



---

# BRNS RESEARCH GAPS AREAS

---



BOARD OF RESEARCH IN NUCLEAR SCIENCES  
DEPARTMENT OF ATOMIC ENERGY  
MUMBAI

## 1.0 Introduction

India has come a long way towards harnessing nuclear science and technology for national development based on research done in the units of DAE and academic institutions in the country. As we make progress and gain insights based on operating experience, research needs keep evolving and a periodic exercise to identify gap areas is needed

During the BRNS 111<sup>th</sup> Board meeting held in March 2025, it was further emphasised to reorient the research focus areas under BRNS to align with the DAE's long-term Amrit kaal objectives to be achieved by the year 2047.

Accordingly, all nine BRNS committees conducted deliberations during Technical Programme Discussion Meetings (TPDMs) to discuss and identify key technology gaps aligned with DAE's mandate.

As per DAE's OM 0302/1/2018/R&D-II/12910, dated: September 30, 2025, BRNS committees were reconstituted wherein nine committees were merged into four. The inputs collected from earlier committees have been reorganised according to the subject domains assigned to the newly formed committees, viz. Nuclear Reactor & Fuel Cycle Committee (NRFCC), Basic Science Committee (BSC), Advance Technology Committee (ATC) and Radiation Technology and Societal Applications Committee (RTSAC). The identified project themes and topics under NRFCC committee of BRNS are listed in the following sections.

## 2.0 Nuclear Reactor & Fuel Cycle Committee (NRFCC)

Nuclear Reactor: Reactor physics, Nuclear Data, Reactor engineering, Structural & Engineering design and analysis, Thermal hydraulic design & safety analysis, Design against External hazards (Seismic, Floods, Wind, Tsunami), Containment structures for Reactors, Construction technologies.

Types of Reactors: PHWR, PWR, FBRs, including future reactors such as MSR, HTGR, Subcritical Reactors (Fusion and Accelerator driven)

Front end Fuel Cycle – Minerals & exploration, advanced fuel design including Accident Tolerant Fuel, Rare earth separation

Back end Fuel Cycle – R&D related to development of related chemical, process, reprocessing & waste management

### 2.1 Reactor Related

#### 2.1.1 Pressurised Water Reactor (PWR) Related

1. Research on Fission product retention in reactor systems during severe accident conditions.
2. Evaluate the fuel degradation / healthiness in case of successful deployment of emergency core cooling system during LOCA and other accident scenarios
3. PWR specific water chemistry studies
4. Pressuriser Swell Level and Flashing studies

#### 2.1.2 Pressurized Heavy Water Reactor (PHWR) Related

1. impact studies on structures/buildings in Nuclear Power Plant.
2. Development of generalised model for Passive Heat Removal Systems (PHRS).
3. CFD modelling for dose assessment studies
4. Source term studies for severe accident scenarios: generate the data on the kinetics for formation of organic iodine during severe accident conditions for accurate estimation of dose release to the public in severe accident scenarios. (Deposition of radionuclides in the concrete cracks)
5. Seismic PSA, Containment Fragility Studies taking into account of effect of temperature and pressure.
6. Steam explosion studies: effect on the various reactor components and containment.
7. Level 2 Probabilistic Safety Analysis (PSA) studies: Containment failure probability estimation during severe accident situation.
8. Development of Advanced Functional Coatings for Accident Tolerant Fuel Clad applications.
9. Temperature effect on concrete, transient thermal creep & durability issues

#### 2.1.3 High-Temperature Gas-Cooled Reactor (HTGCR) Related:

1. Radiation chemistry of CO<sub>2</sub> under high temperature and high pressure and the radiolysis of CO<sub>2</sub>
2. Interaction of CO<sub>2</sub> with structural materials
3. Combined modelling of radiolysis and transport of CO<sub>2</sub>

4. Water Chemistry studies
5. Chemistry studies for dose assessment
6. Fission product retention studies in graphite

#### 2.1.4 Indian Molten Salt Reactor (IMSR) Related

1. Development of alternative salt (e.g., ZrF and NaF system): Corrosion studies, compatibility studies, thermodynamic modelling, evaluation of thermo-physical properties
2. Research and Development of chemical sensor for monitoring the oxygen and moisture in the melt.
3. CFD studies for operation of freeze valve.
4. Exploration of new low melting salt compositions with desired neutronic properties
5. Evaluation of thermo-physical properties including melting point, viscosity, density, heat capacity, thermal conductivity etc., of new salt compositions
6. Innovative gas mixture based methodologies (for example in situ generation of HF) for rapid redox control
7. Innovative metal addition/direct salt addition based methodologies

#### 2.2 Chemistry Related

- 1 Temperature, pressure and radiation dose dependent physico-chemical interactions in zircaloy-water system
- 2 High temperature & high pressure chemistry of borates under ionizing radiation.
- 3 Development of accident tolerant clad materials
- 4 Passive devices for simultaneous removal of hydrogen, iodine and Xe.
- 5 Purification and establishing the specifications CO<sub>2</sub> gas for nuclear applications
- 6 Thermodynamics of interaction of CO<sub>2</sub> with structural materials and CALPHAD modelling
- 7 Development of models for CO<sub>2</sub> coolant.
- 8 Solid-state chemistry of nuclear reactor materials under very high temperatures

#### 2.3 Material Development

- 1 Structure and properties of cladding materials under intense thermal, hydrothermal (or solvothermal)
- 2 Development of oxidation resistant coating for Zr-based accident tolerant fuel cladding
- 3 Development of FeCrAl based accident tolerant fuel cladding material
- 4 Identification, characterization and structure property correlation in domestic serpentine from NorthEast India
- 5 A multidisciplinary approach to assess zircon stability under metamictization and thermal alterations
- 6 Development of high temperature miniature tensile testing facility up to 1500 C.
- 7 Development of a miniature constant true stress tensile creep testing facility up to 1000 C, with option to use non-contact extensometers.
- 8 Development of a tensile split Hopkinson bar with high temperature testing up to 800 C with provision to capture specimen images during testing.
- 9 Development of Silicon carbide composites and their joining techniques for nuclear application.

- 10 Development of piezoelectric materials with high Curie temperatures for under-sodium viewing / imaging and related technology.
- 11 Design and Development of materials related to fast breeder reactor programs
- 12 Development of gauntlets for glove boxes (import substitute)
- 13 High purity target material development for radioisotopes production

#### 2.4 Fast Breeder Reactor (FBR) Related

- 1 Studies on deposition (vapour) behaviour of FBR coolants (molten metal / molten alloys)
- 2 Multiscale multi-physics modelling of metallic fuel and coolant for fast reactors
- 3 Development of an integrated code for pre-disassembly and disassembly phases with realistic a model for core slumping
- 4 Three-dimensional structural mechanics code for analysis of mechanical consequence phase of CDA with all reactor assembly internals
- 5 Development of models for realistic prediction of molten fuel coolant interaction effects
- 6 Simulation of fuel squirting behaviour within fuel pins during Unprotected Transient Over Power Accident (UTOPA)
- 7 Understanding and modelling of debris dispersal during CDA
- 8 Modelling of corium movement from core location to core catcher (structural melt through process)
- 9 Modelling of sodium boiling in porous bed coupled with natural convection simulation in sodium pool
- 10 Development of under-sodium phased array ultrasonic transducers (250 °C) for under sodium viewing and inspection
- 11 High temperature (200°C) Electromagnetic Acoustic Transducers (EMATs) for couplant free ultrasonic inspection of weld joints in main vessel of FBRs
- 12 Optimization study on the kinematic configuration of the Friction Actuator Module (FAM) of the Main Vessel- Safety Vessel Inter Space Crawler (MSISC) system for vertical holding in the Interspace gap
- 13 Modelling, analysis & simulation of various casting processes viz. gravity casting, continuous casting etc. specific to metal alloy compositions.
- 14 Thermodynamic modelling of U-Pu-Zr ternary system and their sub-systems.

#### 2.5 Front End Fuel Cycle

- 1 Increasing the particle size of sodium sulphate produced through forced recirculation evaporator.
- 2 Development of suitable belts and adhesive for joining of SBR transporter belt for horizontal belt filters
- 3 Conversion of sodium sulphate into value added products.
- 4 Application of Artificial Intelligence and Machine Learning in exploration of uranium and associated critical minerals

#### 2.6 Back End Fuel Cycle

- 1 Experiments and modelling of nucleation and growth kinetics of precipitation reactions involving nuclear materials
- 2 Development and validation of gas-liquid reactive two-phase flow model in stirred tank reactor using finite element method

- 3 Development and validation of CFD-Population Balance Model of air pulsed columns using open source CFD solver
- 4 Non-invasive online measurement of dispersed phase holdup in columnar contactors used for solvent extraction.
- 5 Development of equipment/system for I-129 removal from off-gases.
- 6 Development of indigenised media for HEPA filters.
- 7 Development of solvent to prevent third phase formation
- 8 Numerical modelling of settler part, simulation of phase separation and fundamental aspects of solvent extraction
- 9 Synthesis of ligands/solvents/extractants / complexants for the separation of minor actinides (MAs) from FBR HLLW
- 10 Development of sensors/Probes for online monitoring of various metal ions in aqueous streams for reprocessing applications
- 11 Development of a mathematical model for the separation of Am and Lanthanides from FBR HLLW
- 12 Synthesis, Characterization, and Supply of Noble Metal-Based Supported Catalyst for reducing U(VI) to U(IV) Using Hydrazine / Hydrogen as a reducing agent in Nitric Acid Medium
- 13 The selective and efficient removal of Plutonium from radioactive analytical waste
- 14 Synthesis of advanced ligand and adsorbents for the separation of Palladium from High level waste
- 15 Development of High temperature traps for volatile fission products.
- 16 Development of durable reference electrode for molten salt based electrochemical applications.
- 17 Development of sensor for detection of Cd aerosol (ppb level) in argon and air.
- 18 Development of sensor for detection of ppm level nitrogen in argon.
- 19 Development of level probes, flow meters for molten Cadmium and molten salt systems inside hot cells.
- 20 Development of Hermetically sealed blowers to be used in argon gas systems.

## 2.7 Health Safety

- 1 Development of rapid response methods for the analysis of environmental particulate radioactivity for reducing sterilization zone around power reactors/nuclear facilities

### 3.0 Basic Science Committee (BSC)

Development of low dimensional materials, meta materials, Tera Hertz Spectroscopy, Ultrafast Spectroscopy, Quantum materials, Bio physics, laser-matter interaction, multi-wavelength Astro Physics, materials, sensor, and detector development, ultra-high purity single crystal growth.

Materials for nuclear technologies, Reactor water Chemistry, Catalyst for hydrogen generation, materials for hydrogen storage, Materials for cancer diagnostics and therapy, Materials for energy conversion and storage, Environmental and Separation Science, Chemistry with laser and accelerator, Bio-fouling studies, analytical chemistry, Computational Chemistry, actinide separation

Radiation Biology, Chronic and Acute radiation exposure, Cancer Biology, Targeted Chemo/Radiotherapy, Immunotherapy, DNA repair, Epigenetics, Radiation resistance, Radioprotectors, Cancer diagnostics, CRISPR biology and applications, Molecular biology, Stress adaptation, Metal bioremediation, Structural Biology of proteins, Applied genomics, Boron Neutron Capture therapy, AI and ML in Biological systems

#### 3.1 Bio-Science

1. Cancer biology and mechanisms of radio-resistance
2. Development of adjuvants and sensitizers for cancer radiotherapy
3. Precision therapeutics and theranostics for cancer chemo/radiotherapy.
4. Design and development of modified bioactive drug derivatives for tumor-selective and organelle-targeted delivery.
5. High-LET radiobiology (BNCT, proton therapy, and other charged particles)
6. Characterization of high-LET–induced mutants and genome editing in agro-economically important crop plants
7. Therapeutics and diagnostics: Tumor-on-chip, organ-on-chip, patient-derived organoids, xenografts, integrated microfluidics, advanced genome engineering, and high-throughput screening platforms
8. Next-generation immunotherapeutics and peptide/RNA-based therapeutics
9. 3D genome architecture, multi-omics integration, and single-cell sequencing technologies
10. Metal–microbe interactions, biofilms, and biofouling dynamics
11. Bioremediation and phytoremediation of actinides and heavy metals
12. Photobiology and light-mediated biological processes
13. Structural biology of biotechnologically important proteins
14. Nanomaterials and nano-drug delivery systems for cancer therapy and diagnostics

#### 3.2 Physics and Material Science:

1. Synthesis and characterizations of high entropy materials
2. Synthesis and characterisation of Strongly Correlated Electron Materials

3. Synthesis of large volume superhard materials at high pressure and high temperature and their characterization.
4. Basic Research on soft matter, energy materials, quantum systems, Two-dimensional superconductors and spintronics.
5. Development of photonic crystals for filters and sensors.
6. Development of metasurfaces for realizing compact imaging systems.
7. Development of integrated quantum photonics for sensing, metrology, etc.
8. Theoretical modelling of nuclear structure, reactions
9. Nuclear reactions of astrophysical interest
10. Nuclear Data for Basic Science and Applications
11. Development of single crystals and related growth techniques for nuclear radiation detection
12. Research related to Synchrotron radiation/Neutron scattering/heavy ion accelerators
13. Design and Development of thermoelectric materials
14. Development of coatings for Tribological Applications (DLC etc.).
15. Design and Development of Semiconductor Based nuclear radiation Detector
16. Studies on gravitational astrophysics
17. Studies related to dark matter, rare-events measurements including underground laboratories
18. Development of Gas target including jet, liquid etc. for measurement of Spectroscopic S-factor at low energies with inverse [(18O,p), (20Ne,p) and direct (He, 20Ne)] astrophysical reactions
19. Low background experimental setup for radiative capture studies relevant for nuclear Astrophysics
20. Development of MCP based Photomultiplier tube (PMT) for photon detection

### 3.3 Radiochemistry

1. Synthesis of ligands for application in Sensing and Sequestration of actinides from waste streams
2. Design and Synthesis of Highly Selective Metal Organic Frameworks/COFs for specific absorption and separation of Kr, Xe, He etc.
3. Development of ion selective electrodes for various elements of interest in nuclear technology (e.g. UO<sub>2</sub><sup>2+</sup>, Sr<sup>2+</sup>, Cs<sup>+</sup>, F<sup>-</sup>, Cl<sup>-</sup> etc.).
4. Development of selective extractants for the quantification of Rare Earth Elements in geological matrices.
5. Design and Development of extractants/ligands for the recovery of useful radionuclides from radioactive waste.
6. Studies on the interaction of biogenic species with radionuclides (actinides and fission products) for their incorporation.
7. Design and Development of a Portable advance nuclear radiation Detection Devices.
8. Scintillating/Luminescent Nanomaterials and Devices for Nuclear Security.
9. Development of electrochemical techniques and devices for quantitative estimation of actinides.
10. Microstructural characterization of defects in materials using nuclear probes

### 3.4 Chemistry

1. Development of materials for target-specific combinatorial cancer therapies and diagnosis (photo-thermal therapy, photodynamic therapy and radio sensitization).
2. Development of ligands for radiopharmaceuticals
3. Design and synthesis of Boron-based compounds/ $^{10}\text{B}(\text{OH})_3$  loaded formulations for BNCT.
4. Synthesis of DNAs & peptides and their interactions with model cell membrane for understanding targeted drug delivery.
5. Design and synthesis of materials, catalysts/electrodes and processes for reducing carbon foot print.
6. Development of high temperature and high-pressure reference electrodes and pH sensing device.
7. Development of Proton Exchange Membranes and fabrication of fuel cells.
8. Design and development of labelled probes for trace level detection/imaging related to chemical and biological systems.
9. Development of methods for the Synthesis, Purification and characterization of ionic melts.
10. Design and development of biofouling monitors for operating power plants.
11. Design and development of biofilm-reactors for treating/remediation of low-level radioactive effluents.
12. Development of instruments for online detection of elements/ions at ultra-trace levels in water systems.
13. Development of materials for selective recovery of precious and critical elements.
14. Integrated device for simultaneous removal of hydrogen and volatile fission products.
15. Theoretical/Computational sciences related to Fuel cycle processes and technologies.
16. Development of hydrogen storage materials and hydrogen management
17. New materials for sensing pollutant gases in air / gas steams for nuclear applications
18. Thermochemical modelling of metallic fuels and higher order systems
19. Development of sensors for non-metallic impurities in sodium systems
20. Development of sodium/Lithium-ion batteries
21. Materials under extreme conditions
22. Development of luminescence probes for biological applications
23. Chemistry using lasers and accelerators.
24. Identification and synthesis of cancer targeting lead molecules (peptides, small molecules).

## 4.0 Advance Technology Committee (ATC)

Design of components for Accelerators, Fusion, Laser, Klystron, Gyrotron, Electron sources, Magnetron, RF amplifiers, Critical materials such as Niobium, Plasma, Cyclotron, Special stable power supplies, Cryogenics, Cybersecurity, Robotics and Automation, Cyber physical systems

Quantum communication, Quantum encryption, Quantum computing, Teleportation, Development of sensors, radiation detectors, sensitive mass spectrometry, Development of high-speed Cameras.

Instrumentation aspects of Astrophysics, KU band RADAR, Microscopy, Medical instrumentation, Software engineering, Instrumentation and control systems, High performance computing, Advances in AI/ML, Graphics, FPGA/ASIC

### 4.1 Detector Related

Technology and instrumentation for radiation detectors, Simulation studies and data analysis related to detectors, etc.

Topics including but not limited to

1. Neutron instrumentations, detectors, optics
2. Silicon based detectors
3. Single photon detectors, high-resolution X-ray detectors
4. Scintillation detectors for fast neutron spectroscopy, detection of atmospheric neutrons, fundamental physics experiments and medical imaging
5. Simulation and data analysis of dilepton production in relativistic heavy-ion collisions
6. Machine learning techniques for handling missing/incomplete sensor data
7. Advanced detectors for measurement of coherent neutrino nucleus scattering
8. Detectors and sensors for radiation, imaging, and tomography

### 4.2 Quantum Related

Materials and technologies related to Quantum sensing, Quantum computing, Quantum simulators with noise and errors, Quantum communication, Quantum materials, Quantum networks, Applications of quantum technology etc.

Topics including but not limited to

1. Quantum algorithms related to science and engineering
2. Post quantum cryptography
3. Quantum key distribution
4. Quantum secure direct communication
5. Teleportation of quantum states
6. Quantum error correction
7. Quantum enhanced AI and machine learning
8. Quantum-HPC integration
9. Quantum dots for engineering applications
10. Optimization techniques for quantum circuits

### 4.3 Laser & Plasma Related

Lasers and associated fields of laser science and technology, Laser plasma interaction, Characterization of plasma jet, Plasma surface engineering, Industrial applications etc.

Topics including but not limited to

1. High energy Nd:Glass laser, high power fibre lasers, ultra-short pulse duration lasers, laser diodes
2. Laser gain mediums, high harmonic conversion crystals and optics
3. Physics of laser plasma interaction, particle acceleration, intense x-ray generation, laser fusion, high-energy density physics
4. Characterization of plasma jet during its interaction with pathogens
5. Meta-optical measurement tools

### 4.4 Accelerator Related

Accelerator sub-systems, ultra-high vacuum compatible raw materials, high frequency high efficiency RF harmonic kicker, efficient RF cavities, gyrotron, dispenser cathodes, discharge cavity geometries, applications of digital twins in accelerators, green / energy-efficient technologies for accelerators etc.

Topics including but not limited to

1. Accelerator sub-systems for stable and unstable isotopic beams of heavy ions, protons and electrons
2. Design of RF power devices like 3-port circulators, RF LDMOS transistors up to 400 & 700 MHz, ferrite-based components, transmission-based components
3. Solid state amplifiers, their subsystems in RF, DC, control, hot-swapping, cooling, and their components
4. Design and simulation studies of high efficiency klystrons, inductive output tubes (IOT)
5. RF design tools both circuits level and electromagnetic fields level
6. RF interaction section along with the beam tunnel for 170GHz gyrotron, mode converters for 170GHz gyrotron
7. Code development for optimization of longitudinal beam dynamics cyclic accelerators
8. Design studies and prototype development of a high frequency, high efficiency RF harmonic kicker employing slow wave transmission line
9. Design studies and prototype development of efficient specific discharge cavity geometries for low power low emittance negative ion source
10. High current density electron emitters, efficient RF cavities, RF couplers, RF windows, beam collector, and focussing magnets

#### 4.5 Fusion Related

Cryogenic systems, high-temperature superconductors, superconducting magnets, RF sources for plasma heating, fusion materials, blanket materials, multilayer insulation for cryogenic applications, cold helium circulator compressor, Tungsten / Molybdenum wall impurity in plasma and their effect on plasma start-up, Numeric simulations and Computational Fluid Dynamics (CFD) for fusion applications, etc.

Topics including but not limited to

1. Cryogenic control valves for liquid Helium service
2. Magnetron injection gun for gyrotron used in fusion applications
3. Peltier current leads (PCLs) to reduce heat transfer into cryogenic magnet systems with high-temperature superconductors
4. Quench detection simulation studies
5. Parametric studies of fusion core and fission blankets
6. Kinetic modelling of plasma tools for applications in semiconductor processing industry
7. Studies on effect of Tungsten and Boronization on plasma transport
8. Study on neutral breakdown and non-inductive start-up in small aspect ratio tokamak
9. Digital twins for the negative ion source
10. Argon and other high Z impurities spectroscopy in tokamak
11. High Power Polarizers for ECRH system
12. Inorganic adhesives for application in cryopumps at cryogenic temperature
13. Software for Rarefied gas Involved Kinetics and Transmission Analysis (RIKTA) for tokamak vacuum needs
14. Fibre Bragg Grating (FBG) type temperature sensors for signal transmission in optical fibre
15. Plasma emission-based impurity analysers for nitrogen impurity in helium gas
16. Eddy-current brake for helium turbine
17. Direct numerical simulations of magneto-hydro-dynamic duct flow
18. Advanced diagnostics for tokamaks
19. Studies on fusion materials under high plasma flux irradiation and energetic ion irradiation conditions
20. Superconducting magnets for Tokamaks and other plasma devices
21. Operation of LI-VISTA facility to take up specific experiments
22. Advanced ADITYA-U tokamak operation
23. Experiments in ADITYA-U tokamak

#### 4.6 Astro Physics

Prototype radio arrays, Mini particle detector arrays, Machine learning and data analysis for astrophysics, etc.

Topics including but not limited to

1. Prototype radio arrays to enhance the energy reach of cosmic ray experiments
2. Mini particle detector arrays for cosmic ray air shower detection
3. Characterizing the response of GRAPES-3 plastic scintillators to MeV neutrons

4. Monolithic, graded-porosity, metallic-foam mirrors for atmospheric Cherenkov telescopes
5. Multi-messenger observation of transient signals with atmospheric Cherenkov telescopes
6. Test beds for the next generation space and ground-based gamma-ray telescopes

#### 4.7 Robotics and Automation

UAV detection, Machine learning for robotic applications, Robotics for inaccessible environments, etc.

Topics including but not limited to

1. Automation of non-destructive testing and real time health assessment of inaccessible areas in harsh conditions
2. Vacuum compatible geared motors for quick inspection articulated arm for visual inspection inside fusion machine under high vacuum conditions
3. High torque gravity compensated pitching joint for a multi-DOF heavy payload handling robotic arm
4. Machine learning for analysis of sensor data for anomaly monitoring, detection and predictive maintenance
5. Simulators and digital twins for nuclear power plants
6. Hardware and software for neuromorphic computation
7. Algorithms for the UAV detection system using acoustics, thermal camera, LIDAR etc.

#### 4.8 Cyber Physical Systems, KU Band Radar, Cyber Security

Machine learning for cyber security, Object detection algorithms, Radar and applications, etc.

Topics including but not limited to

1. Algorithms for detection of non-metallic objects using X-rays and other techniques
2. Algorithms for TeraHertz based screening systems for non-intrusive scanning of personnel and sealed objects
3. Blockchains for cyber physical system security
4. Antenna Array, Meta Material Antenna, Advanced Signal processing for Radar Applications
5. ML based Anomaly Detection using Network Traffic, Endpoint logs and User behavior Analytics, ML based Random / Phishing Domain detection
6. Spam mail detection using LLM
7. Agentic AI for SOC automation, Security Testing & Vulnerability assessment
8. Deepfake detection of Image / Audio /Video
9. Low-power AI models for sensor processing
10. Vulnerability and risk analysis techniques

#### 4.9 Microscopy, Medical Instrumentation

Scanning Electron Microscope (SEM), Machine Learning and algorithms for medical applications etc.

Topics including but not limited to

1. Studies related to gun, lens, detectors of SEM
2. High sensitivity Cathodoluminescence detector for biological applications
3. Characterization of Tungsten single crystal-based field emission sources
4. Algorithms for interpretation of data from various detectors/sensors associated with SEM
5. Quantitative estimation of radiotherapy outcomes using tumor control and normal tissue complication probability modelling.
6. Real-time rapid plan optimization for Virtual Couch Shift Algorithms.
7. AI-Enabled Patient Digital Twins for Predictive Modelling of Therapeutic Outcomes and Disease Trajectories.
8. Machine learning and algorithms to automatically detect key ECG points, classification of abnormalities

#### 4.10 Software Engineering, Instrumentation and Control

Program Analysis, Formal Verification, Test-case generation, Compiler verification, Model based design, etc.

Topics including but not limited to

1. Translation Validation Techniques for Optimizing Compilers and HDL Synthesizers
2. Scalable Techniques for Formal Verification of Critical Systems
3. Frameworks for Hardware-Software Co-Design and Analysis for Critical Systems
4. Formal Verification of Deep Learning Models
5. Algorithms for Automatic Test-case Generation for Software and HDL Programs
6. Verified Program Synthesis using Machine Learning
7. Scalable Techniques for Static Analysis of Binary Executables
8. Analysis techniques for preparing Assurance/Safety case for C&I systems
9. Model based Design Techniques and Domain Specific Languages for Control Applications

#### 4.11 High Performance Computing (HPC), AI/ML, Graphics, FPGA/ASIC

HPC interconnects, HPC software, Explainable AI, etc.

Topics including but not limited to

1. Technologies, algorithms, tools, software platforms, strategies, interconnects related to new generation high performance computing infrastructure
2. Technologies, agents, software for adapting science, technology, engineering and medical software on the HPC machines
3. Technologies related to safety of HPC infrastructure
4. Automation technologies for quick and efficient generation of dockers and virtualized appliances related to legacy software
5. Augmented Reality and Virtual Reality technologies
6. Explainable AI Techniques for Deep Learning Models

7. Algorithms for Detecting and Mitigating Hallucinations in Large Language Models
8. Machine learning for automation of analog and mixed-signal ASIC design
9. Techniques for FPGA based acceleration of ML models

## 5.0 Radiation Technology and Societal Applications Committee (RTSAC)

Food preservation, food security, Functional foods and Nutrition.

Nuclear agriculture, Genetic engineering of crops, Soil health improvement, Agro waste management,

Radio pharmaceutical research, Synthesis of ligands, radionuclide separation cancer drugs, Bio-informatics and bio-technology

Water purification, ground water remediation, water treatment, isotope hydrology, Conventional waste management.

### 5.1 Health Care

1. Early diagnosis of Metabolic disorders and Cancer
2. Tumour Radioresistance and Cancer Immunotherapy
3. CRISPR/Cas9 research in Disease Diagnosis, Treatment and Antibiotic Resistance
4. Radiation Biodosimetry and Radiogenomics
5. Boron-Neutron Capture Therapy (BNCT) and Low Dose Radiation Research
6. High-LET Radiation Research & Radiobiology
7. Development of intrinsically radiolabelled inorganic nanoplatforms for multimodality imaging and therapy of cancer.
8. Synthesis of resins for radiochemical separation of adjacent radio-lanthanides for potential use in cancer theranostics.
9. Bulk-scale synthesis of lanthanide doped biocompatible glass or ceramic microspheres for use in the treatment of inoperable liver cancer after neutron irradiation.
10. Identification and synthesis of cancer targeting lead molecules (peptides, small molecules).
11. Synthesis of bifunctional chelating agents amenable for complexation with different radiometals
12. Preliminary clinical evaluation of indigenously synthesized promising radiolabelled compounds.
13. Synthesis of modified oligonucleotides for use in targeted in-vivo applications.
14. AI, machine learning modelling and molecular dynamics for healthcare, Food and agriculture security
15. High-LET radiation (electron, proton, other charged particles) - based mutation breeding and mutant characterization
16. Cancer biology and radio-resistance
17. Low dose radiobiology
18. Development of adjuvants for cancer radiotherapy
19. Thermochemical cycles for pink hydrogen production using nuclear heat.

### 5.2 Food Security

1. Radiation dosimetry: Chemical & Biological dosimeters
2. Novel strategies for Prevention of food spoilage and growth of Food borne pathogen in food
3. Rapid detection methods for pathogens in foods

4. Evaluation of phage cocktails on food at commercial scale
5. Detection and mitigation of antibiotics and toxins in foods
6. Detection of pesticide residues in foods
7. Detection of food adulterants
8. Biopolymers for food and allied applications
9. Scientific basis for extension of shelf life and other benefits observed upon radiation processing of food and its processed products
10. Scaling-up studies for radiation processed ready to eat (RTE) and ready to cook (RTC) products
11. Development of new climate resilient crops using random mutagenesis and targeted genome editing methods with more focus on Pulses, millets & horticultural crops
12. Molecular characterization of Trombay mutants
13. Speed breeding where-ever applicable to accelerate the varietal developmental process
14. Novel microbial formulations for better growth promotion and biocontrol of diseases in crop plants
15. Development of eco-friendly insect pest management
16. Efficient ways of converting waste biomass into good quality organic manure/usable carbon source
17. Tri Mega MoUs with trusted State Agriculture University (SAU) partners
18. Popularization & wider penetration of mutant varieties through Field Days/FLDs (Front Line Demonstrations)/Kisan Melas & Farmers/Mini-Kit Seed Distribution
19. Waste to Wealth: Value added products (Biofuels, Biochemicals, and Biomaterials) from agro-waste including algal cultures
20. Protein engineering in healthcare applications
21. Safety and health assessment of functional foods
22. AI, machine learning, and molecular dynamics for healthcare innovation, food security, and agricultural resilience

### 5.3 Water & Waste Management

1. Developing protocols for quantitative estimation of low levels of Sulphur-35 (<sup>35</sup>S) and Beryllium-7 (<sup>7</sup>Be) in natural water samples for residence time estimation of young waters
2. Effective water resources management through isotope enabled machine learning approaches for developing decision support system
3. Studies on climate change impacts on groundwater recharge and deep aquifer sustainability using coupled isotope climate & hydrological models.
4. Isotope hydrological investigation for understanding groundwater dynamic in and around DAE units
5. Deciphering stable isotope signatures of monsoonal precipitation in India: Implications to monsoon circulation processes.
6. Hydrodynamic studies in constructed wetland using radiotracer to enhance its wastewater-treatment capacity.
7. Radiotracer applications for trouble shooting, process optimisation, scale-up and mal-function identification in industrial systems.
8. Radiotracer applications for validation of numerical models in industrial process systems
9. Computational and radiotracer studies in biomass pyrolysis units used for production of high value (biodiesel) from plant waste (bamboo woods).

10. Liquid flow dynamics studies in a multi-impeller gas-liquid system used in front end of nuclear fuel cycle using radiotracer techniques
11. Radioactive particle tracking for velocity profiling and process scaleup in gas-solid fluidized bed systems.
12. Radiation processed materials for mitigation of Micro & Nano plastics (MNPs) and other emerging pollutants
13. Development of radiation engineered robust matrices for room temperature sensing of volatile pollutants.
14. Development of radiation-based protocols and processes for mineralization of recalcitrant pollutants like per- & polyfluoroalkyl substances (PFAS) and contaminants of emerging concerns (CECs).
15. Studies on gamma radiation efficacy for eradication of Antibiotic Resistant Bacteria (ARBs) and Antibiotic Resistant Genes (ARGs) in radiation processed sewage sludge.
16. Plasma Surface Engineering and its Industrial applications
17. Characterization of Plasma jet during its interaction with Fungus
18. Treatment of medical waste for disinfection and making non-polluting end products/ safe disposal of concentrates
19. Development of computational methods/simulation tools expediting plasma/e-beam technology in wider application (for water and industrial effluent treatment)
20. Development of Green, Cost-Effective Adsorbents for selective removal of uranium and other radionuclide from Highly Acidic/alkaline Nuclear Effluents
21. Resource recovery from waste streams using Membrane Technology and Development of indigenous permselective membrane
22. Studies related to Urban waste water treatment and water pollution

#### 5.4 Radiation Technology:

1. Development of radiation engineered robust matrices for room temperature sensing of volatile pollutants.
2. Development of intrinsically radiolabelled inorganic nanoplatfoms for multimodality imaging and therapy of cancer.
3. Synthesis of resins for radiochemical separation of adjacent radio-lanthanides for potential use in cancer theranostics.
4. Bulk-scale synthesis of lanthanide doped biocompatible glass or ceramic microspheres for use in the treatment of inoperable liver cancer after neutron irradiation.
5. Synthesis of bifunctional chelating agents amenable for complexation with different radiometals
6. Low-dose radiobiology, LNT hypothesis assessment, and radiation risk modelling

#### 5.5 Research and analysis of impact of radiation and radioisotopes in healthcare, food security, water and other societal applications