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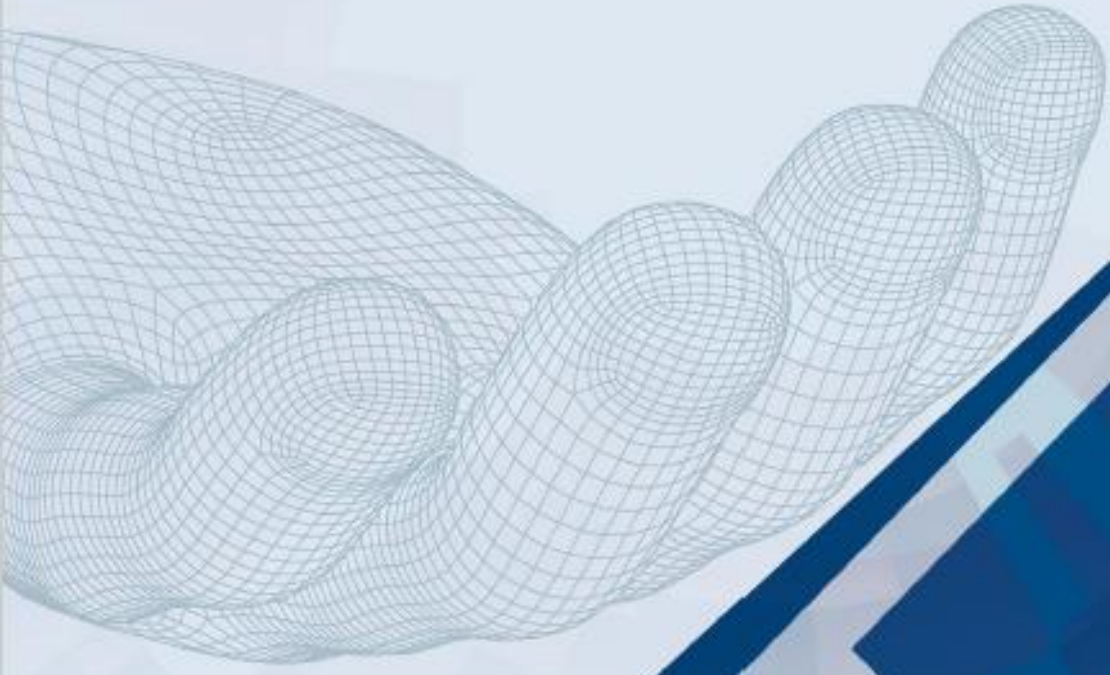
VAIBHAV OUTCOMES AT A GLANCE



VAIBHAV

Vaishwik Bharatiya Vaigyanik Summit

GLOBAL SUMMIT OF OVERSEAS AND RESIDENT INDIAN SCIENTISTS AND ACADEMICIANS - OCT-NOV 2020

शुद्धा हि बुद्धिः किल कामधेनुः ॥

Vertical 1: Quantum Technologies

Vertical Summary

4 Horizontals | 17 Sessions | 34 Hours of Deliberation | 106 International Panellists | 165 National Panellists

Horizontals

- Quantum Computing
- Quantum Sensing and Metrology
- Quantum Communication
- Quantum Materials and Devices

Key Research Areas

- Indigenous developments in quantum materials and devices: Prospects of co-operative engagements
- Material infrastructure for digital and quantum technologies
- Topological quantum matter and hybrid quantum devices
- Building the Indian quantum-materials-and-devices ecosystem : Synergies and future directions
- Building the Indian quantum-sensing-and-metrology ecosystem: Synergies and future directions

Specific Challenges

- Rigorous adoption of technologies at the organizations like digitisation, automation, machine learning and artificial intelligence.
- Hurdles from other countries w.r.t finance and immigration status for allowing our Indian students go abroad for training / participation in research projects.
- Possibility that student on which resources are spend to sponsor their training and research activities finally shifting outside India for their career.
- Utilization of high dimensional quantum correlations for communication and imaging.
- Ill-equipped eco-system with lower number of researchers working on quantum communication, that too in discrete silos.

Mission Mode Projects

- Establish Center for Quantum Technology for undertaking research, education, academic, industry outreach activities and governmental advisory for the application of technological advancements.

Key Recommendations including Short Term/ Long Term Goals

- A robust platform for collaborations between researchers in India and abroad, focussing on both hardware development and exploratory research pertinent to quantum technologies, and spread over theoretical and experimental projects across all horizontals.
- A clear policy of engagement between Indian and Indian-origin researchers from abroad, which would drive manpower training and development, research capability building, and enhancement of the knowledge-base, enabled by short and medium term visits by both parties, short-term and medium-term student-exchange programs, workshops and symposia.
- Formation of an advisory committee comprising of both Indian and India-origin researchers.

Potential Collaborations

- Online programs in collaboration with academics abroad and industry where students of different stream who want to learn about quantum computing or solving algorithms can help to initiate quantum environment.
- Collaborations between entities from defense, telecom and electronic sector operating in India and strategically routing the R&D output to these industries for development of quantum technologies.

Vertical 2: Artificial Intelligence and Machine Learning

Vertical Summary

4 Horizontals | 7 Sessions | 21 Hours of Deliberation | 60 International Panellists | 64 National Panellists

Horizontals

- Foundation of AI
- AI and Robotics
- AI ML and Signals
- AI for Social Good

Key Research Areas

- Healthcare; Digital Heritage; Mobility, Transport and Road Safety; Industry 4.0, Robotic Process Automation; Agriculture, Fisheries, Wildlife Conservation; Human-machine collaborative Computer Vision (CV), Plant phonemics, Manufacturing Sector, Heritage preservation and virtual tourism, Governance, Aids to improve mental health and wellbeing , Wildlife conservation, Gauge urbanization, Defense sector, Self-driving cars, Hardware revolution, Disaster management, Disability services, Biomedical applications, Education, Construction inspection, Crowd monitoring; FATE; Design of low resource machine learning techniques; Autonomous navigation of Drones in Internet of Things (IoT)-enabled but GPS-starved environments; Autonomous Cargo Vehicles in Smart City environments; Design of ADAS (Advanced Driver Assistance Systems); AI and Law etc.

Specific Challenges

- scientific ideas for reducing the burden of future pandemics
- Pressing need to bring legal and law experts along with the AIML scientists to collaborate in order to address the concerns of fairness and ethical practices.
- There is a need for a focused approach and work on reinforced learning in robotics
- Challenges pertaining to strengthening AI infrastructure in India. All AI interventions need to be redesigned from the ground-up to enable last mile reach to the end-users

Mission Mode Projects

- Regular in-person workshops (such as Mysore Park/Dagstuhl workshops) to allow detailed discussions between Indian and international researchers in focused areas of research
- Bring leading AI conferences to India: NeurIPS; ICML, SIGKDD; IJCAI; CVPR; ICCV; etc.

Key Recommendations including Short Term/ Long Term Goals

- *Infrastructure:* Creating AI centers and Centre of Excellence (COE) which encourage collaboration for solving long term problems of societal benefit with researchers and entities abroad
- *Skills Development:* Look beyond institutes such as IITs, IISc, IISERs, etc. and involve less privileged institutes and private institutes which also have a lot of talent.
- *Programs and Missions:* The National Program in AI was declared in the 2018 budget, following which the Niti Aayog came up with a strategic paper on AI. This is an excellent document. However, it needs to be updated now in view of the fast changing nature of the AIML area. The recommendations of the strategic paper should be implemented immediately.
- *General:* There are many existing schemes such as VAJRA, GIAN, STARS, etc. which are very good; however there are delays; there is a need to make collaborations easy between the institutes by reducing the number of permissions and approvals from the authorities

Potential Collaborations

- Collaborations between experts from legal and law background and AI field
- CERN for AI in India – to provide the computational, data, and data sharing infrastructure to enable big data analytics and scalable AI solutions for emerging applications
- Collaborative centers could be launched in areas such as: Computational Epidemiology; AI Driven Education; AI Driven Digital Agriculture; Centre for Responsible AI for Social Good; etc.
- Collaboration between Indian and NRI faculty to design courses.
- Collaborations between EECS researchers and social scientists

Vertical 3: Electronic and Semiconductor Technologies

Vertical Summary

3 Horizontals | 12 Sessions | 24 Hours of Deliberation | 76 International Panellists | 136 National Panellists

Horizontals

- Semiconductor Materials and Process Technology
- Electronic Circuits and System Design
- Electronic Devices: Physics and Technology

Key Research Areas

- Growth of next generation materials; Process challenges in advanced nodes and next generation materials; Manufacturing eco-system for conventional semiconductor-based process technologies; Flexible, printable, wearable electronics, and additive manufacturing; Heterogeneous integration and packaging; Sensing Devices; Power Devices and Reliability Physics; Nanoscale transistors and memory devices; Device Characterization and Compact Modelling; Full custom design; Digital system & Processor design; Board level integration

Specific Challenges

- Lack of robust industry and experimental research and development infrastructure.
- Lack of interaction and collaboration between industry and institutes.
- Lack of increment in core investment in projects by government (fixed at 25-50 lacs only).
- Too many sponsoring agencies which requires going to many websites to search proposals.
- Less exchange programs and collaborations at graduation level.
- Ranking criteria used by Department of Science and Technology for foreign faculty's visit to Indian institutions.
- Lack of prompt actions on project funding proposed out of collaborations.
- More focus on job oriented research rather than entrepreneurship based.
- Non-availability of advanced electronic components in domestic market to support development of advanced hardware.

Mission Mode Projects

- Growth of next generation materials: The development of next generation materials that have not yet undergone complete translation from research labs to industry.
- Manufacturing eco-system for conventional semiconductor-based process technologies: The continued industrial activity in fabrication of Si, GaAs, GaN, and SiC-based devices for various applications, and established materials used for insulation (HfO2, SiO2, etc.) as well as high performance contact stacks used for different technologies (sentence incomplete).
- The Heterogeneous Integration Roadmap is an identification of the challenges and the potential solutions for meeting these requirements for emerging research areas.

Key Recommendations including Short Term/ Long Term Goals

- Sensors, especially chemisensors and biosensors.
- Energy storage devices (such as batteries and supercapacitors).
- Printable processes and wearable electronics.
- Flexible electronics-based manufacturing for consumer electronics.
- Device and system distributed autonomous energy storage device materials and fabrication processes.
- Materials for distributed memory and logic design for AI/ML applications.
- Training of students, and future industry professionals, as well as long term faculty exchange programs.
- Advanced Packaging which includes wafer level packaging, TSV, CSP, wafer-to-wafer bonding & SiP.

Potential Collaborations

- Collaboration between academia-industry to develop wholesome computing and introduce multi-disciplinary topics.
- Collaboration for supplementing the knowledge around metallurgy.
- Collaboration for Intraluminal sensing.

Vertical 4: Communication Technologies

Vertical Summary

4 Horizontals | 4 Sessions | 9 Hours of Deliberation | 21 International Panellists | 23 National Panellists

Horizontals

- Cellular Evolution 5G and Beyond, including THz technologies
- Cognitive Technologies for Futuristic Communications
- Internet of Things: Integrating Sensing, Communication and Computing All Together
- High Speed Optical Communications

Key Research Areas

- Machine-to-Machine (M2M) Communications
- New Spectral Bands (mmWave bands, up to THz bands)
- Ultra Reliable Low Latency Communications (URLLC)
- Improving optical spectral efficiencies, novel optical fibers
- Optical networks - data center networks, seamless integration of mobile fronthauls with optical access networks
- Optical signal processing
- DSP for high speed optical transceivers including error correction
- Photonic Integrated Circuits
- Lasers/frequency combs and detectors - semiconductor devices for optical transceivers.

Specific Challenges

- Challenge of three Rs (Repeatability, replicability, reproductibility) – access to hardware itself is a challenge, replicability not verified by review processes and reproducibility is not valued
- Indian Academia - Heavy on PhDs and post-docs, not enough Research Engineers (REs). Ecosystem is missing for prototyping, system building and field testing. REs offer a pipeline for possible startups and for systems PhD.
- Stronger segregation between hardware and software/algorithms. Not enough focus on ‘embedded device’ or AIoT space. Focus on FPGA, networking protocols, sensor design, AI/ML algorithms.

Mission Mode Projects

- Open a mission mode project where a certain frequency band is opened up for cognitive communications, and various companies are invited

Key Recommendations including Short Term/ Long Term Goals

- 3-5 years project definition, with mandatory industry/public agency partners (there is lack of real industry stakeholders).
- Developing testbeds, working on implementation and standardization.
- Invite for Unpaid review of progress in funded projects.
- Mentoring support for converting research papers to products.
- Establish flagship conferences/periodic summer/winter schools to promote more intense conversation between academia on either countries, specific panels in these for engaging with industry and the Government.
- International Conferences that attract scholars from everywhere like COMSNETS 2021

Potential Collaborations

- Specialty fiber designs for both telecom and micro structured optical fibers for mid-IR and THz wavelengths
- Pushing the limits of Test Beds

Vertical 5: Computational Sciences

Vertical Summary

3 Horizontals | 13 Sessions | 39 Hours of Deliberation | 79 International Panellists | 96 National Panellists

Horizontals

- Computational Natural Sciences
- Cyber Physical Systems
- High-performance computing and its application

Key Research Areas

- Many body systems, atomic and molecular studies using quantum chemistry, large molecules and clusters, neural networks, ML & AI and automation tools, DFT and many body theorists, solar energy materials, thermoelectric materials, battery materials, fuel cells, device materials e.g. beyond silicon, spintronic, optoelectronic, magnetic, and nanomaterials, photosynthesis, conversion of CO to CO2 and to fuels, bio-shielding , bio-active and waste forms, Education, disaster management, pharmaceuticals, medicines, health, and climate need great focus and HPC applications for societal good, Mechanistic Data Science, Bio-inspired computing, Embedded Systems and Control Systems, Smart grids, Smart Buildings, Intelligent Transport Systems and traffic control, Pedagogical material, virtual education, low-cost CPS hardware kits, autonomous navigation, Ethics and Human Aspects of CPS.

Specific Challenges

- Lack of scalable systems and substantial testing mechanism and framework
- Improvements in prediction of band structure, optical properties, conductivity, and other properties of materials
- Lack of computational softwares, applications and codes
- Lack of sufficient number of experimental physical chemists, computing resources
- Lack of interaction between researchers in academic institutions and industry.

Mission Mode Projects

- Arranging CECAM (Centre Européen de Calcul Atomique et Moléculaire) type of advanced workshop for training young students in different parts of India, forming Psi-k like groups of researchers working on similar problems, inviting leading international researchers
- MURI and DAPRA like programs in India

Key Recommendations including Short Term/ Long Term Goals

- *Infrastructure:* Dedicated hub for complex systems related data must be established. Establishing well-funded national key laboratories across India
- *Skills Development:* Special courses and skill upgradation for data science, ML, and AI as these areas are currently attracting great attention. Computer centers to be manned by PhD background personal who could assist researchers with their algorithms or codes
- *Programs and Missions:* Computational sciences should be given more focus to boost up Atma-Nirbhar Bharat scheme. Organizing joint workshops and training programs in specialized areas *General:* Requirement of a National Computer Policy, massive expansion and creation of centralized supercomputer centers Dedicated National/International Centers of excellence for computational materials science. Long term collaboration and dual citizenship to avoid loss of trained workforce. Large scale grants for joint projects focusing on specific research areas.

Potential Collaborations

- Collaboration on multi-scale epidemiological analysis of an infectious disease in India
- Collaboration on new algorithms and big data analysis leveraging ML/AI to accelerate research using HPC
- Developing a Bayesian framework for earthquake location
- Development of whole-cell simulator package and Confluence of Neural Networks, AI/ML, Data Science and CPS
- Developing computational approaches in numerical general relativity and the physics of gravitational waves

Vertical 6: Data Sciences

Vertical Summary

4 Horizontals | 6 Sessions | 19 Hours of Deliberation | 39 International Panellists | 53 National Panellists

Horizontals

- Data Science Project Management
- Data Science Education
- Vision of Data Sciences
- Data Privacy & Security
- Data Science Applications

Key Research Areas

- Role Based Encryption (RBE), Symmetric Searchable Encryption (SSE), Secure multi party computation and searchable encryption mechanisms, Mathematically and algorithmically rigorous framework of differential privacy, Homomorphic encryption and privacy preserving storage and query processing on Aadhaar Database, Anonymous authentication using zero knowledge proofs, Decentralized storage architecture & Blockchain networks, Securely integrate/deploy Aadhaar services with new 5G services and applications, Fraud detection and measuring the extent of fraud orchestrated through abuse through and of Aadhaar, Unified Intelligent transportation system, automated annotations of videos, surveillance/security videos, anomaly detection, wildlife imaging and active sensing,

Specific Challenges

- Lack of adequate resource and infrastructure
- Lack of adequate skilled manpower
- Privacy and legal issue for use of certain data sets
- Data security
- Inadequate infrastructure and facilities for essentials
- Excessive belief in technology

Mission Mode Projects

- Future Aadhaar from Security and Privacy Perspective (Aadhaar 2.0)
- Security and privacy framework for unmanned aerial vehicles in consumer applications
- Need to develop state of the art laboratories to conduct research.
- Need to set up Centre of Research Excellence for data science applications.

Key Recommendations including Short Term/ Long Term Goals

- *Infrastructure:* To build distributed analytics system which can exploit and used across the world. To build right infrastructure that can seamlessly integrate all aspects of data science.
- *Skills Development:* To organize certification programs in data science through international collaborations for upskilling. Guidelines need to be defined for defining core-curriculum for data science programs and education, catering to both research and practice.
- *Programs and Missions:* Need to bring policy to support start-ups working in the field of research on data science by providing grant funding, setting up incubation hubs, etc. Should plan for funding of incubating international conferences in Data Science area with support of an international steering committee for initial three year and then making it sustaining even in subsequent years.

Potential Collaborations

- Collaboration in Data Science Project Management.
- Collaboration on mission related to “Future Aadhaar from Security and Privacy perspective (Aadhaar 2.0)”.
- Collaboration on mission related to “Security and privacy framework for unmanned aerial vehicles in consumer applications”.

Vertical 7: Photonics

Vertical Summary

5 Horizontals | 6 Sessions | 16 Hours of Deliberation | 39 International Panellists | 16 National Panellists

Horizontals

- Nonlinear Optics, Meta-Optics and Quantum Photonics
- Optical Imaging and Biophotonics
- Photonic Materials & Devices
- Micro & Nanophotonics
- Integrated Photonics and Communication

Key Research Areas

- Semiconductor lasers, UV Optoelectronics, Meta Materials and Meta Optics
- Wafer technology, especially GaN and AIN for high performance devices
- Epi and processing services; Free space optical communication using QCL
- Phase change Materials; Nanoscale photonics; new type of detectors
- Quantum Photonics; Integrated and Si photonics; LEDs & Photovoltaics
- Silicon photonics, Optical resistive switching, and Bio-chemical sensing
- Multifunctional active meta and plasmonics devices
- Integrated Photonics (NIR) at room temperature, bolometers for circuit quantum electrodynamic (microwave)
- Single/Multi pixel camera for low illumination, sensor module

Specific Challenges

- Lack of initiatives and trainings at the grass root level in the field of bio-photonics
- Lack of availability and access to high-tech fabrication method for nano-photonic application
- No dedicated R&D labs for integrated photonics and communication in India
- Lack of adequate and timely funding of scientific projects and infrastructure
- Limited flexibility is permitted in use of funds

Mission Mode Projects

- Formation of Centre of Excellence of Photonics
- Establishing Photonics Park at strategic locations within India
- Creation of a start-up culture in photonics in India. Additionally, collaboration with Start-ups across the globe.

Key Recommendations including Short Term / Long Term Goals

- *Infrastructure:* Creation of virtual HUB for trusted and sustainable knowledge exchange, joint entrepreneurial venture and well defined IP sharing protocols with Indian diaspora; establishing infrastructure for high-tech processing for photonics leading to e.g. “one –stop shop” for atleast some thrust areas
- *Skills Development:* Introduction of photonics to a larger audience in the universities and industries; strengthen linkages among researchers from India and overseas for tangible collaborations and identify mutual research benefits and complementary expertise
- *Programs and Missions:* Conducting Student & Faculty exchanges and formulating bilateral research proposals (including industries); signing MoU with foreign universities for joint PhD Programs
- *General:* Industry should work in tandem with academia, to work on researches that is translated into useful products. Also there is a need to leverage the software development skills of India into research & development eco-system

Potential Collaborations

- Set up a packaging centralized facility
- Collaboration on the research areas of chip design, fabrication, methods of testing and applications in optical communications, nonlinear optics and quantum photonic.
- Establishing an advisory panel, which can look at these collaborations regularly and administer any program as well as to identify mutual research benefits and complementary expertise

Vertical 8: Aerospace Technologies

Vertical Summary

5	23	90	169	215
Horizontals	Sessions	Hours of Deliberation	International Panellists	National Panellists

Horizontals

- Aerospace Systems and Design
- Modeling & Simulations
- Propulsion Technologies
- Flight Structure and Integrity
- Unmanned Aerial Systems and Countermeasures

Key Research Areas

- Research on Hypersonics, MDAO, HUMS / IVHM research,
- Flutter and vibration in high aspect ratio wings typical of transport aircraft; exploring use of composites in reducing weight and thereby reducing induced drag
- Investment in NDE research and development for aerospace
- Target emerging technologies – digital twins, rapid prototyping, additive manufactured spares inventory, Corrosion fatigue, Advanced composites and Novel materials
- Gas Turbine – Aeroelasticity - blade flutter taken through COPT and GATET
- Applied AI and ML clusters with applications in aerospace technologies
- Advancing maturity in Biomimetic Unmanned Systems, research in UTM / UAS

Specific Challenges

- Lack of experimental facilities in India for testing hypersonics, drones, UAVs, green propulsion etc.,
- Validation & Verification of HUMS / IVHMS
- LRUs are imported in India; miniaturization of VTOL components & helicopter simulator a challenge.
- Transition from manual control to Fly-by-wire control systems in aircraft
- Interdependencies of the aircraft components that impair reducing associated noise and emissions
- Cost effective NDT and quality control in aircraft systems
- Indigenous development of finite element software, certifying the sensors, radars & cameras

Mission Mode Projects

- Verification / Certification Technology for HUMS (Health and Usage Monitoring Systems)
- development of LRUs (Line Replaceable Units) in India for export purpose
- Design & Development of new generation regional turbo propulsion aircraft optimized for the range and India specific Regional transport aircraft with digital twins, predictive analytics
- Integrating detonative combustive into RAMJET / SCRAMJET configuration
- Exploring Potential for modular battery charging stations for UAMs, Green propulsions

Key Recommendations including Short Term/ Long Term Goals

- Infrastructure: Flying Testbeds for HUMS, UTM/ATM facility for conducting low-altitude flights, Humans-in-the-loop research lab, HPC computers for RTA projects, HT mechanical testing for NDE of CMC, fabrication of composites, Burner Rig tests / wind tunnel test, NDE centre of excellence, UAV centre at Kanpur, Subscale test platform like NASA Airstar, Large drone corridor, UAV Commission
- Skills Development:.Introducing Hypersonics, MDO, SHM, NDT, Aero-elasticity courses, CFD workshops, specialized packages like Incidence / D matrix, training on bio-fuels, Interdisciplinary courses with aerospace + material + mechanical, international competitions in aerospace
- Programs and Missions: Reviving/ Restarting ROSSA scheme of DRDO, Nodal centre for MDO technology, Center of Excellence for Airspace Management Research in India, AFSOR global/ONR global type office, Central body of excellence for R&D of HT materials, Aerospace Commission, Aviation research centre, SBIR (Small Business Innovation & Research), DARPA of USA / STIR / AFWERX in the Indian context, National Scientific Computing Center (NSCC)

Potential Collaborations

- Potential Collaboration for VTOL systems – powerplant, flight controls, wind tunnel testing & simulation
- Collaboration for NDT in SHM, Aero-engine, Additive manufacturing, 3D printing, advanced materials in HT applications, aeroelasticity
- Developing traffic flow management and Dynamic Airspace Management (DAM) for India
- Development of future lightweight multifunctional materials for aerospace applications
- Enhancing S&T Cooperation through Indo-US S&T Agreement, Bi-National S&T Commission, Indio-US S&T Endowment Board and Fund, Indo-US S&T Forum and High technology cooperation group

Vertical 9: Materials and Processing Technologies

Vertical Summary

5 Horizontals | 14 Sessions | 47 Hours of Deliberation | 73 International Panellists | 122 National Panellists

Horizontals

- Structural Materials
- Materials Recycling & Purification
- Advanced & Functional Materials
- Catalytic Materials & Processes
- Computational Materials Science

Key Research Areas

- Ceramic AM/3D Printing Technologies, Advanced ceramic powder synthesis, Solid Oxide Fuel cells and Fuel cell materials, Sintering of Advanced ceramics (Flash Sintering)
- Value recovery from fine industrial product waste, precious materials recovery
- Applications of rare earth materials
- Wide gap semiconductors materials and devices, recyclable electronics, flexible/printable sensors and electronics
- Thermoelectrics, Topological Quantum Materials, 2D layered materials, Ferroelectric and Dielectrics, Low T electronic transport
- Electronic state molecular dynamics, higher accuracy electronic structure possibly using machine learning

Specific Challenges

- India has enormous talent in software but is yet to fully leverage advanced computer simulation in Science–Technology-Engineering-Math (STEM) education and research
- Startup trends/entrepreneurship in Metallurgical/ Material engineering is weak in India
- Some advanced simulation tools are freely available for education and research, but they are not being fully exploited because of lack of training
- Lack of integrated approach especially for electronic waste
- Lack of serious players who want to be in recycling business for long time
- No or less focus on corrosion management research and development activities

Mission Mode Projects

- Develop Science/Technology parks in different strategic locations
- Develop Centre of Excellence

Key Recommendations including Short Term / Long Term Goals

- *Infrastructure:* Invite entrepreneurial researchers to set up JV based cleantech companies in India and extend government and private sector support; invest in business incubation hub which can work closely with academics and increase the translation of science to application.; develop engineering research center model where industries can be members for a token fee and have access to the research the center is producing.
- *Skills Development:* Create a pool of industries which are pro R&D and which can facilitate further interaction between industries and academicians; provide dual-degree for students working on big projects with guides from India and abroad.
- *Programs and Missions:* Conduct joint PhD /student exchange programs with foreign universities and research labs; create joint international labs; provide a platform for academicians to collaborate with industry.
- *General:* Encourage user driven projects that have close interactions with user at every stage of development. Encourage industry and government involvement in Research & Development.

Potential Collaborations

- Testing capacity for composites for high temperature
- Developing a Centre of Excellence and mainly focusing on advanced material research and its commercialization.

Vertical 10: Energy

Vertical Summary

4 Horizontals | 4 Sessions | 8 Hours of Deliberation | 19 International Panellists | 25 National Panellists

Horizontals

- Sustainable Mobility Technologies
- Advanced Fossil and Nuclear Technologies
- Future Electricity System
- Sustainable Future Fuels

Key Research Areas

- Vacuum insulation panels, retrofittable concentrating solar technologies
- Transforming electricity usage by Smart switchgear and “Green” usage i.e. efficiency of electrical equipment; zero intervention, maximum upgradation
- Development of directly absorbing type technology
- Integration of Solar Panels & Optimal Power flow and renewable energy sources
- Engineering of large systems, extra-high power and extra high voltage components and also engineering on a more modest scale
- Production of Sodium–Sulfur batteries
- Fast charge in electric two- and three-wheelers
- Integration of fuel cell technologies

Specific Challenges

- Major challenge for slow growth of EV in India – Technology, Policy, Infrastructure, Investment. And key challenge is Public-Private Partnership
- Safety, high-Cost, short cycle-life of rechargeable battery
- Main obstacles in Sustainable Fuel Cell Vehicles (FCV) are cost of the vehicle, distribution infrastructure and hydrogen production
- Lack of confidence among funders in Indian academic scientists
- Pressurize academics to take industry along, unless they are funded

Mission Mode Projects

- Development of funding mechanisms to support short-term research opportunities for students, faculty and scientists in India to visit universities and research laboratories in USA
- Hosting joint technical symposiums and workshops in non-sensitive areas of nuclear research, such as thermal-hydraulics, open-source computing, safety and security of nuclear power, non-proliferation and safeguards

Key Recommendations including Short Term/ Long Term Goals

- Build and Fund Interdisciplinary Teams of Scientists and Engineers with Focused Goals in the Targeted Energy Sectors
- Development of funding mechanisms to support short-term research opportunities for students, faculty and scientists in India to visit universities and research laboratories in USA
- Collaboration between researchers and policy maker for energy efficient building to assess where policy implications for next 20 years
- Development a research funding model, similar to ARPA-E in USA that aims to advance high-risk, high-reward energy technologies that are too early for private-sector investment
- An overarching energy policy co-ordination by the central government linking to various state governments to create secure, sustainable and affordable energy systems

Potential Collaborations

- The liquid metal experimental facility
- Explore advanced coolant options for Fast reactors – e.g. Gallium alloys

Vertical 11: Environmental Sciences

Vertical Summary

5 Horizontals | 17 Sessions | 55 Hours of Deliberation | 86 International Panellists | 136 National Panellists

Horizontals

- Air Quality Management
- Soil and Waste Management
- Climate Change
- Water Quality Management
- Carbon Sequestration and Biodiversity Conservation

Key Research Areas

- Network Establishment, Energy recovery from solid waste, Improving India's EPI, Energy Efficient and Smart Buildings, Framework for adopting clean fuels, Establishment on the network of communities, government and non-government organizations, industries and policymakers to work on sustainable development, Emerging contaminants in aquatic environment, Monitoring and preparation of Health Card of water bodies, New material or process development for energy positive wastewater treatment; for waste minimization/RO reject management, Terrestrial ecosystem modeling under Indian conditions, Coupled carbon-climate modeling by coupling a carbon model with the IITM Earth System Model, Inverse modeling of carbon and other GHGs

Specific Challenges

- Lack of scalable systems and substantial testing/data recording mechanism and framework
- Lack of collaboration and standardized operating procedures
- Lack of incentives for innovation for ecological conservation

Mission Mode Projects

- National Mission on Sustainable Habitat
- National Water Mission
- National Mission on Strategic Knowledge for Climate Change
- National Mission for Sustainable Agriculture

Key Recommendations including Short Term/ Long Term Goals

- *Infrastructure:* Regional centers for providing technical support for contaminated site assessment and management, Development of AAQ standards based on Air Quality Index and NCAP requirements, Technologies for IAQ control for different microenvironment
- *Skills Development:* Expand MetFlux and other similar programs to observe carbon pools and fluxes in forests and other ecosystems, Development of community based portable water quality monitoring and Redefining the end used based water quality criteria for classifying the water bodies on the basis of it water quality
- *Programs and Missions:* Developing capability for advanced air quality modelling system in Airshed Demarcation for selected Regions in India *General:* Evolve a seamless air quality management system and development of guidelines for Air quality Management area. Risk based contaminated site and solid waste management assessment guidance document. CSIR Lead Pilot project for CO2 injection in collaboration with Indian Diaspora and the Industry Partners to assess the feasibility of CCUS at a larger scale in India

Potential Collaborations

- Collaboration on developing capability for handling solid waste management and productive utilization of generated waste to recover energy in developing nations like India.
- Collaboration on hotspot air quality management using low-cost sensors (SENSurAIR).
- Collaboration on Geo-spatial technology assisted integrated urban hydro-sociological model development for enhanced water security
- Collaboration on revamping of Technology Defined and Water Quality/End Use Defined wastewater discharge standards
- Injection of CO2 in unmineable coal seams for storage and to enhance Coal Bed Methane recovery
- Create dedicated accelerated roadway testing facilities for faster prediction of road performance and preserve assets well before deterioration

Vertical 12: Advanced Manufacturing Technologies

Vertical Summary

5	12	31	44	78
Horizontals	Sessions	Hours of Deliberation	International Panellists	National Panellists

Horizontals

- Additive Manufacturing
- Industrial Machines, Robotics and Automation
- Precision / Micro-Nano manufacturing / Surface Engineering
- Smart Manufacturing, IoT, Digital Manufacturing
- Specialty Products Manufacturing

Key Research Areas

- Additive Manufacturing (AM) – recommend a massive boost
- Focus on precision machine/equipment, sub-systems design and development
- Scaling up manufacturing processes for technology deployment
- Leverage software expertise available in India for smart/digital manufacturing, data analytics
- Frugal innovations: cutting the bells and whistles, low-cost technologies is need of the hour
- Automation – yes, but collaborating with humans and not as a replacement (Human-centric automation projects)
- Focus needed on specialty products such as assistive devices, biomedical and composites

Specific Challenges

- Joint funding opportunities, national laws for IP protection, need for infrastructure improvement in India, limited resources for Indian Scientist to visit their overseas counterparts, funding and exchange of students and post-doctoral researchers
- Indian manufacturing sectors are quite conservative in adopting new technology and market is also price sensitive and this is impacting AM research uptake in India
- Formulating value propositions for initiating collaborations
- Constraint of funding for travel and living

Mission Mode Projects

- Establish regional centers of additive manufacturing research and development accessible to all researchers
- Localization and customization of Industry 4.0 technologies for Indian industries of all scales and training / re-skilling of low-to-middle level employees & focus on adoption of technologies

Key Recommendations including Short Term/ Long Term Goals

- Establish regional centers of additive manufacturing research and development accessible to all researchers
- Localization and customization of Industry 4.0 technologies for Indian industries of all scales and training / re-skilling of low-to-middle level employees & focus on adoption of technologies
- Extra mural funding schemes (along with NRI collaboration) for specific thrust areas in Additive Manufacturing; co-funding with industries can be encouraged
- Sibling research centre model (cloning overseas labs); adjunct faculty appointments, joint-PhD guidance
- Co-development centre model (hardware + software (India)); adjunct faculty appointments, joint-PhD guidance

Potential Collaborations

- Additive Manufacturing Boost : U. Michigan, SEAM Waterford Institute, Cranfield University, Georgia Tech, QUT, RMIT, Univ. of Glasgow and One (regional) host institute supported by group of regional institutes
- Machine / Equipment building focus projects : UIUC, MIT, NUS, CMTI, IITM (AMTDC), IITB, IITD, IITKGP, CMERI, other relevant Indian institutes, USC, U. Michigan, U. Edinburgh, NIST, NPL (UK), NTU, NC State
- Human-centric automation projects : UIUC, U. Edinburgh, USC, IITM, IITD etc. and any relevant institute in India

Vertical 13: Earth Sciences

Vertical Summary

4	20	45	150	108
Horizontals	Sessions	Hours of Deliberation	International Panellists	National Panellists

Horizontals

- Atmospheric Science and Technology
- Ocean Science and Technology
- Polar Science
- Geo Science

Key Research Areas

- New materials for construction including high strength plastics and polymers for the armour blocks and new type of wave dampers
- Design of multipurpose coastal protection structures
- Modelling complementing measurement of coastal parameters
- Use of GIS/ IT and AI in coastal management information system
- Fine scale variability of air-sea fluxes and its impact on monsoon dynamics
- Marine micro, macro algae for food, nutraceuticals, industrial chemicals and bio-fuel
- Offshore mariculture, submersible cage, feeding, mooring system and environmental health monitoring
- Remote sensing to monitor the water quality

Specific Challenges

- Lack of focused developmental activity towards Exascale weather and climate applications
- Biggest bottle neck in present day modelling is representation of clouds and teleconnections
- Lack of detailed resources and sitting studies
- Too high capital cost & upfront investment
- Flexible and timely funding for the projects
- Infrastructure for collaboration
- No dedicate institute/centre for pure and applied research

Mission Mode Projects

A detailed science plan and implementation strategy (SPIS) should to be developed to meet the objectives and goals. Indian scientists/academicians working in Indian Institutions and foreign countries should jointly develop SPIS and work in collaborations to achieve the goals

Key Recommendations including Short Term/ Long Term Goals

- Data collection and algorithm development for vision guided exploration and image mosaicking for biodiversity / ocean mineral resource applications
- Role of Instabilities (barotropic, baroclinic, mixed layer, fronts) in stratification and modulation of air-sea interaction
- Development of algorithms for retrieval of ocean color products in the north Indian
- Addressing the gap with R&D outcome with joint efforts towards harvesting the resources from ocean basins for the benefit of mankind
- Develop of cost efficient shallow and deep-water low frequency and high frequency electro-acoustic devices.
- Evolve a comprehensive observation strategy in the Arabian Sea to benefit climate models with data assimilation to improve sub-seasonal predictive capabilities

Potential Collaborations

- Collaboration on “Advanced techniques for ocean parameter estimation” on Institute to Institute basis.
- Collaboration on “Marine mammal monitoring”
- Collaboration with Indian Institute to build a data cube system
- Collaboration on the aerosols clouds, convection, precipitation (ACCP)
- collaborating for tropical meteorology

Vertical 14: Health, Medical Sciences and Biomedical Devices

Vertical Summary

4 Horizontals | 23 Sessions | 70 Hours of Deliberation | 105 International Panellists | 150 National Panellists

Horizontals

- Precision Health
- Holistic Heath
- Remote and Rural Health – Reaching the unreached
- Technologies for Biomedical devices in Healthcare

Key Research Areas

- Identify neurological disease genes and investigate the mechanism by which genetic mutations cause neurological disease, develop gene-based therapeutics for neurological and psychiatric disorders and develop resources for neuro-genetic research, throughput "-omics" technologies including next generation sequencing, circulating tumor cell characterization, single-cell RNA sequencing and circulating DNA analysis - cancer genome, circulating exosomal biomarkers, molecular typing, AI and targeted drug delivery, Geo-linking air pollution levels with brain function, sleep disorders, and respiratory disease, using wearable devices to develop evidence for association between ambient air pollution and burden of ailments in India at the individual level.

Specific Challenges

- Diversity of population.
- Large population with diverse genetic pool.
- Different population structure as compared to west and hence western world studies cannot be replicated as it is.
- Stratified population and high level of endogamy.
- Lack of baseline data and demography.

Mission Mode Projects

- Need to create baseline genetic data for Indian populations to improve diagnostic accuracy of genetic tests.
- Need to bring in policies and setup consortium for enhancing and expanding the infrastructure and capacity building for steering international level research in this area.
- Need to define mechanism for funding of research programs and incentivized collaborative research.

Key Recommendations including Short Term/ Long Term Goals

- To develop system for newborn screening in collaboration with US and other countries. Newborn screening includes disorders which can be managed and babies saved.
- To explore the role of neuro biomarkers in alternative medicine.
- Bring cutting edge technology as well as latest investigations for patient care, minimizing turnaround time and cost per test.
- A nation-wide common large-scale database for genomic data acquisition in the country along with clinical data and guidelines for interpreting the data to be made.
- We need translation and hypothesis driven research that will bring results in long term
- To develop facilities of FMT @ AIIMS Rishikesh in collaboration with other institutes & USA.

Potential Collaborations

- Develop a consortium of scientists from different institutes of India and Indian diaspora of an indigenous robotics platform in India.
- Develop artificial intelligence backed mobile app for e-health monitoring, including mental health.

Vertical 15: Pharmaceutical and Biotechnology

Vertical Summary

4 Horizontals | 13 Sessions | 41 Hours of Deliberation | 70 International Panellists | 101 National Panellists

Horizontals

- Biotherapeutics and Biosimilars
- Infectious Diseases/ Disease biology
- Industrial Biotechnology
- Drug Discovery, Repurposing and Drug delivery

Key Research Areas

- Regulatory Perspectives on Biosimilars, Biosimilars, Affordability of Biotherapeutic Products, Biotechnology of Industrial Enzymes, Environmental Biotechnology (Bioremediation), COVID 19, TB, Malaria & Leishmaniasis, Chemical Therapeutics, Drug Delivery and Nanoformulations, Drug Repurposing, Affordable drugs, Drugs for Neglected Diseases, AMR bacterial pathogens in India

Specific Challenges

- Lack of understanding on complex/rigid rules on manufacturing biosimilars laid out by Regulatory Bodies
- Non-availability of reference data structures
- Less expenditure on research & technological development by the industry
- Lack of coordination between industry, academia and regulatory agencies
- Lack of collaborations, student/faculty exchanges due to stringent norms & policies and meagre funding

Mission Mode Projects

- Adopt the 'Polluter Pays Principle' to remediate polluted sites via industrial effluents.
- Establish a National Centre or Institute on Industrial Enzymes for research and technological developments (RTD) and commercialization activities of industrial enzymes
- Develop a legal framework for establishing agreements with foreign companies using India's Pre-IND and Clinical Trials 'Hubs' that ensures availability of new drugs at reduced prices
- Incentivize the development of new scalable technologies, e.g. FLOW SYNTHESIS. This will help manufacture intermediates and APIs faster, cheaper, and in a more environment friendly manner
- Develop branding strategies around biosimilars, discussing more about them in conferences and making discussion forums around them

Key Recommendations including Short Term/ Long Term Goals

- *Infrastructure:* Develop "Manufacturing Parks" that focus on indigenous production of raw materials, intermediates, which enable production of APIs and excipients.
- *Skills Development:* Train and build a critical mass of excellent researchers in various areas
- *Programs and Missions:* Proper system of monitoring and surveillance, dedicated sustainable funding, facilitate mutual knowledge/personnel sharing through collaborations between scientists across different countries
- *Others:* Startups to take a major role in the steps after preclinical discovery to help create new antibiotics

Vertical 16: Agro Economy and Food Security

Vertical Summary

6	17	69	104	193
Horizontals	Sessions	Hours of Deliberation	International Panellists	National Panellists

Horizontals

- Precision Agriculture
- Sustainabale and Climate Smart Agriculture
- Food Safety and Nutritional Security
- Application of Nanotrechnology in Sustainable Agriculture and Food Safety
- Modern Fisheries, Aquaculture and Seed Production

Key Research Areas

- Research and development in the areas of food science and technology. Research focus of CSIR-CFTRI has broadly been into the following areas: Engineering Sciences, Technology Development, Translational Research, Food Protection and Safety. Translational research leading to the development of novel vaccines, diagnostics and improved therapeutic molecules for farm animals, technologies which are globally competitive and technologies are eco-friendly and economically viable. It has a comprehensive mandate of research, training and extension in different aspects of freshwater aquaculture, crop health status determination, crop phenotyping, detection of weeds , micro-orgasnisms and pest management, non-destructive soil sensing, yield estimation and prediction, fruit quality determination, and in sensor networks

Specific Challenges

- Lack of scalable funding models.
- Lack of understanding with respect to evolving threats and challenges
- Lack of computational softwares, applications and codes

Key Recommendations including Short Term/ Long Term Goals

- *Infrastructure:* - Need to explore collaboration opportunities in the sector of primary processing of agricultural products with support of international panelist and institutes.
- *Skills Development:* Special courses and skill upgradation for data science, ML, and AI as these areas are currently attracting great attention. Computer centers to be manned by PhD background personal who could assist researchers with their algorithms or codes
- *Programs and Missions:* - Screening of existing national programmes, policies and strategies for options with potential contribution to CSA (Climate-smart agriculture) objectives *General:* Need to promote funding to researchers with collaborative effort by State and Central Government and industrialists. Assessment and mapping of CSA-SDG interlinkages,

Potential Collaborations

- Precision Agriculture to increase per acreage production
- Reduce potential environmental risks
- GPS soil sampling
- Remote sensing technology
- Metabolism engineering is an area of collaboration
- Affordable technology
- Investigate use of various plant based anti-microbial into packaging materials
- Area of Diagnostics, Packaging and Encapsulation

Vertical 17: Social Sciences

Vertical Summary

4 Horizontals | 16 Sessions | 40 Hours of Deliberation | 51 International Panellists | 20 National Panellists

Horizontals

- Socio-Economic aspect of Development
- Societal aspect of Technology Development with cause
- Community-centric developmental approaches and their impact
- Community health & Preventive care

Key Research Areas

- Pension Fund Regulatory and Development Authority (PFRDA), Ayushman Bharat Yojana
- Healthcare sector focused on building evidence around allopathy and other Indian systems of healthcare for its greater acceptance.
- Digital Learning Technologies and Content Designing for online Education
- Refurbishing Rural Planning-Techniques, facilities, and processes
- Urban planning with a focus on socially deprived groups
- Digital & Print Media, and Content Creation in Media 2.0
- Assistive Technology, Disability and Ageing
- Technology to address Sustainable Development Goals (SDGs)

Specific Challenges

- Tie up with leading industrialist and set up some sort of apprenticeships- opportunity should be provided by schools
- Digital divide and accessibility (crisis to opportunity). Need for education + IT industry partnership and creative use of existing resources
- Private sector should channelize funds into an integrated rural development program
- Lack of community participation, awareness – lack of education/information, access to healthcare, affordability and accountability – social.

Key Recommendations including Short Term/ Long Term Goals

- An integrated 5-years community development course should be planned consisting of values, respect for human life, gender etc.
- Academic courses should be classified/grouped based on skills/employability. Flexibility/longer period should be provided to students to discontinue a course – work – and then again continue a course. This will encourage upskilling in students.
- Policy to ensure that engineering students go out and work in communities or identify engineering problems and there should be credits for this.
- India needs an apex center for Assistive Technology (AT) and AT should be part of Ayushman Bharat, Make in India and Skill India programs.

Vertical 18: Management

Vertical Summary

6 Horizontals | 6 Sessions | 11 Hours of Deliberation | 26 International Panellists | 25 National Panellists

Horizontals

- Fostering academic collaborations
- Mechanisms to increase R&D outputs from Indian institutions
- Business Innovation
- Entrepreneurship for growth
- Management of New-Age (Knowledge) Organizations
- Making India Center of Practice-Oriented Management Knowledge

Key Research Areas

- Fostering Academic Collaborations
- Mechanisms to increase R&D outputs from Indian institutions
- Business innovation
- Entrepreneurship for growth
- Management of New-Age (Knowledge) Organizations
- Making India Center of Practice-Oriented Management Knowledge

Specific Challenges

- Lack of incentive programs by the government.
- Fast changing and rigorous adoption of technologies at the organizations like digitisation, automation and artificial intelligence.
- Lack of focus policy maker's focus on local or state level.
- Low visibility of Indian institutes on international platforms.
- Inability of Indian system to retain talent.
- Lack of interdisciplinary researches.
- Micromanagement approach by organisations for managing talents limiting innovation.
- Hierarchical structure and resilience to criticism at the top level.

Mission Mode Projects

- If the objectives of Vaibhav 2020 are to come to fruition and the broad goals of the National Education Policy (NEP) are to be achieved, a key pillar and platform for them would be what we broadly call: GENESIS. This stands for and represents a unique Global Education Network for Entrepreneurship, Science, Innovation and Scholarship. This network of (Indian and Global) educators could teach in, and provide academic advice to, Institutions of Higher Learning (IHL) in India and South Asia. The goal would be to develop "faculty exchanges" anchored at leading institutions for Management (an IIM or ISB), STEMM (IITs, IIITs, AIIMS) and Law. Financial support from Centre or Corporates or Foundations for activities at these exchanges would be needed with appropriate acknowledgement for help from industry leaders (e.g., faculty can be "Tata Fellows" or "Birla Fellows"). We also need support from the corporate community and foundations of both Indian family-business owned and the multinational corporations that are operating in India. In this context, India could learn from the policies implemented by Singapore to channel private funds to institutes of higher learning and research initiatives. For faculty exchange programmes, the Terms of Engagement can be flexible and multi-faceted: from 2 to 6 week modular courses (Summer, Winter) to Semester Long Engagements (Sabbaticals), Year Long Engagements (Retired Faculty), Financial Considerations (Travel, living + % of typical executive teaching rates [which may vary by discipline]), development and management PhD and Doctoral (Practice) Programmes. In fact, India can well be the Sabbatical Academic Capital of the world.

Key Recommendations including Short Term/ Long Term Goals

- At the government level, a database of technologies/IPs/Patents being invented may be maintained that can be referred to be corporate members to scope for inventions. Some R&D institutions may be given the responsibility to maintain such databases.
- Given the importance of leadership in R&D institutions, all appointments and promotions in R&D institutions must be based on objective criterion and must be held in a fair and transparent manner.
- Incentives for R&D professionals
- Identification of nodal agencies