for Human space missions

Name of Co PI from ISRO Centre/Unit
Mr. Sreejith Sreekumar

Contact Address of Co PI and e-mail id
sreejith-hsfc@isro.gov.in

Area of Research

Human Machine Interface

Summary of the proposed research and expected deliverables

Usage of Human gestures to control activities in the missions is an area of research. For non-critical operations, if crew gestures can be tracked by suitable devices, the gesture can be decoded using suitable logics involving ML or CNN and the onboard system can operate systems as an outcome.

Scope of the Work:

It involves definition of basic gestures for operation during the mission. After definition, the onboard systems can be track the gestures and then initiate a training program to decode the gesture and carry out operations during the mission. It can be augmented by audio commands wherein NLP logics can be used to decode the audio command and operate various systems.

Linkages to Space Programme:

It can be used in long duration human space missions where operation on a physical console can be avoided by this technique.

Expected Deliverables:

A study report on the various logics that can be used for this study as well as the design files as part of the study outcome.

RES-HSFC-2023-004

Name of ISRO Centre/Unit

Human Space Flight Centre, Bengaluru

Title of the research proposal

Development of gravity off-load system for simulating microgravity in ground for human spaceflight operations

Name of Co PI from ISRO Centre/Unit

Dr. Chiranjeevi Phanindra

Contact Address of Co PI and e-mail id

chiran-hsfc@isro.gov.in

Area of Research

Human spaceflight operations

Summary of the proposed research and expected deliverables

Microgravity conditions on Earth are generally simulated using (a) Gravity offload and (b) Frictionless movement.

This simulated environment will enable assessment of Human operation in space such as:

- Payload operation by Humans in space.
- Space suit mobility evaluation.

- Simulation of Crew module performing rendezvous and docking with space station along with thruster firings to adjust its alignment.
- Operation of Robotic manipulators.
- Testing humanoid robots in space.

Scope of the Work:

Design and implement a gravity off- load system for simulating microgravity in ground for evaluating human spaceflight operations. It should include the following features:

- Configuration of the system — mechanical and electronic design.
- Control system design and implementation.
- Environment and Human activity simulation through Mixed reality.
- System should allow for 6 DOF motion of Human.
- System should allow for reduced gravity operations also.
- Modular approach.

Linkages to Space Programme:

Long duration human space flight missions involve extensive research in microgravity environment. By simulating microgravity on ground, assessment of human operations in space can be carried out.

Expected Deliverables:

Detailed design of the gravity offload system.

LABORATORY FOR ELECTRO-OPTICS SYSTEMS

BENGALURU

RES-LEOS-2023-001

Name of ISRO Centre/Unit

Laboratory for Electro-Optics Systems, Bengaluru

Title of the research proposal

Development of optical clad layer coating on sintered silicon carbide mirror substrate for space telescope applications

Name of Co PI from ISRO Centre/Unit

Mrs. Tayaramma D P V Jalluri

Contact Address of Co PI and e-mail id

pushpavalli@leos.gov.in

Area of Research

Coating development for reflective optics

Summary of the proposed research and expected deliverables

Silicon carbide (SiC) is gaining importance in the manufacturing of optical telescope mirrors due to its superior mechanical rigidity and optical surfacing feasibility which is quite useful for large-area high-resolution optics. The properties of the SiC substrate can be reconfigured depending on the manufacturing method used and sintered SiC is one of the most popular methods of substrate preparation. The as-developed substrate has an inherent α-HCP phase and cannot be used directly for high-end optical applications like high-resolution imaging or spectroscopy.

This calls for specific cladding on the base SiC substrate, such as SiC layer with ß-cubic phase or Si clad layer.

Scope of the Work:

Generally, size of a telescope mirror is around 50mm to 200mm with a typical clad layer thickness of about 100-500 µm. The proposed research work shall focus primarily on the development of clad layer coating over sintered silicon carbide that would facilitates optical polishing with the final micro-roughness <20 Å. In this regard, silicon carbide or silicon materials can be potential candidates for coating as their thermal expansion matches with the sintered silicon carbide. The final coatings will have good adhesive properties. Research shall also address challenges in achieving the large-area uniformity of coating, long-term stability and durability, large-scale production and space environmental-compatibility.

Suggested Methodology for coating: Tape casting process using sintering method.

Linkages to Space Programme:

These deliverables would be useful in the development of SiC based large area, high resolution telescope optics for future inter-planetary space missions.

Expected Deliverables:

Space sustainable coatings on Sintered silicon carbide substrates.

RES-LEOS-2023-002

Name of ISRO Centre/Unit

Laboratory for Electro-Optics Systems, Bengaluru

Title of the research proposal

Indigenization of thickness monitor for precise control of thin-film depositions in optical coating applications

Name of Co PI from ISRO Centre/Unit

Dr. Praveen K C

Contact Address of Co PI and e-mail id

kcp@leos.gov.in

Area of Research

Optics design, instrumentation and software development

Summary of the proposed research and expected deliverables

Narrow band pass filter, long/short wave pass filter are realized by depositing multi-layer thin film optical coatings. State-of-the-art technologies are used for in-situ estimation of optical thickness (nt) during the coating process. Typically, spectrophotometric technique is employed for monitoring the deposition of quarter-wave or non-quarter-wave thick films. This proposal envisages indigenous design and development of an in-situ broadband optical thickness monitor to measure layer thickness via transmission/reflection with accuracy better than 0.01%. The objectives also include development of a software based on theoretical model for real-time fitting of experimental data with simulated data to estimate turning point for the termination of each layer.

Scope of the Work:

Development of spectrophotometer can be used for in-situ measurements during filter fabrication and even as standalone instrument. Also, the development of software based on theoretical-model is a technological know-how to be mastered. The coatings such as band-pass /notch /long-pass /short-pass filters operating in UV/VIS/NIR are realizable with optical thickness monitor.

Advancements in this research even leads to realization of dense wavelength division multiplexing (DWDM) filters for optical communication. These optical filters and optical thickness monitor have high industrial and market value.

Linkages to Space Programme:

Earth observation satellites require narrow band pass filters like in OCM, Resourcesat, Trishna, etc. Scientific payloads like LIBS, Raman spectrometer need long pass or short pass and/or laser line filters. Optical thickness monitors find application in optical coatings, for online process control in semiconductor manufacturing. Technology transfer to potential manufacturers in India can facilitate the sector to develop the coating plant indigenously.

Expected Deliverables:

- Development of theoretical model and software for layer termination and spectrophotometer control.
- Optics design of thickness monitor operating in reflection mode.
- Realization of spectrophotometer and calibration.
- Retrofitting to coating plant and demonstration of filter coating at LEOS premises.

RES-LEOS-2023-003

Name of ISRO Centre/Unit

Laboratory for Electro-Optics Systems, Bengaluru

Title of the research proposal

Development and realization of effective calibration-free analytical algorithm for LIBS spectra

Name of Co PI from ISRO Centre/Unit

Mr. V L N Sridhar Raja

Contact Address of Co PI and e-mail id

rvlnsridhar@leos.gov.in

Area of Research

Laser Induced Plasma Spectroscopy/Planetary Surface Exploration

Summary of the proposed research and expected deliverables

Projected proposal is aimed at the realization of effective calibration-free analytical algorithm (viz., Self-Absorption corrected CF-LIBS, Multi Element Saha Boltzmann Plot coupled CF-LIBS, One Point Calibration CF- LIBS etc.) along with the development of associated coding as well as GUI tools. Further, the developed algorithm shall be tested on ground generated spectra of standard and certified reference soil samples (in powder, pellet forms) and/or metal alloys in vacuum environment. The applied analytical approach shall be tested on spectra acquired employing medium resolution spectrometers. At the end, the proposed research shall conclusively estimate accuracy levels and limitations. The spectral data sets acquired in high-vacuum environment at room temperature employing standard and certified reference soils samples using a medium-resolution spectrometer (0.7-0.8 nm resolution) will be shared by the focal point (Co- PI) LEOS. Standard and certified metal-alloy samples or soil-samples can be provided to LEOS for spectral acquisition in vacuum-environment.

The experimental plans for acquiring spectral data shall be formulated beforehand with mutual discussion.

Scope of the Work:

Proposed work will lead to realizing effective and accurate analytical algorithm model to analyse laser induced plasma spectra of soil samples comprising multi-elements without depending on standard samples for calibration. Such approaches will complement the traditional calibration based analytical approaches and also helps in quantitative analysis of individual elements in unknown samples.

Linkages to Space Programme:

The proposal has linkages to planetary surface exploration missions (Moon, Mars, Asteroids etc.) that employ rover/landers equipped with LIBS technique, as a tool to analyze the surface chemistry.

Expected Deliverables:

- Source Code of algorithm and the corresponding GUI.
- Publications or patent on the outcome of data analysis.

Annexure-1

Declaration Form

Terms and Conditions of ISRO Research Grants

1. The approved funds should be utilized solely for the purpose for which they have been granted unless ISRO agrees otherwise. A Certification that the funds have been so used should be produced by the grantee Institution after the end of each year of the support.
2. Due acknowledgement to ISRO should be made in all reports and publications arising out of the part of the work supported by ISRO. The grantee will take prior permission of ISRO before publishing any work based on the ISRO supported project.
3. Two copies of all the publications resulting from the research conducted with the aid of the grant should be submitted to ISRO.
4. Any intellectual property rights or such information/knowledge being able to sustain or create or any such right arising out of the projects sponsored by ISRO will be held jointly by the Academic Institution/R & D institution and ISRO as per RESPOND norms. Academic Institute/R & D institution and ISRO shall inform each other before filing for any protection of any Intellectual Property Rights resulting from any of the project sponsored by ISRO. Academic institute/
R & D institution and ISRO will ensure appropriate protection of Intellectual Property Rights generated from cooperation, consistent with laws, rules and regulations of India. The expenses for filling the Patent protection in India and abroad shall be borne equally between Institute and ISRO. Any/all financial accruals due to any commercial exploitation, of this patent shall be shared equally between them, on 50:50 basis. However any of the parties is free to utilize the IPR for their own use on non commercial basis.
5. The principal Investigator is required to submit two copies of yearly reports indicating the progress of the work accomplished. He is also required to submit two copies of a detailed technical report on the results of the research/development after the completion of the project. The reports will become the property of ISRO.
6. In addition, ISRO may designate Scientists/specialists to visit the Institution periodically for reviewing the progress of the work.
7. An inventory of items purchased from ISRO funds should be sent to ISRO, giving the description of equipment, cost in rupees, date of purchase and name of the supplier along with a purchase certificate from the Administration of the Institution. All items of equipments and unconsumable items costing more than Rs. 5,000/- shall remain the property of ISRO and ISRO reserves the right to transfer them or dispose of them on the termination of the project as ISRO may deem fit.
8. The accounts of the expenses incurred out of ISRO funds should be properly maintained and should be authenticated by an approved auditor. The final accounts statement in duplicate duly audit should be sent to the pay & Accounts Officer, DOS/Senior Accounts Officer, ISRO Headquarters, as the case may be, at the end of each financial year of support.

9. If the total amount sanctioned is not spent during the period of support, the remainder amount should be surrendered to the Pay & Accounts Officer, ISRO Headquarters, as the case may be, within one month after the completion of the project.
10. The assets acquired wholly or substantially out of the ISRO grant should not, without its prior sanction, be disposed off, encumbered or utilized for purposes other than that for which the grant is sanctioned.
11. A register of assets permanent and semi-permanent should be maintained by the grantee Institution, which should be available for scrutiny by Audit.
12. The grantee institution should not divert the grants-in-aid for utilization of the same for similar objects of another institution if it is not in a position to execute or complete the assignment. The entire amount of the grant should then be immediately refunded to ISRO by the institution.
13. The terms and condition of ISRO research grants are subject to change from time to time, but the funding of any project will be governed by the terms and conditions existing on the date of starting of the project with ISRO funds.

Declaration

I / We have clearly read the above terms and conditions and hereby agree to abide by the rules and regulations of ISRO research grants and accept to be governed by all the terms and conditions laid down for this purpose.

I / We certify that I / We have not received any grant-in-aid for the same purpose from any other Department of the Central Government / State Government / Public Sector Enterprise during the period to which the grant relates.

	Signature & Name	**Designation**
Principal Investigator		
Head of the Department / Area		
Head of the Institution		

Annexure-2

RESPOND COORDINATORS OF ISRO/DOS CENTRES

Sl. No	ISRO/ DOS Centre	Name & Designation	Contact details
1.	VSSC	Shri Santhosh Kumar S, Scientist/Engineer RESPOND Coordinator Programme Planning & Evaluation Group Vikram Sarabhai Space Centre (VSSC) ISRO PO Thiruvananthapuram : 695 022	Tel Phone No: 0471-2564620 Email: s_santhoshkumar@vssc.gov.in
2.	SAC	Dr. Abha Chhabra Head, RESPOND and Research Management Division Research, Outreach and Training Management Group Management and Information Systems Area Space Applications Centre (SAC), ISRO Ahmedabad-380 015, Gujarat	Tel Phone No: 079-2691 3333/3334 Email: research_sac@sac.isro.gov.in
3.	URSC	Dr. J Krishna Kishore Scientist/Engineer GD, ATDG U R Rao Satellite Centre (URSC) HAL Airport Road Vimanapura PO Bangalore: 560 017	Tel Phone No: 080-25084480/81 080-25084391 Email: jkk@ursc.gov.in
4.	NRSC	Shri P Krishnaiah Scientist/Engineer Head, TMD RESPOND Coordinator National Remote Sensing Centre (NRSC) Balanagar, Hyderabad: 500 037	Tel Phone No: 040-23884051 Email: krishnaiah_p@nrsc.gov.in
5.	LPSC	Shri TV Sreejith Scientist/Engineer RESPOND Coordinator PPEG, MSA Entity Liquid Propulsion Systems Centre (LPSC) Valiamala PO Thiruvananthapuram: 695 547	Tel Phone No: 0471-2567562 Email: tvshreejith@lpsc.gov.in, respond@lpsc.gov.in
6.	IPRC	Shri Nagarajan C Scientist/Engineer Manager, HRD IPRC Mahendragiri: 627 133	Tel Phone No: 04637 281776 Email: nagarajan.c@iprc.gov.in

7.	PRL	Dr. Nandita Srivastava Professor and Deputy Head (Admin), Udaipur Solar Observatory Physical Research Laboratory (PRL) Badi Road, Dewali Udaipur-313001, Rajasthan	Tel Phone No: 0294-2457211 (office) Email: nandita@prl.res.in; respond@prl.res.in
8.	SDSC-SHAR	Shri Bala Narayanan N R, Scientist/Engineer PPEG / MSA Sriharikota - SDSC-SHAR Andhra Pradesh: 524 124	Tel Phone No: 08623 22 6382 Email: nrbala@shar.gov.in
9.	IISU	Shri K S Nandhakumar Scientist/Engineer Head-PPEG, PPED ISRO Inertial Systems Unit (IISU) Vattiyoorkavu PO Thiruvananthapuram: 695 013 Kerala	Tel Phone No : 0471 2569340 Email:ks_nandhakumar@vssc.gov.in
10.	IIRS	Dr. Ashutosh Bhardwaj Scientist/Engineer RESPOND Coordinator & Head, RPMD Programme Planning and Evaluation Group (PPEG), Indian Institute of Remote Sensing (IIRS), Indian Space Research Organization (ISRO), 4 Kalidas Road, Dehradun – 248001	Tel Phone No: 0135-2524350, 4351 (Off.) Email: respond@iirs.gov.in; ashutosh@iirs.gov.in
11.	NARL	Dr. S. Sridharan Scientist/Engineer National Atmospheric Research Laboratory (NARL) Gadanki-517 112, Pakala Mandal Chittoor, Andhra Pradesh	Tel Phone No: +91-8585-272124 Email: susridharan@narl.gov.in
12.	NESAC	Dr. K K Sharma RESPOND Committee Chairman Scientist/Engineer North Eastern Space Applications Centre, (NESAC) ISRO, Umiam, Meghalaya : 793 103	Tel Phone No: 0364 2570138 Email : sarmakk@gmail.com

13.	ISTRAC	Shri Pradeep Kumar C, Scientist/Engineer Group Head, Signal Processing & Software Development Group, Radar Development Area, ISTRAC/ISRO, Plot No 12 & 13, 3rd Main, Phase II, Peenya Industrial Area, Bangalore-560058	Tel Phone No :+91-80-28094489 Email: pradeepkc@istrac.gov.in
14.	MCF	Shri S.N. Jaggannatha, Scientist/Engineer Master Control Facility, Hassan-573201 Karnataka	Tel Phone No : 08172-273112 Email: jagannath@mcf.gov.in
15.	HSFC	Smt. Ramya V Scientist/Engineer RESPOND Coordinator MSA, Human Space Flight Centre (HSFC), ISRO HQ, Bangalore 560094	Tel Phone No : 080-22172643 Email: ramya-hsfc@isro.gov.in
16.	LEOS	Dr. Prashanth C. Upadhya Division Head, AETD, Laboratory for Electro-Optics Systems (LEOS), Bengaluru	Tel Phone No : 080-22685197 Email: pupadhya@leos.gov.in

RESPOND & Academic Interface

Capacity Building and Public Outreach

Indian Space Research Organisation

Bengaluru