Detailed Project Report for Establishing a Technology Innovation Hub (TIH) in the Technology Vertical

Bio Cyber Physical Systems (Bio-CPS)

Submitted to

NM-ICPS, DST

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Vice Chancellor
Birla Institute of Technology & Science, Pilani

CERTIFICATE

Name of the TIH: BITS BioCyTiH Foundation **Technology Vertical: Bio-CPS**

1. This is to certify that the Detailed Project Report (DPR) on the Technology Vertical Bio-CPS is prepared and submitted to Mission Office, NM-ICPS, DST is as part of implementation of Technology Innovation Hub (TIH) at BITS Pilani, Vidyavihar, Pilani Jhunjhunu, Rajasthan 333 031under National Mission on Interdisciplinary Cyber-Physical System (NM-ICPS).
2. This is to certify that this DPR has been checked for plagiarism and the contents are original and not copied/taken from any one or from any other sources. If some content was taken from certain sources, it is duly acknowledged and referenced accordingly.
3. The DPR will be implemented as per the Terms, Reference and Clauses stated in Tripartite Agreement signed on 13 day of April 2021 between Mission Office, DST, BITS Pilani and BITS BioCYTiH Foundation.

Date:17.08.2022
Place: Goa

(Prof Sunil Bhand)
Project Director(s)

(Dr. Satya Dash)
CEO

Endorsement from the Head of the Institution

1. Certified that the Institute welcomes participation of Prof Sunil Bhand, Prof Samit Chattopadhyay and Prof Syamantak Majumder as the Project Director(s) for the Technology Innovation Hub (TIH) and that in the unforeseen event of discontinuance by the Project Director, the Vice Chancellor, BITS Pilani will identify and place a suitable faculty as Project Director for fruitful completion of the TIH activities.
2. Certified that the Host Institute shall provide basic facilities, faculty support and such other administrative facilities as per Terms and Conditions of the award of TIH, will be extended to TIH.
3. As per Tri-partite Agreement, the Host Institute (HI) shall play its role and fulfill its responsibilities for the success of TIH.

Date: 17.08.2022
Place: Pilani (RJ)

(Prof Souvik Bhattacharyya)
Vice Chancellor
BITS Pilani

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Glossary

AADL	Analysis and Definition Language
ABB	ASEA Brown Boveri
ABLE	Association of Biotechnology Led Enterprises
AFM	Atomic force microscopy
AI	Artificial Intelligence
AICTE	All India Council for Technical Education
AIDS	Acquired Immunodeficiency Syndrome
AIIMS	All India Institute of Medical Sciences
AoA	Articles of Association
AR	Augmented Reality
BARC	Bhabha Atomic Research Centre
BioNEST	Bioincubators Nurturing Entrepreneurship for Scaling Technologies
BIRAC	Biotechnology Industry Research Assistance Council
BITS	Birla Institute of Technology and Science
BITSAA	BITS Pilani Alumni Association
BPCL	Bharat Petroleum Corporation Limited
BRBC	BIRAC Regional Bio-Innovation Centre
BREC	BIRAC Regional Entrepreneurship Centre
BRIC	BIRAC Regional Innovation Centre
BRICS	Brazil, Russia, India, China and South Africa
BRTC-E & NE	BIRAC Regional Techno-Entrepreneurship Centre East and North East Region
CAGR	Compounded Annual Growth Rate
CALTECH	California Institute of Technology
CAPEX	Capital expenditure
CDAC	Centre for Development of Advanced Computing
CDS	Content Delivery Systems
CEERI	Central Electronics Engineering Research Institute
CEO	Chief Executive Officer
cfDNA	Circulating free DNA
CIIE	Centre for Innovation Incubation & Entrepreneurship
CKD	Chronic Kidney Disease
CORE	Centre of Research Excellence
CPS	Cyber Physical Systems
CPS- DIAL	CPS – Dedicated Innovation Accelerator
CPS - EIR	CPS – Entrepreneur in Residence
CPS- GCC	CPS – Grand Challenge and Competition
CPS- PRAYAS	CPS-Promotion and Acceleration of Young and Aspiring technology entrepreneurs
CPS - SSS	CPS – Seed Support System

CPS- DIAL	CPS-Dedicated Innovation Accelerator
CPS-EIR	CPS-Entrepreneur in Residence
CPS-GCC	CPS- Grand Challenges and Competitions
CPS-PRAYAS	CPS-Promotion and Acceleration of Young and Aspiring technology entrepreneurs
CPS-SSS	CPS-Seed Support System
CPS-TBI	CPS- Technology Business Incubator
CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats
CSIR	Council of Scientific and Industrial Research
CSIR-IICB	CSIR Indian Institute of Chemical Biology
CSIR-IICT	CSIR Indian Institute of Chemical Technology
CSIR-NCL	CSIR National Chemical Laboratory
DAAD	Deutscher Akademischer Austauschdienst
DALY	Disability-Adjusted Life Year
DBT	Department of Biotechnology
DST	Department of Science & Technology
EAT	Earnings After Tax
EBIT	Earnings before Interest and Taxes
EBITDA	Earnings before Interest, Taxes, Depreciation and Amortization
EBT	Earnings Before Tax
ECE	Electronics and Communication Engineering
EEE	Electrical and Electronics Engineering
EEG	Electroencephalography
EiR	Entrepreneur in Residence
EIS	Electrochemical impedance spectroscopy
ESRD	End-stage renal disease
FIST	Fund for Improvement of S&T Infrastructure in Higher Educational Institutions
FSSAI	Food Safety and Standards Authority of India
FTIR	Fourier Transform Infrared Spectroscopy
FTPs	Fast Track Projects
GAIL	Gas Authority of India Limited
GaN	Gallium Nitride
GBD	Global Burden of Disease Study
GDP	Gross Domestic Product
GERD	Gross expenditure on Research and Development
HEV	Hepatitis E Virus
HGB	Hub Governing Body
HIPC	Hub's Intellectual Property Committee
HP	Hewlett-Packard
HRD	Human resource development
I&E	income and expenditure

IBAB	Institute of Bioinformatics and Applied Biotechnology
IBM	International Business Machines
ICAR	Indian Council of Agricultural Research
ICMR	Indian Council of Medical Research
ICT	Information and Communications Technology
IDF	International Diabetes Federation
IISc	Indian Institute of Science
IIT	Indian Institute of Technology
IITMIC	IITM Incubation Cell
IITMRP	Indian Institute of Technology Madras Research Park
IoT	Internet of Things
IP	Intellectual Property
IPD	In-patient department
IPR	Intellectual Property Rights
IT	Information Technology
JD	Job Description
KPI	Key Performance Indicator
M.Sc.	Master of Science
MTech	Master of Technology
MAR	Matrix Attachment Region
MBA	Master of Business Administration
MBBS	Bachelor of Medicine and Bachelor of Surgery
MD	Doctor of Medicine
MEMS	Microelectromechanical Systems
MEMS	Miniaturized Mechanical and Electromechanical Elements
MGB	Mission Governing Body
MHRD	Ministry of Human Resource Development
MIS	Management Information System
MIT	Massachusetts Institute of Technology
ML	Machine Learning
MNRE	Ministry of New and Renewable Energy
MoA	Memorandum of Association
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
MoU	Memorandum of Understanding
MVP	Minimum Viable Product
NAAC	National Assessment and Accreditation Council
NASA	National Aeronautics and Space Administration
NCCS	National Centre for Cell Science
NCD	Noncommunicable disease
NCR	National Capital Region
NDHA	National Digital Health Authority

NDHM	National Digital Health Mission
NEIST	North East Institute of Science and Technology
NEP	National Education Policy
NGS	Next Generation Sequencing
NHP	National Health Policy
NHS	National Health Services
NIH	National Institutes of Health
NIPER	National Institute of Pharmaceutical Education and Research
NIRF	National Institutional Ranking Framework
NIV	National Institute of Virology
NLEM	National List of Essential Medicines
NM-ICPS	National Mission on Interdisciplinary Cyber Physical Systems
NPCDCS	National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular disease and Stroke
NRF	National Research Foundation
NSCLC	Non-small Cell Lung Cancer
NSF	National Science Foundation
NSS	National Sample Survey
NSTEDB	National Science & Technology Entrepreneurship Development Board
NVC	New Venture Creation
NY	New York
ONGC	Oil and Natural Gas Corporation Limited
OPD	Out-patient department
OPEX	Operating expenses
OPPI	Organisation of Pharmaceutical Producers of India
P&L	Profit and Loss
PACE	Promoting Academic Research Conversion to Enterprise
PARC	Palo Alto Research Center
PFMS	Public Fund Management System
PG	Postgraduate
PHC	Primary Healthcare
PhD	Doctor of Philosophy
PI	Principal Investigator
PIEDS	Pilani Innovation and Entrepreneurship Development Society
PRECISE	Penn Research in Embedded Computing and Integrated Systems Engineering
QS	Quacquarelli Symonds
R&D	Research and Development
RBD	Receptor Binding Domain
RBM	Receptor Binding Motif
RFID	Radio Frequency Identification

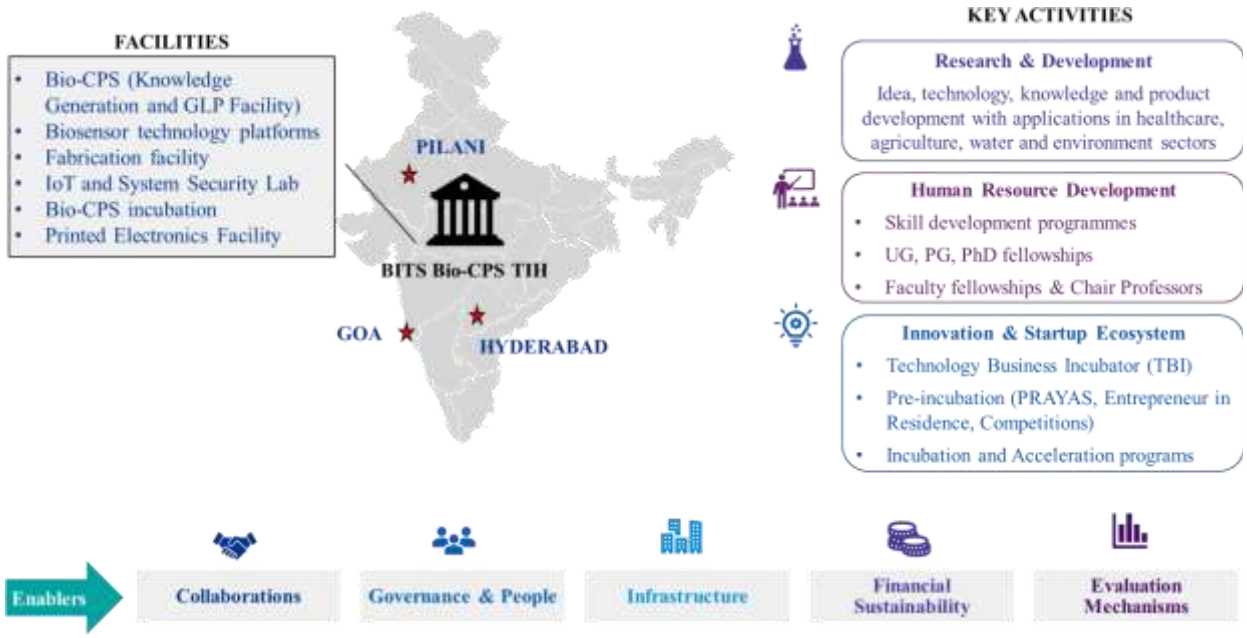
RNA	Ribonucleic Acid
RRSFP	Research Resources, Service Facilities and Platforms
RRT	Renal Replacement Therapy
RTBI	Rural Technology and Business Incubator
S&T	Science and Technology
SAC	Scientific Advisory Committee
SAH	Sector Application Hub
SBIRI	Small Business Innovation Research Initiative
SCI	Science Citation Index
SDG	Sustainable Development Goal
SDGs	Sustainable Development Goals
SEED	Sustainable Entrepreneurship and Enterprise Development
SEM	Scanning Electron Microscope
SFT	Square Feet
SGRI	Saint Gobain Research India
SiC	Silicon Carbide
SINTEF	Stiftelsen for industriell og teknisk forskning
SMAR1	Scaffold Matrix Attachment Region-Binding Protein 1
SME	Small and Medium sized Enterprise
SoP	Standard Operating Procedure
SPICe	Submission of application - integrated eForms
SPOC	Single Point of Contact
SSVEP	Steady State Visual Evoked Potential
STEM	Science, Technology, Engineering and Mathematics
SWAYAM	Study Webs of Active-Learning for Young Aspiring Minds
TBI	Technology Business Incubator
TCS	Tata Consultancy Service
TEM	Transmission Electron Microscopy
TIH	Technology Innovation Hub
TRL	Technology Readiness Level
TWAS	The World Academy of Sciences
UCL	University College London
UDSC	University of Delhi South Campus
UG	Undergraduate
UK	United Kingdom
UML	Unified Modeling Language
UNMC	University of Nebraska Medical Center
UNME	University of Nebraska Medical Center
US	United States
USD	United States Dollar
V2X	Vehicle-to-Everything

VLSI	Very-large-scale integration
VR	Virtual Reality
WHO	World Health Organization
WILP	Work Integrated Learning Programme
XPS	X-ray photoelectron spectroscopy
XRD	X-ray powder diffraction

Executive Summary

Realizing the importance of cyber physical systems (CPS) in the modern world, the Department of Science & Technology, Government of India, instituted the National Mission for Interdisciplinary Cyber Physical Systems (NM-ICPS) to identify the technology needs of Ministries/ Departments, develop solutions and provide technical support in CPS implementation. The implementation of this mission will be done through 25 hubs, out of which 18 will be Technology Innovation Hubs (TIH) and the rest will be Sector Application Hubs (SAH). BITS Pilani has been selected to establish a Technology Innovation Hub in the field of Bio Cyber Physical Systems.

Figure 1: BITS Bio-CPS TIH



The TIH will focus on three main activities:

- **Research and development:** Idea, technology, knowledge and product development in Bio-CPS will be undertaken by the Bio-CPS TIH. It will also focus on developing prototypes and commercializing technologies in the areas of healthcare, agriculture, water and environment, thereby contributing to various sustainable development goals, national policies/ programmes and other development objectives. The Hub will contribute towards policy and standards development in the area of Bio-CPS. The Hub will also offer data as a service by creating data banks across strategic areas of focus.
- **Human resource development:** The Hub will conduct skill development programmes for various target segments such as industry professionals, students, faculty, etc. Fellowship programmes (UG/ PG/ PhD) in Bio-CPS will be offered and supported by the TIH. Faculty fellowships and Chair Professorships shall also be offered by the TIH.

- **Innovation and Entrepreneurship:** A Technology Business Incubator (TBI) shall be set up which will run various programs to nurture innovation across pre-incubation, incubation and post incubation stages, thereby leading to creation of new start-ups, employment and better economic growth.

The TIH shall work towards addressing the following grand problems:

Table 1: Grand problems addressed by the TIH

Sectoral Problems	
Healthcare	• Innovative research through discovery/evaluation of biomarkers for the named diseases; providing the basis for affordable IoT enabled devices. • Novel Diagnostics of diseases such as cancer, cardiovascular disease, malaria, chronic kidney diseases and diabetes • Develop affordable, miniaturized POC and high-throughput devices for detection, diagnosis and therapy for real-time monitoring of patient health • Platform for detection of COVID-19 or similar pandemics in the future • Diagnostics and monitoring of mental health disorders using smart devices and neuroimaging techniques • Aiding the differently abled through development of assistive technology
Agriculture	• Improve food and milk quality using smart Biosensor sensing platforms • Detection of fertilizers using sensors, resulting in reduced losses and enhanced income for farmers
Water and Environment	• Improving water quality and monitoring through development of biosensors for, bacterial pathogens, antibiotics & pesticide residues meeting appropriate regulatory standards
R&D Problems	
• The TIH will perform interdisciplinary research in Bio-CPS bringing together experts across the fields of biology, electronics, computer science and associated disciplines to solve challenging problems. • Current university research in CPS is restricted to theoretical or laboratory scale. The TIH will provide experimental validation of these ideas or technologies at large scale • There is a dire need to perform translational research in CPS. The TIH shall enable this by translating academic R&D into technologies for the industries such as healthtech, pharmaceuticals, medical devices, wearables, diagnostics, clean water, food processing, etc.	
HRD and Skill Development	
• There is a dearth of talent with interdisciplinary knowledge and skills in the upcoming area of Bio-CPS. The TIH will create this future talent pipeline in the area of Bio-CPS through	

fellowships and skill training in the areas of healthcare technology, next generation sequencing, proteomics, metabolomics, MEMS, biosensors, Bio-CPS entrepreneurship, etc.
Startup/ Innovation Ecosystem
• Startups play a huge role in economic development and job creation. The TIH will nurture startups in the area of Bio-CPS such as healthcare, agri-electronics, cognitive science, envirotech, IoT platforms, telemedicine, farm to fork, etc. through investing and handholding support

Keeping in view the above grand problems, the TIH shall focus on the following objectives:

- Develop mature technologies and products in the Bio-CPS arena and propel them towards commercialization.
- Create infrastructure facilities to undertake innovation and translational activities in the area of Bio-CPS through device lab, flexible electronics lab., IoT lab, data security lab, bio-sensor lab, incubator etc.
- Identification & validation of novel biomolecules through Omics based approach - DNA, RNA, protein, metabolites, etc. and their association with human diseases. including cancer and other infectious diseases
- Develop devices/systems (FET, nanowire, microfluidics, etc.), diagnostic tools for monitoring human health, food safety and quality, food supply chain and water quality monitoring
- Integrate wireless communication [RFIDs & WSN] for real time monitoring and decision support systems through mobile devices including drones.
- Develop data driven mitigation strategies through sensor based IoT & AI systems
- Create an understanding of the diseases of national importance including COVID-19
- Develop affordable devices for detection, diagnosis and therapy
- Undertake development of new drone based agri -technologies for pest detection, control and minimizaiton of food losses
- Establish incubator in the Bio-CPS space and train human resources for entrepreneurship, nurture research start-ups
- Offer fellowship, training and certification programs in Bio-CPS domain
- Create future talent pipeline through upskilling and reskilling in the area of Bio-CPS
- Create a financially sustainable hub

The TIH will deliver the following through its activities:

Table 2: TIH Deliverables

Area	Deliverable
Healthcare	• Novel biomolecules through Omics based approach | DNA, RNA, protein, metabolites, etc. | aptamers, antibodies, sequences • Deliver technologies / diagnostic systems/devices based on the identified novel biomolecules/sequences • Develop IoT based system for community health monitoring using antibiotic susceptibility test platform

Area	Deliverable
	• Develop a COVID-19 diagnostic platform and identification of anti-COVID peptide and small molecule drugs • Develop IoT enabled plug-and-play smart devices focusing on better accuracy, cost-effectiveness, rapid detection, data analysis/transfer and security harnessing the core-competencies of Microfluidics, Nanoelectronics, Biology, IoT, and Security. These devices will include printed, wearable and implantable devices, point-of-care bio-diagnostic devices and environment monitoring devices • New editing technologies for diagnostics and Smart wearable sensors • New anti-cancer drug candidates for oral cancer.
Agriculture	• Demonstrate an IoT field sensor network for food supply chain monitoring for food toxin detection and reduce economic losses Detection of fertilizers using sensors, resulting in reduced losses and enhanced income for farmers Waste to wealth and increasing crop productivity with Bio-CPS component
Water and Environment	• Mapping of bio diversity such as coral reefs using under water network • Deliver an IoT based biosensor network for bacterial contamination and pesticide residue monitoring in drinking water • Rapid detection of antibiotic residues in water • Waste management with Bio-CPS component
Startup/ innovation ecosystem	• Set up an incubator in Bio-CPS and support start-ups in the domain; leverage on BITS Pilani's start-up eco-system along with network of corporate and academia collaborators. Create platforms for interaction between startups and industry for boosting collaboration and technology transfer of the innovative devices, tools and Systems.
HRD and Skill development	• Train at least 200 researchers /Scientists /Post Docs/Students in the area of Bio- CPS • Offer skilling and upskilling courses for professionals, job seekers and academia in Bio-CPS, its application and entrepreneurship • Increase awareness of issues related to Bio-CPS in the society.

The TIH will target the following outcomes by the end of Year 5:

Table 3: TIH Targets

Particulars	Target defined in ToR	Total estimated achievement	YoY estimated achievement				
			Y1	Y2	Y3	Y4	Y5
Technology Development							
No. of Technologies	23	23	-	2	5	7	9
Technology products	18	18	-	3	4	5	6
Publications, IPR and other Intellectual activities	54	60	-	8	10	18	24
CPS Research base	75	80	-	12	18	25	25
Entrepreneurship Development							
CPS-Technology Business Incubator	1	1	-	1	-	-	-
CPS-Start-ups & Spin-off companies	38	42	-	5	10	12	15
CPS-GCC - Grand Challenges and Competitions	1	1	-	-	-	1	-
CPS-Promotion and Acceleration of Young and Aspiring technology entrepreneurs (CPS-PRAYAS)	1	1	-	-	1	-	-
CPS-Entrepreneur in Residence (CPS-EIR)	23	24	-	2	5	7	10
CPS-Dedicated Innovation Accelerator (CPS- DIAL)	1	1	-	-	1	-	-
CPS-Seed Support System (CPS- SSS)	1	1	-	1	-	-	-

Particulars	Target defined in ToR	Total estimated achievement	YoY estimated achievement				
			Y1	Y2	Y3	Y4	Y5
Job creation	9,375	9,500	-	750	2,000	3,000	3,750
Human Resource Development							
Graduate Fellowships	250	261	24	27	60	60	90
Postgraduate Fellowships	48	62	11	11	11	14	30
Doctoral Fellowships	24	25	25	25	25	25	25
Faculty Fellowships	4	6	-	1	2	2	1
Chair Professors	4	7	-	2	3	1	1
Skill Development	450	4,888	-	722	1,306	1,380	1,480
International Collaboration							
International collaboration	**1**	**2**	-	1	-	1	-

The TIH shall comprise of 20,000 sq. ft. spread across the three campuses of BITS in Pilani, Hyderabad and Goa, with options to scale up in the future. The innate strengths of BITS in terms of people, collaborations and knowledge ecosystem will be leveraged by the TIH to emerge as a thought leader in this space. More than 10 collaborations with industry/ startups/ MSMEs have already been initiated (Initial confirmation received). The Hub may also engage Spokes or collaborate with other domestic and overseas higher education institutes, R&D institutes or industries to achieve targets across the activities mentioned above.

The TIH will be governed by the Hub Governing Body who will be supported by various subcommittees across Finances, Academics and Research, Entrepreneurship and Infrastructure verticals. The Execution Team will be headed by a CEO and will be supported by project team for efficient operation of the hub. The TIH will be incorporated as a Section 8 company and a tripartite agreement shall be signed between the Mission, BITS and the Hub clearly stating the roles and responsibilities of each party. A systematic evaluation mechanism shall be put in place with multiple checks and balances to ensure that targets are met on time. The hub will take various

initiatives to establish itself as an apex centre for research, innovation and technology commercialization in the area of Bio-CPS in the country through a collaborative approach.

The Hub will receive a funding of INR 125 crores over five years from the Mission. A major part of this funding will be utilized for non-recurring expenses (~60%) in procuring and establishing R&D infrastructure. The other key area where the funding will be utilized is for the recurring expenses / opex (~40%) which includes technology development / research related expenses, training related expense and other overheads. The Hub will take up various revenue generating activities across the verticals of R&D, human resource development and entrepreneurship to ensure financial sustainability on the longer run and has charted out a plan. Additionally, the hub is eligible to receive gifts or donations by tapping into CSR funds, donor funding, etc. to scale up operations in the later years.

Table 4: Sources and Application of Funds

Budget Head	Budget in INR Crore					
	Y1	Y2	Y3	Y4	Y5	Total
Recurring Expenses	7.25	12.5	19.75	12.5	7.75	**59.75**
Non-Recurring Expenses		17.5	20.25	17.5	10.00	**65.25**
Total	**7.25**	**30.00**	**40.00**	**30.00**	**17.75**	**125.00**

1. Project Context

1.1. Cyber Physical Systems

Cyber-physical systems integrate sensing, computation, control and networking into physical objects and infrastructure, connecting them to the Internet and to each other[1]. Examples of cyber physical systems include autonomous vehicles, smart grids, medical monitoring, and industrial control systems. It is a highly interdisciplinary field presenting huge opportunities across robotics, artificial intelligence (AI), big data analysis, deep learning, Internet of Things (IoT), etc. Some of the applications of CPS include:

Table 5: CPS Applications

Domain	Applications
Smart living spaces	✓ Enable efficient energy consumption by users by monitoring humidity, temperature based on real time sensor data
Manufacturing & Logistics	✓ Inspection and Mitigation of hazards like radioactivity, pipe leaks ✓ Smart monitoring and tracking of shipments across the shop floor
Healthcare	✓ Remote monitoring of patients ✓ Find newer therapeutic molecules to cure diseases ✓ Newer solution to combat infectious diseases like Covid-19
Driverless Cars	✓ Routing directions to the car based on analyzing real time data ✓ Providing safety instructions to the car in case of emergencies
Agriculture	✓ Real time information on plant health, environmental conditions, soil quality ✓ Monitor crops to identify diseases to reduce yield destruction
Environment	✓ Monitoring environmental conditions and weather at remote locations through real-time aggregation and processing of data

India has recognized cyber physical systems as one of its priorities. Hon'ble Prime Minister had highlighted the importance of cyber physical systems during the 104th Indian National Science Congress. Vigyan 2030 also echoed the same and established the need to set up a National Mission to coordinate efforts in strengthening research and development (R&D) and imparting skills in CPS.

Though research in systems has been prevalent in the United States (US) and Europe for some years, the highly interdisciplinary area of CPS has seen its beginning only in the last few years. Some universities such as Massachusetts Institute of Technology (MIT) and Columbia University

1 National Science Foundation

have set up interdisciplinary research centers which will provide an impetus to CPS research. There are numerous conferences and events happening across the world on the same topic, indicating an increasing interest in the area. India, with its huge supply of talented scientists and engineers, is well positioned to contribute towards this emerging area.

1.2. National Mission on Interdisciplinary Cyber Physical Systems

The National Mission on Interdisciplinary Cyber Physical Systems (NM-ICPS) under the Department of Science & Technology (DST) was set up to identify the technology needs of Ministries/ Departments, develop solutions and provide technical support in CPS implementation. It will create an integrated and overarching national platform for cyber physical systems by bringing together stakeholders such as academia, industry, government ministries and international organizations by creating strong linkages between them. The implementation of the mission will be done through 25 hubs, out of which 18 will be Technology Innovation Hubs (TIH) and the rest will be Sector Application Hubs (SAH).

Technology Innovation Hubs under the NM-ICPS will be focused on 18 domain areas ranging from artificial intelligence and machine learning to autonomous navigation and cybersecurity. The TIHs will work on a hub and spoke model with connection to researchers, R&D Institutes and other centers of excellence. The Hub will be set up as a Section 8 company and managed by a Hub Governing Body consisting of members from the host institute, industry and the DST.

The activities of the TIH will be focused on four major streams:

a. **Technology development**: Meeting the specific requirements of the industry, government verticals based on expert research
b. **Human resource development & skill development:** Developing highly knowledgeable human resources with skills accustomed to the industry standards
c. **Innovation, entrepreneurship and start up ecosystem:** Nurturing the innovation and start up ecosystem in the area of CPS
d. **International collaborations:** Strengthening international collaborative research in CPS

The government would support the TIHs for the initial five years, subject to meeting the minimum targets achieved, post which they need to be self-sustainable.

NM-ICPCS had invited applications from top academic and R&D institutions to establish Technology Innovation Hubs (TIH).

1.3. Birla Institute of Technology and Science, Pilani

Birla Institute of Technology and Science, Pilani (BITS Pilani), established in 1964, is one of the top ranked private deemed-to-be universities in India offering science and technology programmes. BITS Pilani has three campuses in India (Pilani, Goa and Hyderabad) and one campus overseas (Dubai). BITS Pilani has been awarded an 'A' grade by National Assessment

and Accreditation Council (NAAC) and is ranked 15th in the National Institutional Ranking Framework (NIRF) 2020 University category. In QS Asia 2020, it is ranked at 175, the only private institute in the top 200 from India. In QS World Subject Rankings 2020, BITS Pilani is ranked at 351-400 in four subjects of engineering. BITS Pilani is ranked 9th in Nature Index India 2020 in the Physical Sciences category. The Ministry of Education has approved BITS Pilani to be an Institution of Eminence.

People: The current talent pool of research and innovation comprises 815 qualified faculty members in Life Science and Physical Sciences (Biological Sciences, Pharmacy, Chemistry, Physics, Mathematics) and Engineering (Chemical, Electrical, Electronics, Mechanical, Civil, and Computer Science), Humanities and Social Sciences and Management. The institute currently has 1280+ registered PhD Students and about 1600+ Masters Students with around 120 PhDs awarded per year which is growing at a healthy rate.

Research: BITS Pilani has transformed from a very eminent teaching-focused institute to a teaching and research-focused institute in a short span of time. Since 2009, through *strategic improvement exercises*, BITS Pilani has significantly bolstered its research and innovation capabilities through a strong focus on interdisciplinary research and industry income. The sponsored research grant has grown significantly at a compounded annual growth rate (CAGR) of 40% during 2015-20 to around INR 50 crores in 2019-20. The departments of biological sciences, chemistry, pharmacy, physics, mathematics, chemical engineering, mechanical engineering, electrical and electronics engineering, computer science, civil engineering across the three campuses have been recognized through Fund for Improvement of S&T Infrastructure in Higher Educational Institutions (FIST) funding support of DST. A total of INR 28 crores worth of major equipment has been sanctioned and procured since 2012 and put to effective usage by researchers, faculty, industries, academia and R&D organizations such as CSIR Labs. BITS Pilani's research output has always stood out in terms of both quantity and quality; with citations per paper at 10.7, Scopus h-index of 118 and Web of Science h-index of 101, BITS Pilani is competitive nationally. In the last 2 years, the growth in number of Scopus publications has been 44% reaching 1871 in 2019. The number of citations in Scopus witnessed a growth of 52% since 2017 reaching about 1,16,250 currently.

Collaborations: BITS Pilani has demonstrated good industry engagement for research. About 18% of the research grants has been received from industry during the last 5 years. Faculty through internal funding such as Additional Competitive Grant, CORE Centre of Research Excellence grant, Industry funded grants (Aditya Birla Group sponsored projects) have demonstrated their teamwork and peer recognition to collaborate within and outside world. Several international and national consortia projects and network projects have been successfully demonstrated such as Bill and Melinda Gates Foundation Grants, The World Bank funding (National Agricultural Innovation Project), Research Council Norway, Swedish Research Council, Royal Academy of Engineering, Medical Research Council UK, DAAD Germany, NIH USA, Centre for High technology BPCL, ONGC, GAIL field projects, multiple international bilateral projects, EU H2020, Quantum D wave

computing facility of NASA and the joint national collaborative funding with reputed institutes such as CALTECH, Karolinska Institute, University of Ghent, Cranfield University, Hiroshima University, University of Virginia, University of Lund, University of Leeds, Cardiff University and several top 100 world ranking universities and Industries and Industries such as TCS, ABB, IBM, FESTO (Germany), SINTEF (Norway), Aditya Birla Science and Technology Company, Grasim, Thermax, Accenture, HP, Unichem, Ranbaxy Ltd, Cipla Biotech. etc. A number of patents have been filed by faculty jointly with other academia or industry. BITS Pilani is also actively collaborating with several eminent academic institutions within India such as IIT Delhi, IISc Bangalore, IIT Kharagpur, IIT Bombay, IIT Madras, IIT Roorkee, IISER, medical institutes such as PGIMER Chandigarh, AIIMS N. Delhi & Jodhpur, SP Medical College, Bikaner alongside several government R&D laboratories of CSIR, DBT, DRDO, ICAR, MeitY, DAE, ISRO in externally funded projects.

Innovation ecosystem: The innovation ecosystem at BITS is supported through incubators funded by DST, TIDE as well as BIRAC BioNEST to support and mentor innovative startups both from within and outside of BITS. In 2018, BITS Pilani signed agreements with Rajasthan State Innovation Council to extend its research and innovation facilities for startups. 68 incubates have graduated from these TBIs and currently 43 more incubates are functioning there. BITS has been ranked 3rd in the country behind IIT Delhi and IIT Bombay in terms of number of Indian start-ups founded by graduates of an institute in the last 3 years as well as in the last 10 years. It is also ranked 3rd in India in number of Unicorns founded by the Alumni. *(Details of existing innovation ecosystem in BITS are given in Annexure 1)*

1.4. Technology Innovation Hub at BITS

BITS Pilani has been selected to establish a Technology Innovation Hub (TIH) in the field of Bio-Cyber Physical Systems (Bio-CPS) with applications across healthcare, agriculture and environment sectors. The TIH will also focus on creating a startup ecosystem and skill development in the area of Bio-CPS. The innate strengths of BITS in terms of people, collaborations and knowledge ecosystem will be leveraged by the TIH to emerge as a thought leader in this space. The TIH at BITS will receive a funding of INR 125 crores over five years, post which it has to be self-sustainable.

2. Problems to be Addressed by the TIH

Combining biological knowledge with the advances in computing and physical system provides a holistic approach to tackling multiple problems across various sectors. Automation, machine learning and advances in bio machine interfaces have begun to shape R&D in this area. Healthcare, agriculture, consumer products, environment, information and communication technologies (bio-computing) etc. are some of the areas in which Bio-CPS can make an impact.

The TIH at BITS will focus on the areas of health, agriculture, water and environment, in addition to contributing towards the R&D and innovation ecosystem of India and human resource development.

2.1. Research Ecosystem

In the past decade, the Gross expenditure on R&D (GERD) in India has almost tripled from INR 39,438 crores in 2007- 08 to INR 1,13,825 crores in 2017-18[2]. Also, around 0.7% of India's Gross Domestic Product (GDP) was spent on R&D in 2017-18, while among other developing BRICS countries, it was: Brazil 1.3%, Russian Federation 1.1%, China 2.1% and South Africa 0.8%. The GERD of India is majorly driven by five types of entities: Central Government, Private Sector Industry, State Sector, Public Sector Industry and Higher Education Sector.

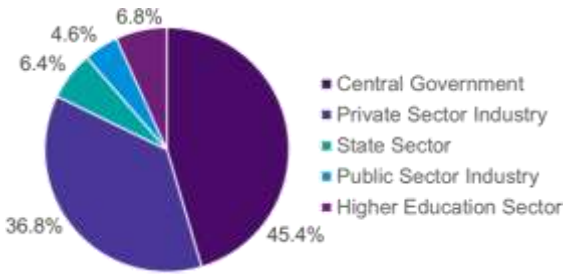


Figure 2: Sector-wise National R&D Expenditure

Source: Research & Development Statistics at a Glance, Department of Science & Technology, 2019-20

During 2018, as per the National Science Foundation (NSF), Scopus and Science Citation Index (SCI) database, India was ranked at 3rd, 5th and 9th in scientific publication output respectively.

Research in Higher Education Institutes in India

As per the NEP 2020, the higher education system of India is currently facing many issues and the principle problems include lesser emphasis on research at most colleges and universities, and inadequate funding for competitive peer-reviewed research across disciplines. In the year 2019, only 1,69,710 enrolled as PhD students which is less than 0.5% of the country's student enrollment.[3] Furthermore, only one Indian institute is in the top 500 research institutes globally basis analysis made by Scimago Institutions rankings.[4] With respect to quality of research, the H-Index of research publications produced by the USA is 2386 which is significantly higher than the H-Index of research publications produced by India which is 624. In addition to this, the number of publications produced by China and USA is 3.66 and 3.63 times higher than that of India.[5] Hence, the policy's vision includes formation of National Research Foundation (NRF) to actively lookout for research in universities and colleges and fund outstanding peer-reviewed research.

2 Research & Development Statistics at a Glance, Department of Science & Technology, 2019-20

3 AISHE report, 2018-19

4 Scimago Institute ranking

5 Scimago Country rankings

With the view to promote biotechnology and growth of life science in the university system of India and linking research to education by creating/ reengineering/ remodeling/ up-grading life science departments in central/state universities, various infrastructural facilities have been created by DBT in several universities/ institutions under Research Resources, Service Facilities and Platforms (RRSFP) programme.

Research in Cyber Physical Systems

Cyber Physical Systems has been identified as a focus area of research by many countries across the world, including India and the US. The number of patents published globally in CPS and related area almost doubled from close to 200 in 2015 to more than 350 in 2016. Corporates have been heavily investing in R&D in this area with Siemens (Germany) leading with 107 patents, followed by Rockwell (US) with 59 patents[6].

There are many independent research centres and reputed universities working towards this agenda. Some examples of global institutes undertaking research in CPS are:

- Center for Cyber Physical Systems and the Internet of Things, University of Southern California
- Link Lab, University of Virginia
- Penn Research in Embedded Computing and Integrated Systems Engineering (PRECISE)

Academic and R&D institutes in India have also started focusing in this emerging area of CPS. Indian Institute of Science (IISc) in India has set up a Centre focused on Cyber Physical System in 2011. Council of Scientific & Industrial Research's (CSIR) Central Electronics Engineering Research Institute (CEERI) has around 40 scientists in the department of Cyber Physical Systems with expertise in control systems, structural health monitoring, agri-electronics and water technologies. Many IITs and Central/ State Universities too are developing capabilities around CPS. However, all this research is happening in silos, and there is a dire need to adopt an interdisciplinary approach. Additionally, we have observed that current research undertaken in CPS is happening in theoretical or laboratory set-ups. Enabling pilot/ large scale test beds/ laboratories will be a value addition to CPS research in India.

Division of Interdisciplinary Sciences, IISc

The Division of Interdisciplinary Sciences at IISc consists of a wide range of Departments/ Centres which come together to perform interdisciplinary research. The Division has 43 faculty and scientific staff, 388 PhD or Integrated PhD students and 120 Master's students.

The core research areas of this Division include Bioengineering, Nanoscale Materials, Urban Infrastructure and Transportation, Nano Devices and Systems, Finance, Economics, Human Resource Management, Optimization, Marketing, Public Policy, Water, Energy, Internet of

6 NM-ICPS DPR

Things, Computer Systems, Distributed Sensing, Computational Science, Bioinformatics and Data Sciences.

The various departments under this division are:

- Centre for Biosystems Science and Engineering
- Centre for Society and Policy
- Center for infrastructure, Sustainable Transportation and Urban Planning
- Centre for Nano Science and Engineering
- Department of Computational and Data Sciences
- Department of Management Studies
- Interdisciplinary Centre for Energy Research
- Interdisciplinary Mathematical Sciences
- Interdisciplinary Centre for Water Research
- Robert Bosch Centre for Cyber Physical Systems
- Supercomputer Education and Research Centre

Source: IISc website, accessed September 2020, https://www.iisc.ac.in/academics/divisions/division-of-interdisciplinary-research/

Emerging Technologies as a National Priority

In order to improve research quality and standards, the Government of India is promoting investment in basic research by leveraging international Science and Technology (S&T) co-operation. The country has also planned co-investment of resources for collaborative initiatives with Canada, Australia, and Germany among others. However, the focus is less on the R&D required with regards to emerging technologies such as in the field of AI, ML, Robotics, Data Analytics, Simulation, Biological Cybernetics etc. Additionally, as more and more translational corporations are setting up their R&D centres in India, the Science and Technology sector has seen an uptrend in investment in recent years.

With the aim to develop India into a global innovation hub by 2020 and to provide an enabling environment that promotes research and development in India, the government is extensively promoting technology by taking various measures including policy support, infrastructure support and funding support for education and skilling, research parks and technology business incubators (TBIs). Furthermore, the government has also expressed its intentions of setting up a National AI portal and launching a national programme on AI in the interim budget 2019-20. The Ministry of Electronics & Information Technology has set up Centers of Excellence in Internet of Things and Virtual and Augmented Reality to promote innovation in these technologies. DST has initiated the Big Data Initiative to promote the technology and develop tools and technologies for applications in the government. Even state governments have shown interest in adoption of such emerging technologies. For example, the state government of Uttar Pradesh is trying out AI based anti-collision devices on state transport buses to reduce accidents[7]. The government of Maharashtra has

[7] *'AI-based tech upgrade in UP buses to curb accidents', Outlook, 20 August 2019, Accessed September 2020, https://www.outlookindia.com/newsscroll/aibased-tech-upgrade-in-up-buses-to-curb-accidents/1600214*

instituted the Maha Agri Tech project in which such emerging technologies are used to address various issues in agriculture[8]. Such initiatives showcase the government's focus and commitment towards adoption of emerging technologies across sectors.

Research in Bio and Related Sectors

The Biotechnology's industry in India is valued at USD51 billion for FY 2018 registering a growth of 14.68%[9] and the revenue from India's Biotech industry stood at USD 12 billion with workforce of around 1 million. In the accompanied figure, share by all the four segments of bio-economy has been illustrated. The Biopharma segment consists of medical devices (50%), vaccines (30%) and biologics/therapeutics (20%), The Bioagri is dominated by Bt cotton which generates 99% of the value while the rest is by pesticides and fertilizers. And, under the bio industrial segment, the contributions of enzymes and biofuels is estimated at 52 and 48% respectively.

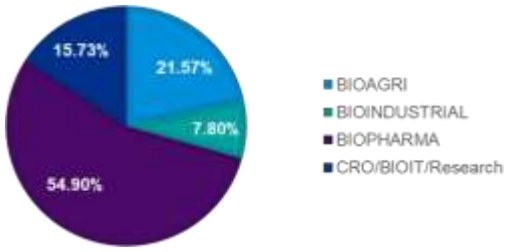


Figure 3 Biotech Industry Segments and their Share

Source: Indian Biotech Report 2019, BIRAC

Currently, Indian biotech industry is the third largest in Asia-Pacific region, holding around 3% of the global market share. With the aim of achieving $100 billion Bioeconomy by 2025, the Department of Biotechnology (DBT) along with Biotechnology Industry Research Assistance Council (BIRAC), a public sector undertaking established by DBT to empower and augment the Biotech enterprise, is playing a pivotal role in the execution and delivery of the flagship programs such as 'Startup India' and 'Make-in-India.' Additionally, BIRAC has initiated several schemes such as to facilitate production of novel, high quality affordable products through cutting edge technologies and bridge the existing industry-academia innovation research gaps. BIRAC has also established partnerships with numerous national and global partners to collaborate. Moreover, the focus can be noticed by the expenditure on R&D by Department of Biotechnology, which has increased from merely INR 41 crore in the year 1991 to INR 1772 crore in the year 2018[10].

[8] *'Satellite imagery, artificial intelligence to improve farm yields in Maharashtra', 7 October 2019, Accessed September 2020, https://indianexpress.com/article/india/satellite-imagery-artificial-intelligence-to-improve-farm-yields-in-maharashtra-6056933/*

9 India Bioeconomy Report 2019, BIRAC

10 Research and Development Statistics, 2019-20, Department of Science & Technology

Figure 4: Broad areas of research, with special focus on applications of emerging technologies

- **Big data and network analysis**
- **Bioimage analysis**
- **Genomics and epigenetics**
- **Machine learning and AI**
- **Metagenomics**
- **Molecular biology**
- **Quantitative population genetics**
- **Structural biology**
- **Systems biology**
- **Implanted sensor based drug delivery**
- **3D printing (organs and prosthetics)**
- **Nano robots**

There are many institutes which have a separate interdisciplinary center that promotes the intersection of biology, computer science and various other disciplines. Few examples of such centers are provided below:

Stanford Bio-X

Stanford Bio-X is an interdisciplinary research center where fields of engineering, computer science, physics, chemistry is intersected with biology and medicine. The center promotes research by offering financial resources such as seed grants, graduate fellowship and venture funds and other facilities. It also promotes entrepreneurial activities by acting as an incubator.

The seed grants provided in research are an average of $200,000 for a period of two years.

The emerging fields of focus at the center include:

- Computational biology
- Neurobiology
- Statistics
- Genomics
- Bioinformatics

So far, the center has hosted 500 interdisciplinary teams from 7 schools at Stanford with more than 60 departments. The team has also generated over 30 patent filings and have launched projects that have turned into federally funded labs.

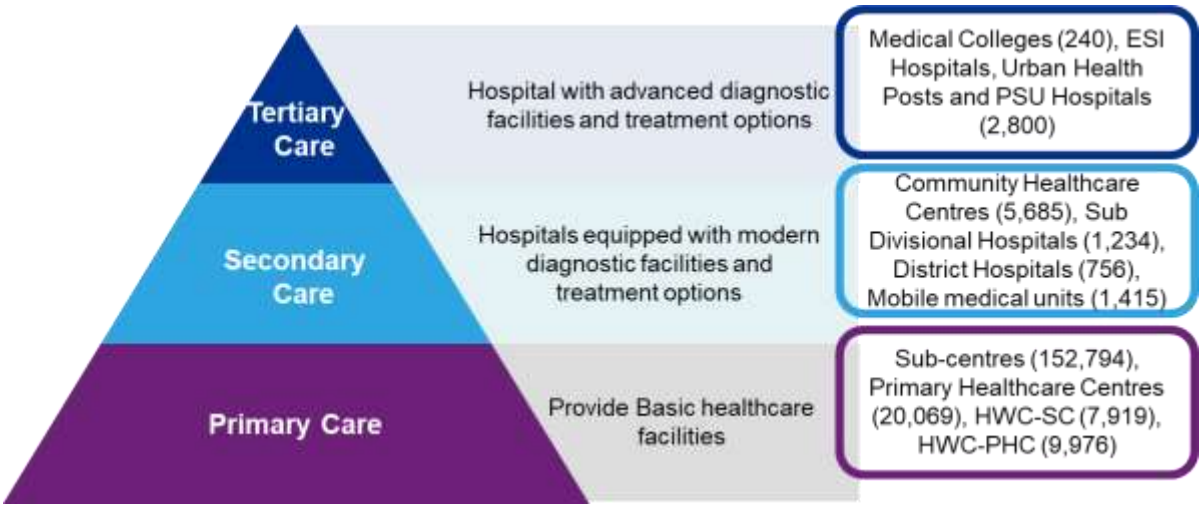
Source: Stanford Bio-X website, accessed September 2020, https://biox.stanford.edu/

2.2. Sectoral Problems

a. Health

As per the Global Burden of Disease Study (GBD), India is at 154th position among 195 countries on the healthcare index, which is below other developing countries such as Bhutan, Nepal, Sri Lanka and Bangladesh. Thus, it is critical to do more research on diseases that are real burden to the large population. Healthcare delivery in India is classified under three categories[11] as shown below:

Figure 5: Healthcare Delivery in India



With the current population of ~135 crore, the public health infrastructure in the country faces formidable challenges including deficient infrastructure, deficient manpower and high out of pocket expenditure.

Some of the issues/areas relating to healthcare sector have been discussed below where the proposed TIH aims to fill the gap:

i. Access to healthcare

The discrepancy in healthcare facilities in rural and urban areas is not unknown in India. Equitable access to healthcare may be defined where equal healthcare facilities, irrespective of social, economic and geographic background, are received by people. However, serving a country having more than 1.3 billion population, India's healthcare system is a far cry from such an egalitarian access. In the KPMG report "Healthcare in India: current state and key imperatives," it has been observed that about 60% of hospitals, 80% of doctors and 75% of dispensaries are present in urban areas whereas 72% of India's population lives in rural areas. Moreover, a report by Organisation of Pharmaceutical Producers of India (OPPI) published in 2016 reveals that only 37% of people

11 Rural Health Statistics 2018-19, Ministry of Health and Family Welfare

living in rural spaces can access in-patient department (IPD) facilities at a distance of 5 km radius, whereas 68% people are forced to go for out-patient department (OPD), leading to an increasing 'out-of-pocket' expenditure in healthcare for rural communities. Since timely access to healthcare is critical, the emergence of technology which enables real-time monitoring of patients with different diseases is the need of the hour.

ii. Disease burden

As per the report of Indian Council of Medical Research (ICMR), India: Health of the Nation's States (2017), it has been found that non-communicable diseases burden increased from 30 per cent in 1990 to 55 per cent in 2016, measured using disability-adjusted life years (DALYs), while the disease burden due to communicable, maternal, neonatal, and nutritional diseases decreased from 61 per cent to 33 per cent between 1990 and 2016[12]. With respect to communicable diseases, maternal, neonatal and nutritional diseases, the maximum number of deaths (15.5 million) has been caused by diarrhoea, low respiratory and other infections. This is followed by HIV/AIDS and tuberculosis (5.4 million). In addition, NCDs have occurred as the leading cause of death in India accounting for 61% of total deaths and has been recognized as one among the top 10 global health threats of 2019. With the above in view and in response to the "WHO Global Action Plan for the Prevention and Control of NCDs 2013-2020", India has implemented the National Action Plan, aiming to reduce the tally of global premature deaths from NCDs by 25% by 2025. Additionally, the Government of India has introduced "National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular disease and Stroke" (NPCDCS) with the motive to enhance knowledge and increase awareness on risk factors, to set up infrastructure (like cardiac care units and NCD clinics) and to conduct opportunistic screening at primary health care levels. Since the availability of frontline workers is critical for periodic screening of diabetes, hypertension and common cancers (breast, cervical, oral cancers), the system can be augmented through radical technologies and innovations. The TIH will focus on developing new diagnostic approaches to detect/ treat the following diseases:

A. Cancer

In 2018, India had around 2.2 million people living with cancer and it is estimated that there will be over 17 lakh new cases of cancer with over 8 lakh deaths.[13] Furthermore, one woman dies of cervical cancer every 8 minutes in India. This type of cancer accounts for 12% of cancer cases in India and 22.86% of the cases for women alone. It can be easily prevented by taking required vaccine measures and conducting regular cancer screening tests. Length of survival with cancer highly depends on the stage in which the disease is detected and treated. Moreover, early diagnosis of the disease can help prevent suffering and additional financial burdens. However, in India, almost 75-80% of the patients have stage 3-4 disease of cancer at the time of diagnosis. [14] Most of

12 https://www.nhp.gov.in/healthlyliving/ncd2019

13 Cancer India website

14 Cancer research in India: Challenges and opportunities, Indian journal of Medical research, October 2018

the developing countries will have to provide for diagnostic services to detect cancer at an early stage so that the treatment can be planned accordingly. TIH can contribute towards developing low cost high quality diagnostic services for this purpose.

B. Cardiovascular Disease

Cardiovascular diseases (CVDs), commonly referred to as heart disease or stroke, is one of the leading causes of mortality in India. One of the studies estimates that 25% of the NCD deaths in India are now because of CVDs with ischemic heart disease and stroke responsible for >80% of this burden[15]. Two major factors which can help reduce the number of deaths due to CVD are medications and diagnostic tests. To improve healthcare delivery, India published National List of Essential Medicines (NLEM) in 1996. The list includes drugs that satisfy the health care needs of the population and are always intended to be available at an affordable price. Looking at the CVD scenario and demand for stents, India, in 2016, added stents to its NLEM to make it available at a price the individual and community can afford. On the diagnosis front, India published a draft for National List of Essential Diagnostics (NLED) which includes laboratory and non-laboratory diagnostics. Given the growing burden of CVDs in India, NLED lists down CVD-related diagnostics on the draft as well as highlights additional diagnostic tests that should be considered in the diagnosis and management of CVDs.[16]Thus, TIH would be equipped to explore the newer diagnostic mechanisms using the CPS technology.

C. Malaria

Due to diversity in geo-ecology and ethnicity, along with the wide dispersal of nine anopheline vectors transmitting three Plasmodial species namely *P. falciparum, P. vivax, and P. malariae*, the epidemiology of malaria is complex in India. The World Malaria Report 2019 shows that 85% of worldwide malaria deaths in 2018 were concentrated in 20 countries- 19 African Regions and India[17]. As ending malaria remains one of the top priorities in India, the country has introduced its first national Framework for Malaria Elimination (2016-30) to reduce the burden from malaria cases. In addition, the Government of India has increased support to the Global Fund to Fight AIDS, Tuberculosis and Malaria and raised funding for the National Vector Borne Disease Control Programme by more than 25%[18]. On similar lines, the BITS TIH tends to place innovative strategies along with the latest technologies such as remote detection and diagnosis to reduce the burden of Malaria in India.

D. Chronic Kidney Diseases

[15] *https://www.ahajournals.org/doi/full/10.1161/CIRCULATIONAHA.114.008729*

[16]*https://www.ahajournals.org/doi/10.1161/CIRCOUTCOMES.118.005195#:~:text=In%202016%2C%20the%20estimated%20prevalence,estimated%20to%20be%2054.5%20million.&text=One%20in%204%20deaths%20in,%3E80%25%20of%20this%20burden.*

[17] *https://www.who.int/news-room/feature-stories/detail/world-malaria-report-2019*

[18] *https://www.malarianomore.org/our-impact/country-programs/india/*

Since there are no national or regional reports on incidence or pervasiveness of either chronic kidney disease (CKD) or end-stage renal disease (ESRD), which is the last stage of CKD, the overall magnitude and pattern of CKD is not known in India. However, one report estimates that incidence rate of ESRD is one in every 4000 people, whereas more than 100,000 new patients enter renal replacement programs annually in India[19]. Since the cost of treatment is very high and resources are scarce, only 10% ESRD patients avail any form of renal replacement therapy (RRT). Additionally, In the 2015 Global Burden of Disease Study, kidney disease was highlighted as the 12th most common cause of death, which accounts for around 1.1 million deaths globally. TIH aims to solve the problem of CKD patient detection at advanced stage and timely detection of CKD and ESRD with its latest technology.

E. Diabetes

India has an estimated 77 million diabetic people, which makes it the second most affected country in the world as China tops the list with 116 million people with diabetes[20]. The IDF Diabetes Atlas 2019 projects that the diabetic patients in India will grow as high as 134 million by 2045[21]. It has been estimated by The WHO that almost 80 per cent of diabetes deaths occur in low and middle-income countries, which is expected to go double between 2016 and 2030[22]. In 2010, it was ascertained that nearly 1 million Indians die due to diabetes every year[23]. Hence, Diabetes is considered as a chronic condition that calls for continuous medical care and self-management knowledge so that acute long-term complications can be prevented or reduced. Moreover, the IDF report reveals that number of people with undiagnosed diabetes is also very high and stands at 43.9 million. Thus, it can be inferred that poor awareness among people and cost to patients are some of the barriers that persist in the practice of evidence-based diabetes management. Therefore, TIH aims to establish technologies that may enable prompt actions and proper use of existing therapies that facilitate glycemic control.

F. COVID-19 Pandemic

Considering the impact of recent outbreak of COVID 19, India has reported largest figure of confirmed COVID 19 cases in Asia and has the third highest figure of confirmed cases in the world after the USA and Brazil with the total number of confirmed cases around 3.7 million as on September 1, 2020 and deaths breaching out the mark of 65,000[24]. It is important to limit the spread of the virus and eventually eradicate by identifying the affected people through testing and isolating them for a few days until they are healthy again. Hence, aggressive testing and contracting are some of the controlling measures of COVID 19. The TIH therefore proposes the use of Aptamers for the early detection of COVID 19 and specifies its advantages over other techniques

[19] *http://www.sjkdt.org/article.asp?issn=1319-2442;year=2019;volume=30;issue=6;spage=1431;epage=1438;aulast=Rai#ref7*
[20] *India is home to 77 million diabetics, second highest in the world, The Hindu, Nov 14, 2019, accessed on 27 Sept 2020*
[21] *https://idf.org/*
[22] *India is the diabetes capital of the world, Economic Times, January 28, 2016, accessed on 27 Sept 2020*
[23] *https://www.bloomberg.com/news/articles/2010-11-07/india-s-deadly-diabetes-scourge-cuts-down-millions-rising-to-middle-class*
24 https://www.worldometers.info/coronavirus/country/india/

viz. ease of synthesis at low cost, greater stability in different environments, ability to adapt to unique tertiary structures, more affinity and specificity for target molecules and ability to conjugate with different enzymes and linkages to solid surfaces. Upon leveraging the learnings from the COVID 19 pandemic, the aptamers will also be used by TIH for future needs during pandemics or for detection of other such diseases.

iii. Snakebite Mortality in India

As India is home to many species of venomous snakes, including vipers, cobras and kraits, it is one of the most drastically affected countries by snakebite. A study "Trends in snakebites deaths in India from 2000 to 2019 in a nationality representative mortality study" claims that India has witnessed 1.2 million snakebite death with the average 58,000/year from year 2000 to 2019[25]. The report further explored the factors affecting deaths due to snakebites such as seasonality, geography i.e. rural or urban. And, pointed out that 50 per cent of all the snakebite deaths came about during the monsoon period i.e. from the month of June to September and occurred mostly in rural areas (97%). The study also indicated that snakebites is more common in males (59%) than females (41%) and peaked at ages 15-29 years (25%). While WHO claims that India has an estimated 2.8 million snakebites cases cumulatively, it is argued that there is under-reporting of snakebites in India as many of the snakebite victims do not make it to even a health care centre. Hence, the actual number could be a way more than what is on the reports.

While it is a well-known fact that bites from any of the venomous snakes could cause shock, paralysis, local tissue damage, haemorrhage, and kidney injury and without timely treatment, could turn fatal, a little has been done to ameliorate the situation. The report mentioned above highlights that enough focus has not been given to snakebite management in the medical programmes, making health workers in remote areas ineffective in treating snakebites. Moreover, health workers in remote areas are reluctant to treat such cases as they are afraid of managing adverse reactions of anti-venom. Thus, inadequate treatment is a key factor behind such a severe death toll in India. With this in view, there is a heightened need to provide on-time access to specific anti-venoms, that are proven to be safe and effective along with proper medical assistance to avert the deaths. The TIH aims to address this problem by developing technologies for quick venom detection and anti-venom production.

iv. Mental Health Disorders

In 2017, the total number of people suffering from mental disorders was ~197 million which is around 14.3% of India's total population. The highest was contributed by intellectual disability (4.5% out of 14.3%), anxiety disorders (3.3%), depressive disorders (3.3%) and conduct disorders

[25]*https://elifesciences.org/articles/54076#:~:text=We%20estimate%20that%20India%20had,home%20in%20the%20rural%20areas.*

(0.8%).[26] Early detection of mental health can be done with technological advancements such as introduction of smart devices that can support mental health diagnosis and treatment. Various tools such as neuroimaging biomarkers, machine learning for understanding several neuroimaging data, virtual and augmented reality for generating difficult visual and auditory stimulus which is difficult to generate can be developed by TIH to cater to the need and continuous monitoring of mental health patients.

v. The Importance of Diagnostics in the Medical Journey

Diagnostic services play a pivotal role in identifying infectious as well as non-infectious diseases. In case of infectious diseases, diagnostic technologies are used in detecting microorganism causing infection and prescribing the most appropriate medical interventions. During the period 2015-18, the diagnostic industry grew at a CAGR of approximately 16.5% in India. In FY 2018, the industry stood at approximately ₹ 596 billion (USD 9.1 billion) and expected to reach approximately INR 802 billion (USD 12.3 billion)[27] by 2010. The diagnostic industry in India can be classified into pathology testing services and radiology testing. The pathology testing segment includes biochemistry, haematology, immunology, molecular diagnosis, urine analysis and microbiology and the other segment involves imaging procedures such as ultrasounds and x-rays, which help mark anatomical or physiological changes inside a patient's body. In India, pathology testing forms a major portion of the diagnostic industry i.e. approximately 58% of total market by revenue while the rest 42% is contributed by radiology segment[27]. Additionally, 65% of the total revenues of the diagnostics industry is contributed by the urban population of India as health facilities and infrastructure is better there.

With the advent of new technologies and increasing focus on research and development, new types of tests are getting listed frequently. Emerging technologies in the diagnostic market, such as next-generation sequencing, liquid biopsy, microfluidics, and multiplex molecular diagnosis are also widening the scope of tests. Hence, realizing the need for developing new diagnostic tools/systems/devices to closely monitor the health condition of the patients, the TIH proposes to employ its knowledge and expertise in this space to develop new diagnostic devices/tools which are minimally invasive and cost efficient for monitoring the health condition of the patients.

vi. Assistive Technologies for the Differently Abled

As per the 76th round of the National Sample Survey (NSS) conducted during the year 2018, 2.2% of India's population is differently abled. The spread is more in rural areas of the country where 2.3% of the rural population is differently abled when compared to 2% of the urban population. Among these people, around 62.1% was supported with a care giver and only 37.7% claimed that

[26] *The burden of mental disorders across the states of India: The Global Burden of Disease Study 1990–2017, Lancet Psychiatry, December 2019*

27 https://www.sebi.gov.in/sebi_data/attachdocs/sep-2018/1538132305423.pdf

a care giver was not required. Furthermore, only 23.8% of differently abled people participate in the labour force.[28] TIH can support in developing technology which can be leveraged to aid the differently abled. For example, offering devices for outdoor mobility and simple everyday actions, such as access to lights, doors, TV remotes, helping people with cerebral palsy correct their posture, providing real time braille convertor for blind people, etc. This will help them lead their lives independently, free from poverty and illiteracy.

vii. National Health Policy and Focus on Digital Health

Recognising the indispensable role of technology in the healthcare delivery, viz. eHealth, mHealth, Internet of things, Cloud, etc. National Health Policy (NHP) 2017 proposes to establish National Digital Health Authority (NDHA) to develop, regulate and deploy digital health across the cohesion of care[29]. With the purpose of improving the productivity and efficiency of the healthcare system of the country, the policy focuses on massive deployment of digital tools. The policy aims to develop an integrated health information system having the capability of serving needs of all stakeholders and improving transparency, efficiency of system and experience of citizens. The use of "Aadhaar" has also been suggested for (Unique ID) for identification. The policy also throws light on exploring the creation of registries (i.e. patients, provider, service, diseases, document and event) for enhanced public health/big data analytics. This policy was reemphasized by the government under the National Digital Health Mission (NDHM) in the month of August 2019. The platform technologies developed by the TIH can provide their expertise and infrastructure which will help in the seamless execution of this mission.

viii. Transformation of Healthcare System with Integration of Emerging Technologies

Recognising the crucial role of health research in the growth of a nation's health, the Government of India aims to improve health research in India on the following fronts- research in health system and facilities, innovation in medical products (including point of care diagnostics and related technologies and internet of things) and basic research in all health-related fields such as Biochemistry, Physiology, Pharmacology, Pathology, Microbiology, Cell Sciences and Molecular Sciences. Also, the National Health Policy is committed to improving institutional structure and capacity for evaluation and implementation of health technology to ensure that the choice of technology is participatory and is informed by scientific evidence, safety, cost effectiveness and social values considerations. Furthermore, there has been an uptick in the involvement of private sector in transforming the healthcare system. More than 85% of the of tertiary care beds are a part of the private sector and in addition to this, the Prime Minister aims to open 2,500 to 3,000 new hospitals in India where the contribution of private sector in terms of developing technologies, providing patient centric services and infrastructure will significantly increase.[30] Thus, both the

[28] *Person with disabilities in India, 76th NSS round, July – December 2018*
29 National Health Policy, 2017
30 Healthcare 3.0 – re-imaging healthcare in the next decade, KPMG in India, February 2020

public and private companies are pivoting their focus towards involving latest technologies such as AI, blockchain, 3D printing, IoT, augmented reality (AR)/ virtual reality (VR) in the healthcare industry which will give rise to commercialization of interdisciplinary technology research, need for skilled talent and disruptive business models. With the help of technology, entrepreneurship and skill development activities, TIH aims to cater to the futuristic needs of India's healthcare industry.

ix. Cold Chain Logistics in Pharmaceutical Industry

The introduction of new types of medicines called biologic drugs, which are being considered heavily effective, has led to adoption and wide consumption of cold chain logistic in the pharmaceutical industry. Contrary to the chemically produced medicines, biologic drugs are produced from living cells thus require time and temperature dependent storing and delivery. Since damaged biologics might end up not performing as desired or may cause devastating effects on the health of patient, a slight misalignment in logistics of such delicate drugs renders them waste incurring massive costs to health facilities. Therefore, cold chain logistics play a vital role in pharmaceutics that require effective temperature and time control. Quality assurance is another factor which makes health facilities to invest in cold chain logistics.

However, the dynamic environments, complex production and transportation challenges the management of supply chains and high levels of operational flexibility is required to deal with such characteristics. Cyber-physical system (CPS) may be considered one such system that has the ability and capability to deal with the physical as well as informational aspects of processes. Thus, the BITS TIH tends to integrate CPS into the cold chain logistics in order to reduce costs and enhance logistic performance.

b. Agriculture

An important adversary on Indian agriculture industry is the food spoilage and post-harvest processing losses. India produces a large amount of grains, pulses, groundnut, rice, fruits etc. Some environmental conditions such as drought, susceptibility to cultivation, mechanical damage and humidity are the reasons that destroy or damage agricultural crops as they promote the production of mycotoxins in crops. Insect infestation is another cause of infected crops during growth, harvest, storage, and processing. *Aspergillus spp., Alternaria spp., Penicillum spp and Fusarium spp.* are the most popular storage and postharvest fungi of fruits. Country in general and farmers in particular suffer huge economic losses due to spoilage of crores of rupees worth crops annually becoming unfit for consumption or processing due to presence of fungal toxins such as Aflatoxin (B1, B2, G1, G2) in pulses, groundnut/peanut, Ochratoxin A and Pautulin, Zeralenone etc. In addition to the direct losses due to food spoilage, the contamination of crops even in storage results in contamination of food. The presence of these mycotoxins in processed food, or even animal feed causes sever diseases such as variety of cancers. Hence their detection is of extreme importance to improve storage and shelf life of raw as well as processed food. The processed food

also contains exceeding amount of these mycotoxins which results in rejection of exports and economic losses. Groundnut is one such example where there is need to develop biosensor-based CPS systems to detect Aflatoxin B1 (AFB1) before processing and during storage.

India also among the largest producer of milk in the world. Milk is primary diet of many infants and adults and consumed heavily. Presence of Aflatoxin M1 which is present even after pasteurization (the fungus being heat resistant) causes cancer among infants and even adults due to consumption of AFM1 contaminated milk. A huge amount of milk gets contaminated due to presence of Aflatoxin M1. The FSSAI standards and European Union standards require stringent quality control to screen contaminated milk and milk powder to ensure safety and quality of milk for domestic consumption and export products. Hence there is need to develop smart Biosensor sensing platforms which will enable the detection in pre and post processing products such as milk powder, cheese, etc.

Fruits production and processing is another key area which suffers heavy economic losses due to presence of various toxins in fruit and fruit juices post processing. Hence, several farmers suffer losses due to spoilage of their fruits or due to contaminated fruit juices, they cannot be exported to external markets as the presence of toxins renders them unfit for public consumption due to stringent regulatory standards[31].

In addition to mycotoxin detection, urea is an important fertilizer that is extensively used by farmers. Currently they are used manually. There is no way currently to know how much urea is actually used and how much goes waste in runoff during irrigation. The development of field sensors for urea in irrigation system will enable resource recovery of urea in runoff water. This will not only allow recovery and reuse of unused urea but also allow recovery of wastewater which is rich in urea. This in turn reduce losses and costs on irrigation and in turn enhance farmer's income by reducing losses.

Indian farmers and agricultural supply chain including food processing industry, dairies etc. heavily suffer due to the unavailability of such sensors to detect mycotoxins in raw material and processed products (groundnut, milk, fruit juices etc.).

c. Environment

Like many other global nations, India is also battling the problems of climate change and pollution. It is estimated that India's average temperature rose by 0.7 degree Celsius between 1901-2018 and will rise by 4.4 degrees between 2070 to 2099 unless necessary steps are taken[32]. India has made commitments under the Paris Agreement to reduce greenhouse gas emissions, improve forest cover and switch to non-fossil fuel sources. However, various forms of pollutions continue to affect the quality of life across the country.

[31] *WHO Food safety facts, major illness and causes, 2020* https://www.who.int/news-room/fact-sheets/detail/food-safety

[32] *India Climate Dialogue, Accessed September 2020, https://indiaclimatedialogue.net/2020/06/16/climate-change-is-making-india-less-liveable/*

Water Pollution: Water pollution is one of the major environmental challenges facing both India and the world. As per the World Health Organization[33], as large as 785 million people, including 144 million people relying on surface water, lack even a basic drinking-water supply. Globally, at least 2 billion people use a source of faeces-contaminated drinking water. Diseases such as diarrhoea, cholera, dysentery, typhoid, and polio may be transmitted by contaminated drinking water. It is estimated that contaminated drinking causes 485 000 deaths per year from diarrhoea and the figure of people dying from diarrhoea as a result of unsafe drinking-water, sanitation, and hand hygiene is expected to reach 829,000 people each year. In 2018, 2439 people died due to the four major water-borne diseases in India (cholera, acute diarrheal diseases, typhoid and viral hepatitis)[34]. Yet diarrhoea is largely preventable, and if the risk factors were tackled, the deaths of around 297 000 children aged under 5 years could be avoided each year.

Presence of small particles of heavy metals such as cadmium and mercury, lead and arsenic in drinking water can cause kidney and neurological damage. Such contamination by heavy metal occurs primarily due to pollution of air, water and soil. However, Arsenic is highly toxic in its inorganic form and is naturally present at high levels in the groundwater of a number of countries. Arsenic-contaminated water used for drinking, food preparation and irrigation of food crops poses the greatest threat to public health; exposure to arsenic from drinking-water and food for a long period of time can cause cancer and skin lesions. Cardiovascular disease and diabetes have also been related to it. In utero and early childhood, exposure has been linked to detrimental effects on cognitive growth and increased deaths in young adults. It is estimated that 1.6 million people in Assam, 1.2 million in Bihar, 9.6 million in West Bengal and 0.5 million in Uttar Pradesh drink arsenic-contaminated water much above the permissible limit[35].

Sustainable Development Goal target 6.1 calls for universal and equitable access to safe and affordable drinking water. The WHO Guidelines for Drinking-water Quality (2004) suggest setting health-based targets reflecting national contexts and realities. And, ongoing efforts should be made to preserve and enhance the quality of drinking-water to the highest possible degree as water sources options used for drinking water and irrigation will continue to evolve, with an increasing dependency on groundwater and alternative sources, including wastewater. The Government of India has also taken several steps towards addressing the drinking water quality problem in India, including setting up of a three-tier laboratory system for analysing water quality. The biosensors developed by the TIH will contribute towards this cause of improving India's water quality index.

[33] *WHO report on Drinking water key facts June 2019 and Food Safety key facts (April 2020)* https://www.who.int/news-room/fact-sheets/detail/drinking-water

[34] *'Polluted water killed 7 every day in 2018', Times of India, 29 June 2019, Accessed September 2020, https://timesofindia.indiatimes.com/india/polluted-water-killed-7-every-day-in-2018/articleshow/69996658.cms*

[35] *'Arsenic: Lurking in the shadows across Ganga, Brahmaputra basins', DownToEarth, 10 February 2020, Accessed September 2020, https://www.downtoearth.org.in/news/food/arsenic-lurking-in-the-shadows-across-ganga-brahmaputra-basins-69004*

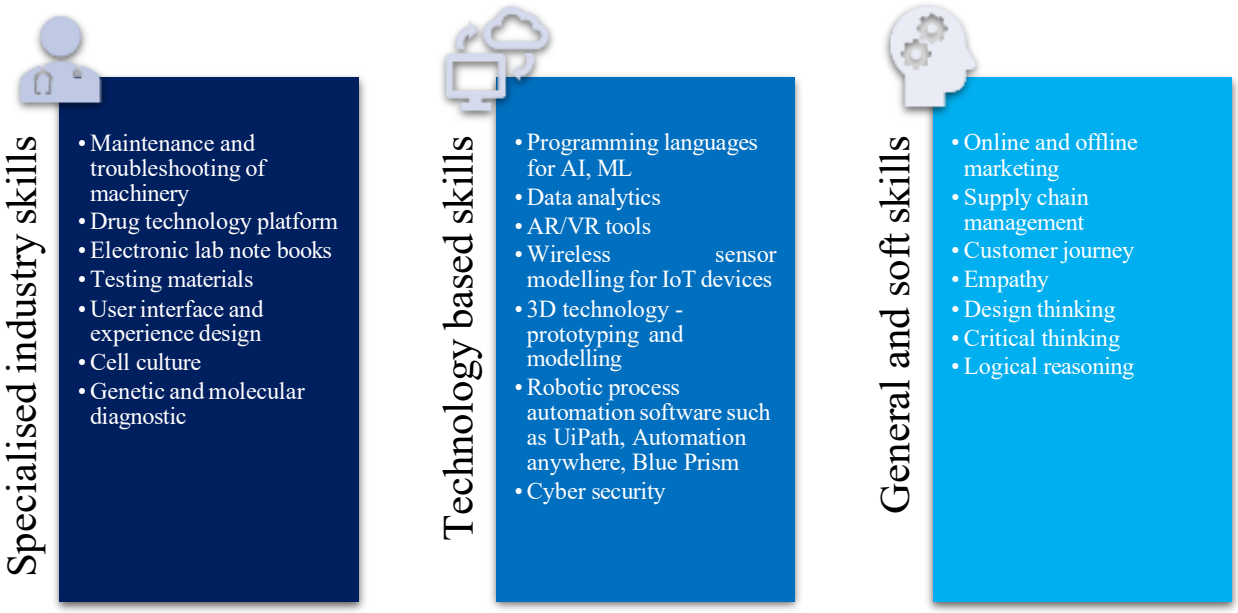
2.3. Science & Technology Education in India

Demand for Science & Technology Programmes

There has been a steady increase in number of students (CAGR 9%) graduating from biology related disciplines (biochemistry, biophysics, biostatistics, biotechnology, bioscience, genetics, life science, botany and zoology).

The biotech industry in India comprises of workforce with over 1 million people and produces 15,500+ graduates every year.[36] This industry requires employees to have multidisciplinary knowledge across the fields of engineering, manufacturing, data analytics and pharmaceutical sciences or biotechnology. Furthermore, these professionals will be required to leverage artificial intelligence to analyse data received from sensors and IoT based devices. This will help in empathizing with the consumers, addressing their pain points and personalizing the given product or service according to their needs. In addition to this, some employees will be required to work on emerging technology-based devices such as AI based surgery devices, biomedical sensors and robotic prosthetics to design consumer centric solutions and ensure that the interactions between the various stakeholders (healthcare personnel, consumers) and the technology devices are seamless.

Figure 6: Specialized industry skills, technology, general and soft skills required in the pharmaceutical/life sciences industry



Science & Technology Education in India

36 India bioeconomy report, BIRAC, March 2020

Among the top 50 universities in the NIRF engineering 2020 ranking, only 8 universities offer UG/PG engineering degrees in emerging technologies such as artificial intelligence, data science, robotics, IoT, blockchain, 3D printing, indicating a lacuna in the emerging technologies education space where BITS Pilani can play a key role. As per the new policy by All India Council for Technical Education (AICTE), technical institutes can be started only if they introduce new courses related to emerging technologies such as IoT, AI, blockchain, 3D printing, data science, cyber security, robotics, quantum computing. Furthermore, the National Education Policy (NEP), 2020 lays emphasis on multi-disciplinary holistic education with multiple entry and exit points for students which will create possibilities of lifelong learning for students[37]. Along with multidisciplinary education, the NEP focuses on empowering the society with digital skills. Universities will play an important role in trans-disciplinary education by ensuring PhD and Masters degrees are offered in key areas such as machine learning and AI and professional areas such as healthcare, agriculture and law. For quicker adoption, these courses will be offered through online platforms such as Study Webs of Active-Learning for Young Aspiring Minds (SWAYAM) or as online courses for blended learning degrees with the traditional courses. In addition, the policy focuses on collaborations among academic institutions and with industries for providing opportunities for internships so that students may consciously participate in the practical side of their learning and further improve their employability as a by-product[38].

[37] *Press release: Cabinet approves NEP 2020, paving way for transformational reforms in school and higher education systems in the country*

[38] *National Education Policy, Ministry of Human Resource Development, Government of India, 2020*

Figure 7: Trends in STEM related higher education programmes

Trends in STEM related higher education		
1	Significant prominence given to **courses based on emerging technologies such as AI, IoT**, blockchain, 3D printing and design	
2	Increasing emphasis for **inter-disciplinary learnings** and transferable skills in the evolving employment market	
3	Increased focus on **hands on practical learning** (such as internships, projects with industry players) to improve employability	
4	Greater thrust on **integration of skill education** within higher education; rise in HEIs offering skill development courses	
5	**Blended learning is being used as in approach to track student progress and improve personalization of the course for the student**	
6	**Personalization of educational experience** of a student across their lifecycle by leveraging technology	

Case Examples (interdisciplinary programmes in bio related fields):

IIT Madras (Interdisciplinary dual degree – B.S and M.S in Biomedical engineering)

- **Duration**: 5 years
- **Enrolments**: 20
- **Fees**: INR 0.43-1.10 lakhs (depending on parental income)
- **Research collaboration opportunities for the students** with renowned global universities such as Queensland University of Technology and RWTH Aachen
- **Interdisciplinary lab sessions** which involve circuit building exercises and research-oriented experiments
- **Frequent field visits to hospitals and research centres** and **short term/long term internships** with companies and research organisations in order to ensure students receive practical experience in product development for the healthcare industry

Source: IIT Madras website, accessed September 2020, https://www.iitm.ac.in/

Interdisciplinary Education at BITS

BITS has always been at the forefront of offering interdisciplinary programmes for its students. The Institute has created an option in the curricular structure by which a student admitted to the

integrated M.Sc. program (in Physics, Chemistry, Mathematics and Biological Sciences) is offered an opportunity to pursue a second UG degree in Engineering (B.E.) under the dual degree scheme based on the academic performance of the student in the M.Sc. program after his/her first year. The institute also provides students the flexibility to take up a dual degree within their same group, i.e. a **student can pursue two M.Sc. programs or two B.E. programs**. Students in the dual degree scheme, have to complete a larger number of units and normally enroll for 10 consecutive semesters in the institute. The B.E program runs for 8 consecutive semesters, in contrast. Additionally, dual degree students are required to complete a 6-month thesis or a 6-month Practice School in both streams they are pursuing. This provides them with ample opportunity to hone their research and problem-solving skills and work on interdisciplinary topics at the confluence of both their streams.

This is a unique program, opted by most of the incoming MSc students and provides an opportunity for students to pursue interests in both Science and Engineering streams. The TIH will contribute towards this programme by offering an option for students to enroll in the M.Sc. (Biological Sciences) program and a B.E. (hons.) (Computer Science) program enabling him/her to pursue research or design products in the field of Bio-Cyber Physical Systems. This probably is one of a very few available interdisciplinary curricular frameworks in the country at the undergraduate level. Thus, The TIH will contribute towards human resource development through such interdisciplinary programmes, other Fellowship programmes and skill training programmes to create a pipeline of talent in the area of Bio-CPS.

2.4. Start-up/ innovation ecosystem in India

The Indian technology landscape has seen a tremendous growth in the development of innovative start-ups and has emerged as the 3rd largest technology start-up hub in the world, after USA and China. With the base of over 50,000 start-ups, the star- up ecosystem in India is growing at YoY 12–15%. As per the NASSCOM report[39], the cumulative valuation of start-ups in India stands at USD 95-101 billion as of FY 2018 which is expected to reach USD350 billion by 2025. Moreover, these organisations have created an estimated 4 lakh direct jobs and 15 lakh indirect jobs in the past and have the potential to reach benchmark of 12 lakhs and 40 lakh direct and indirect jobs respectively by 2025.

During year 2014-19, 8900-9300 startups got incepted and out of these, around 1300 startups emerged in year 2019 alone. 14% of them were in the healthtech sector.

39 Indian Tech Start-up Ecosystem, Edition 2019, NASSCOM

Additionally, it has been found that 18% of all start-ups emerged during 2014-19 are leveraging deep-tech. The share of start-ups by technology has been illustrated in the adjacent pie chart. In the graph, others include Robotics, 3D printing, virtualisation and cybersecurity etc. The pool of 18% has expanded from just 8% in the year 2014, meaning that start-ups have started to enlarge their focus on the new-age technologies. Thus, TIH of BITS holds numerous opportunities in further expanding this trend in the Biotechnology sector by providing incubator and handholding support in the domain.

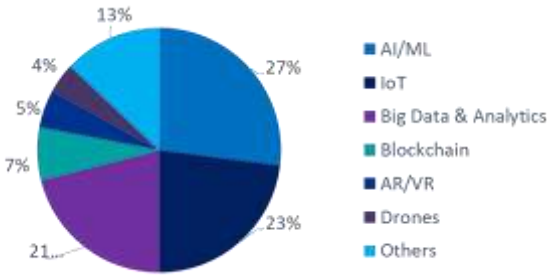


Figure 8: % share of startups by technology

Source: Indian Tech Start-up Ecosystem, Edition 2019, NASSCOM

Bio-based startups and incubators in India

With the addition 937 startups in 2018, the country's number of biotech startups has increased to 2,669 at the end of 2018, witnessing 32% increase in biotech start up formation. As per the study done by Association of Biotechnology Led Enterprises' (ABLE) research group[40], the concentration of Bio-tech start-ups i.e. ~60% is mainly spread in five states of India with Maharashtra contributing around 15% of the total bio-tech startups followed by National Capital Region (NCR), Andhra Pradesh & Telangana, Karnataka contributing 13% each and Tamil Nadu 5%. With the base of around 2700 start-ups in biotechnology, India is among the top 12[41] destinations for biotechnology in the world, with approximately 3% share in the global Biotechnology industry. It is also the leader in the global supply of DPT, BCG and measles vaccines. Hence, in order to remain globally competitive and grow in the sector, Government of India has been taking various initiatives on policy fronts as well as on infrastructure fronts. To provide facilities to scientists, and Small and Medium sized Enterprises (SMEs) for technology incubation, technology demonstration and pilot plant studies, Biotechnology Parks (BP) and Incubators have been established across the country which provide necessary infrastructure support for translation of research into products and services. There are total 9 BPs which have been supported by BIRAC so far[42]. BIRAC has also created four regional centres to promote and encourage bio-entrepreneurship by providing bio-entrepreneurs requisite knowledge and skills to turn innovative biotech ideas into successful & sustainable ventures that generate national and global impact: BIRAC Regional Innovation Centre (BRIC), BIRAC Regional Entrepreneurship Centre (BREC), BIRAC Regional Bio-Innovation Centre (BRBC) and BIRAC Regional Techno-Entrepreneurship Centre East and North East Region (BRTC-E & NE).

[40] *India BioEconomy Report 2019, BIRAC*

41 https://www.investindia.gov.in/sector/biotechnology

42Biotech Park, Lucknow, Uttar Pradesh, Biotechnology Incubation Centre, Hyderabad, Telangana, Tidco Centre For Life Sciences (TICEL) Biotech Park, Chennai, Tamil Nadu, The Golden Jubilee Biotech Park for Women, Chennai, Tamil Nadu, Biotech Park Technology Incubation Centre, Guwahati, Assam, Biotechnology Incubation Centre, Cochin, Kerala, Biotechnology Park, Bangalore, Karnataka, Industrial Biotechnology Parks (IBTPs), Jammu & Kashmir, Chhattisgarh Biotech Park, Naya Raipur, Chhattisgarh

Keeping in view the growth of bio sector in India and various initiatives the government of India has been taking for the sector, it can be seen that a strong focus of the government is placed on development of biotech products, processes and technologies for enhanced performance, productivity and cost-effectiveness in the fields of agriculture, food and nutritional security; affordable health care and well-being; environmental safety; clean energy, biofuels, and bio-manufacturing. Leveraging this trend, TIH of BITS can further contribute in enabling and nurturing an ecosystem that aims to prepare technological and product development capabilities of India in biopharmaceutical and bio-agricultural to a globally competitive level over the next decade and transform the health standards of India's population through affordable product development.

3. Aims and Objectives of the TIH

TIH Scope

The potential of emerging opportunity in the Bio-CPS space can be harnessed by offering a common platform to nurture interdisciplinary and collaborative research supported by a vibrant innovation ecosystem where industry, academia, medical experts, healthcare professionals and hospitals interact closely.

BITS Pilani has a proven strength in all these areas and will enable development of new and disruptive technologies by way of establishing the TIH to create an impact in the society.

TIH Vision

"To foster research, innovation, skill development and training in the interdisciplinary area of Bio-CPS through mentoring and nurturing startups and entrepreneurs, and industry & academia collaborations to undertake cutting edge research and provide affordable solutions in the areas of healthcare, agriculture, water and environment"

TIH Mission

- Form cross functional and interdisciplinary teams
- Provide state-of-the-art facilities to undertake research and development in Bio-CPS
- Bring together subject matter experts from academia and industry across the world
- Offer education and skill development programs to create a high-quality talent pool in the Bio-CPS domain
- Develop affordable devices for detection, diagnosis and therapy
- Create a platform for startups in Bio-CPS to establish and scale
- Create a talent pipeline in Bio-CPS through skill development programmes

TIH Objectives

- Develop mature technologies and products in the Bio-CPS arena and propel them towards commercialization
- Create infrastructure facilities to undertake innovation and translational activities in the area of Bio-CPS through device lab, flexible electronics lab., IoT lab, data security lab, bio-sensor lab, incubator etc.
- Identification & validation of novel biomolecules through Omics based approach - DNA, RNA, protein, metabolites, etc. and their association with human diseases. including cancer and other infectious diseases
- Develop devices/systems, diagnostic tools for monitoring human health, food safety and quality, food supply chain and water quality monitoring
- Integrate wireless communication [RFIDs & WSN] for real time monitoring and decision support systems through mobile devices including drones
- Develop data driven mitigation strategies through sensor based IoT & AI systems
- Create an understanding of the diseases of national importance including COVID-19
- Develop affordable devices for detection, diagnosis and therapy
- Undertake development of new drone based agri -technologies for pest detection, control and minimizaiton of food losses
- Establish incubator in the Bio-CPS space and train human resources for entrepreneurship, nurture research start-ups
- Offer fellowship, training and certification programs in Bio-CPS domain
- Create future talent pipeline through upskilling and reskilling in the area of Bio-CPS
- Create a financially sustainable hub

TIH Deliverables

The following table lists the deliverables the TIH shall produce across areas:

Table 6: TIH Deliverables

Area	Deliverable
Healthcare	• Novel biomolecules through Omics based approach | DNA, RNA, protein, metabolites, etc. | aptamers, antibodies, sequences • Deliver technologies / diagnostic systems/devices based on the identified novel biomolecules/sequences • Develop IoT based system for community health monitoring using antibiotic susceptibility test platform • Develop a COVID-19 diagnostic platform and identification of anti-COVID peptide and small molecule drugs • Develop IoT enabled plug-and-play smart devices focusing on better accuracy, cost-effectiveness, rapid detection, data analysis/transfer and security harnessing the core-competencies of Microfluidics, Nanoelectronics, Biology, IoT, and Security. These devices will include printed, wearable and implantable devices, point-of-care bio-diagnostic

	devices and environment monitoring devices • New editing technologies for diagnostics and Smart wearable sensors • New anti-cancer drug candidates for oral cancer.
Agriculture	• Demonstrate an IoT field sensor network for food supply chain monitoring for food toxin detection and reduce economic losses • Detection of fertilizers using sensors, resulting in reduced losses and enhanced income for farmers • Waste to wealth and increasing crop productivity with Bio-CPS component
Water and Environment	• Mapping of bio diversity such as coral reefs using under water network • Deliver an IoT based biosensor network for bacterial contamination and pesticide residue monitoring in drinking water • Rapid detection of antibiotic residues in water • Waste management with Bio-CPS component
Startup/ innovation ecosystem	• Set up an incubator in Bio-CPS and support start-ups in the domain; leverage on BITS Pilani's startup eco-system along with network of corporate and academia collaborators • Create platforms for interaction between Start-ups and Industry for boosting collaboration and technology transfer of the innovative devices, tools and Systems.
HRD and Skill development	• Train at least 200 researchers /Scientists /Post Docs/Students in the area of Bio- CPS • Offer skilling and upskilling courses for professionals, job seekers and academia in Bio-CPS, its application and entrepreneurship • Increase awareness of issues related to Bio-CPS in the society.

The Hub will thereby contribute towards achieving several national developmental goals, directly or indirectly. The following are some of the areas where the Hub will create an impact:

Figure 9: Areas of Impact of the TIH

Healthcare

Goal 3 of Sustainable Development Goals (SDGs) refers to Good Health and Well-being. India has achieved an index score of 61 out of 100 in SDG3[43]. However, there are regional disparities with the index ranging between 29 and 82 among states. India has set the target to eliminate the incidence of AIDS, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases by 2030[44]. The National Health Policy (NHP) 2017 has also set the goal of reducing premature mortality from cardiovascular diseases, cancer, diabetes or chronic respiratory diseases by 25% by 2025. The TIH will develop tools for diagnosis of cancers, cardiovascular diseases, malaria, chronic kidney diseases, snake bites, pandemics such as COVID thereby playing a key role in achieving targets under SDG3.

The National Health Policy 2017 also lays down clear goals and objectives related to Health Management Information such as health surveillance system, registries for diseases of public health importance, federated integrated health information architecture, etc. The Policy also calls for private sector engagement for manufacturing of medical devices. It advocates extensive deployment of digital tools such as eHealth, mHealth, Cloud, Internet of things, wearables, etc. for improving the efficiency and outcome of the healthcare system and scaling of various initiatives in the area of teleconsultation[45]. The technologies developed by the TIH shall contribute towards achieving all these goals and objectives laid out in the National Health Policy.

[43] *SDG India Index & Dashboard, Niti Aayog, 2019*
[44] *SDG India Index & Dashboard, Niti Aayog, 2019*
[45] *National Health Policy 2017*

Agriculture & Food Processing

SDG2 refers to Zero Hunger which also accounts for agricultural productivity and income. In India, 58% of population depends on agriculture as their primary means of livelihood[46]. The Government of India has recommended a multipronged strategy to double farmers' income by 2022 through improved crop and livestock productivity. Pradhan Mantri Kisan SAMPADA focuses on creating modern infrastructure to manage the food processing supply chain, including food safety and quality assurance. The technologies developed by the TIH shall help in modernizing the agricultural and food processing sectors in the country.

Water and Environment

SDG6 refers to Clean Water and Sanitization. India has achieved a score of 88 out of 100 in this index. Though India has made great strides in providing access to drinking water in all households, there are some pertinent issues with water quality. One such issue is arsenic contamination which affects 26 districts across 4 states[47]. The TIH will develop an IoT enabled device which can detect the presence of arsenic or other contaminants in drinking water, thereby contributing to the cause of providing safe drinking water to all.

Human resource development

The Hub will focus on creating qualified and skilled future workforce in the interdisciplinary area of Bio Cyber Physical Systems. This is also in line with the National Education Policy's (NEP) focus on cutting edge technologies such as AI, big data analysis, machine learning (ML), genomic studies, biotechnology, nanotechnology, etc.

Contribution to economy

It is estimated that biological applications could unlock an estimated potential of USD 2–4 trillion in annual direct global economic impact in the next 10–20 years. Out of this, majority of the impact (~70%) is expected to be in the fields of human health and agriculture[48]. The TIH will also contribute towards these sectors through technology and product development in the bio-related domains.

The TIH would also contribute towards the various flagship programmes of the government for boosting the economy such as Digital India, Startup India, Aatma Nirbhar Bharat Abhiyan, Make in India. The R&D activities in the hub will pave the way for India to become an exporter of technologies in the life sciences/ medical devices industry. It will also attract global companies to set up their R&D centers in India. This R&D and innovation ecosystem will create more jobs, thereby providing opportunities for Indian talent pool. Thus, the Hub will contribute towards SDG8 (Decent Work and Economic Growth), SDG9 (Industry, Innovation and Infrastructure) and

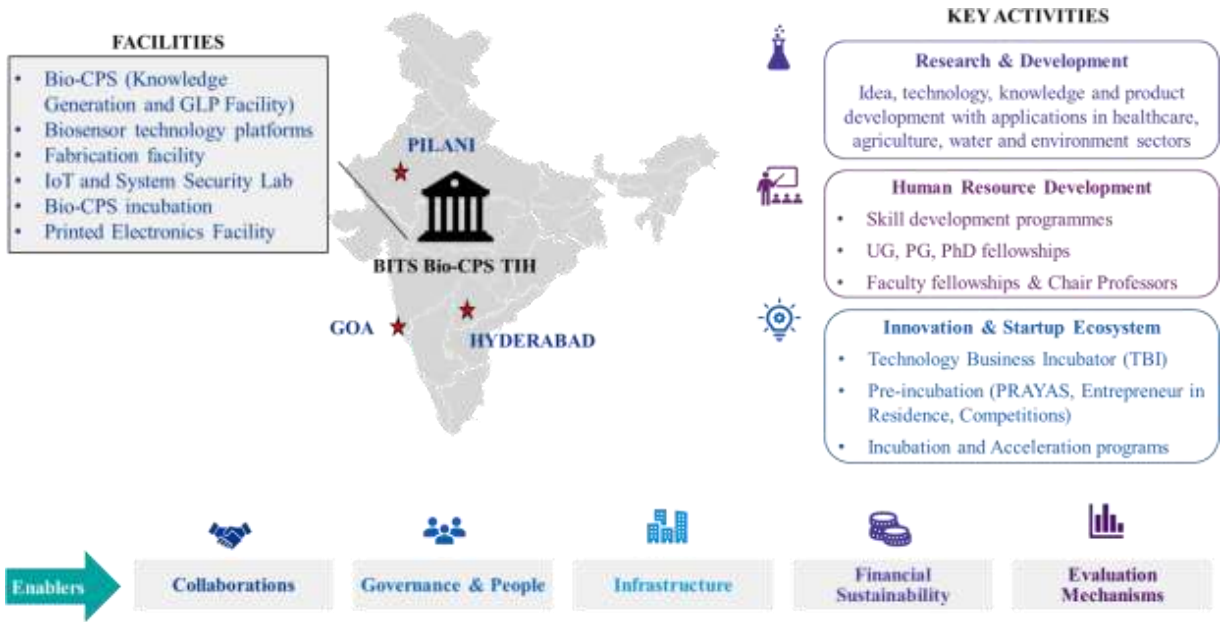
[46] IBEF
[47] SDG India Index and Dashboard 2019-20, Niti Aayog, 2019
48 The Bio Revolution: Innovations transforming economies, societies, and our lives, McKinsey Global Institute, 2020

the goal of becoming a USD 5 trillion economy by 2025[49]. Additionally, the national and international collaborations established by the Hub will create an impact on SDG17 (Partnerships). *(Note: Specific problems that shall be addressed by the TIH was detailed out in the previous section)*

4. Strategy

The TIH will involve multidisciplinary teams divided into 6 facilities spread across the three campuses of BITS.

Figure 10: Bio-CPS TIH- Operating Model



4.1. Hub Activities

The strategy of the Hub shall be mainly around three verticals, supported by collaborations (national/ international):

Figure 11: TIH – Key Activities

i. Research & Development

Research and Development at the TIH will focus on the following:

- New idea and knowledge generation /discovery (TRL 1-3)

[49] *SDG India Index & Dashboard 2019-20, Niti Aayog, 2019*

- Development of products /prototypes from existing knowledge (TRL 4-6)
- Technology/ product delivery in specific sectors, i.e., projects that involve knowledge generation and also conversion to technology and demonstration of full working technology (TRL 7-10)

This activity will produce several technologies, and technology products of national importance, and patents or any other intellectual activities and several CPS research base over first five years.

Knowledge Generation

The TIH will act as a Centre of Excellence in creating new knowledge through basic research in areas listed in the previous section. The TIH shall focus on creating intellectual property in Bio-CPS through papers and patents, in addition to establishing global collaborations for carrying out research.

Technology development

Under this activity, the TIH will focus on the following:

- Application-based technology development and deployment based on industry requirements
- Take up TRL improvement of previously developed technologies and deliver technology ready for commercialization. This will be achieved by turning ideas or concepts into ready-to-deploy technologies or marketable products.

The proposed center will include a prototyping facility to provide a one stop shop to convert a scientific breakthrough into a product:

- The shared facility will provide basic fabrication facilities for researchers working in the fields of nano-electronics, novel materials, biosensors, diagnostic device, MEMS, bioengineering, flexible and wearable electronics to build prototypes of devices
- Full wafer/Wafer pieces' fabrication facility: The intent of this facility is not to provide a CMOS manufacturing line, but rather support processing of new materials and nonstandard structures. Systems will need to be put in place to manage new materials (ex. High vapor pressure) and cross contamination to minimize impact to other research projects. Will also support other non-standard substrates like GaN, glass, SiC etc.
- Basic fabrication expertise available will include most common steps including basic level patterning, common contact creation steps, anneals and encapsulation
- Off-line material (Auger, XRD) and structural (SEM and AFM) characterization will be supported. Few in-line tools like microscope and profilometers will be available

Devices that may be fabricated at this facility will include:

- MOSFET based sensors – Activated surfaces show high responsivity when used as a MOS gate interface
- MEMS based devices – availability of high aspect ratio lithography and reactive ion- etching will enable deep trenches or tall mesa's that may be used for sensing applications in the fields

of medical imaging. This technology may also be used to develop microneedles for targeted delivery mechanisms

- Microfluidics – etching deep trenches may be used to build lab-on-chip configurations that will aid with building quick test mechanisms. These may be exploited for large design of experiments to identify optimal receptors etc.
- Flexible Electronics – low power systems, especially for IoT networks, will need deployment of large number of sensor units. These need to be low cost and will need to be built on plastic/glass substrates integrated with suitable wireless transmitters.

Additionally, expertise is available in the institute to interface any new sensors to existing microcontroller-based setups for ease of implementation.

Patented technologies, specifically devices for detection cardiac marker, mycotoxins, infectious diseases, bacterial biosensors etc. will be taken up for TRL improvement. Their batch production will be explored and large- scale validation will be carried out. The Hub will leverage BITS Pilani's existing collaborations in this endeavour.

At least one platform technology will be optimized for fabrication of devises that can help take existing IPs to market. For instance, the E. Coli biosensor will be demonstrated for IOT based community health monitoring.

The technologies developed by the TIH will be licensed to industries and startups to create commercially viable products. Industries/ startups may also set up their R&D facility within the Hub to enable faster prototyping and product development. There are several advantages for industries to locate their corporate innovation centre at the TIH:

- Access to working spaces and labs
- Access to university faculty and researchers across various departments
- Licensing/ co-development of technology
- Co-bidding for sponsored research projects
- Student interns for staff augmentation in research projects

Policy Guidance and help in formulation

The TIH will develop standards and assist in policy creation for rapid adoption of Bio-CPS among various stakeholders.

Data bank creation across strategic areas of focus

The TIH will work on aggregating data banks across verticals from government and industry for offering data as a service for bootstrapping Bio-CPS applications.

ii. Human Resource Development and Skill Development

The programmes offered by the TIH would be selected in such a manner that they fall appropriately within the ambit of Bio-CPS to develop a set of future thought leaders and practitioners with sufficient skills and knowledge. The focus areas have been benchmarked against global institutes

offering programmes in related areas. Following is an indicative list of programmes which can be offered by the TIH:

Skill development programmes:

Skill development programmes shall be offered by the TIH aimed at the following segments:

Table 7: Skill development programmes- target segment

Target Segment	Type of Programme
Executives (industries such as pharmaceuticals, medical devices, health tech, etc. and govt. officials in the health department), Entrepreneurs, graduate students	Upskilling in the area of Bio-CPS and its applications, entrepreneurship Equipment training to various stakeholders (students, job seekers, employees, MSME etc.) – Short duration course for multiple batches
ITI/ polytechnic students, General public interested in skilling programmes	Skilling programmes for installation, diagnostics, repairs, operations and maintenance of CPS products/ equipment
Faculty/ researchers	• Faculty development programmes • Knowledge dissemination through seminars, conferences, etc.

The various types of courses that shall be offered are:

Table 8: Skill development programmes- type, intake and fees

Duration	Type	Intake[50]	Proposed Fees (INR)
Short term	Basic/ Fundamentals	150–180	8,000-12,000
	Advance/ Higher Order Skills	100–120	50,000-70,000
	Equipment training	750–1000	1,000-10,000
	Other professional courses	100–120	20,000-30,000
Long term	Basic/ Fundamentals	120–150	10,000-20,000
	Advance/ Higher Order Skills	100–120	70,000-90,000
	Online certification	300–450	20,000-30,000
	Other professional courses	100–120	40,000-60,000

[50] *At steady state after Year 5*

In-person classroom courses shall be conducted mostly during summer breaks, thereby ensuring efficient utilization of existing infrastructure and resources. Blended/ online delivery of programmes shall also be explored. These programmes may be offered in partnership with BITS / other HEIs or industry players. Revenue sharing option will be explored in cases of partnership-based delivery. It is estimated that the TIH will provide different types of skill development and training programs (long term, short terms, online / blended model etc.) for more than 4500 students over the first five years. The hub will be offering equipment training to various stakeholders (students, job seekers, employees, MSME etc.,) which will help in scale of the training programs offered by the hub. Paid internships such as BITP programme of Department of Biotechnology shall also be explored, thereby creating a pool of trainees to work dedicatedly for the commercial/ monetizable R&D projects, often interdisciplinary.

It is proposed to conduct the following advanced training programmes:

- Healthcare Technology program to be initiated and broadened in different formats (regular classes, practice school, online training for students as well as working professionals etc.). New coursework to be introduced on Public Health and Medical Biotechnology
- Scope for hands on training and participation in real projects (to train 200 young senior students, doctors towards advanced technologies including tissue culture and handling transgenic and knock-out mice etc.
- Next generation sequencing- understanding and applications
- Proteomics: Introduction and application
- Metabolomics: Introduction and application
- Mutiomics approach towards biomarker discovery in health science
- Micro Electromechanical Systems (MEMS) and Microfabrication
- Nanoelectronic device fabrication: hands-on training to build biosensors, TFT etc.
- Emerging semiconductor Devices and their applications for next generation startups including uses in agriculture, biomedical devices, healthcare monitoring, optoelectronic devices, energy harvesting and smart materials.
- Hands-on workshops may be conducted in the fields of biosensor fabrication, MEMS fabrication and software tool training including TCAD, COMSOL, Ansys etc.
- Biosensor & CPS applications in Agri, health and environment
- Rapidly Prototyped Microfabrication and Bio Applications
- Internet of smart Sensors /Internet of Things (IOT) enabled BioMicrofluidic Sensors
- Flexible and Wearable Healthcare Sensors
- Mobile-based healthcare
- Management of chronic diseases via smart wearables
- Bio-CPS entrepreneurship program

The TIH may also conduct visibility exercises such as project exhibitions, seminars, conferences, symposiums, etc. to bring together experts and practitioners in the area of bio-CPS.

Case Example

Indian Institute of Science (IISc), Bangalore offers short-term trainings spanning from two-days programmes to around 20 days, in its campus at Centre for Continuing Education (CCE). The various courses offered in the last three years include Traffic System Modelling and Simulation, Sustainable Roadways-Design and Construction, Advanced Choice Modelling Methods in an Evolving Urban Travel Behaviour Landscape etc. For such trainings, registration fee is charged ranging from INR4,000 to INR40,000 depending upon the category of participant viz. students, overseas students, industry and other participants from low-income, lower-middle-income, upper-middle-income and high-income countries. The institute also mentions minimum qualifications and pre-requisites/prior knowledge required for the course(s). The programmes are delivered by experienced academics and other staff from the institute along with other partners of IISc.

Source: IISc website, accessed September 2020, https://cistup.iisc.ac.in/CiSTUP_Website/pages/events/short-courses.php

First Degree, Higher Degree and Doctoral Fellowships:

The TIH shall offer fellowships in First Degree (Undergraduate), Higher Degree (Postgraduate) and Doctoral programmes in areas related to Bio-CPS. First Degree and Higher Degree students will work with the various teams in TIH to solve industry relevant problems during their final year. The Doctoral programme would involve course work, qualifying examinations, seminars, thesis work, open seminars and thesis examination, thereby preparing the candidates to become independent researchers. Some of the focus areas for the Doctoral programme are:

- Cancer detection and drug discovery
- Viral Diseases like HIV and COVID
- Snake Venomics detection systems
- Chronic Kidney Diseases
- Cardiovascular Disease
- Malaria
- Diabetes
- Biosensor development

Table 9: Details of Fellowship Programmes

Level	Fellowship Amount
First Degree (UG)	INR 6,500 per month
Higher Degree (PG)	INR 13,400 per month
Doctoral	INR 31,000 – 35,000 per month

**for selection of fellowship students, additionally, any criteria set up the academic committee will be considered time to time (as required)*

Around 260 UG Fellowships, 60 PG Fellowships and 25 Doctoral Fellowships will be offered by the TIH over the first five years.

Minor Programmes:

Minor programme shall be offered during the summer break for UG/ PG students at an additional fee. The following is an indicative list of Minors that shall be offered by the TIH:

- Introduction to Omics - Genomics, Transcriptomics, Metabolomics and Proteomics
- Tools, Analysis and Application of Genomics, Transciptomics, Proteomics and Metabolomics
- BioMEMS
- Bioelectronics
- Micro and Nano-biosensors
- Emerging semiconductor Devices
- BioMicrofluidics
- Nanoengineering
- Smart BioSensors
- Flexible and wearable electronics
- Cyber physical systems
- IoT
- Pervasive Computing
- Theory of Machine Learning

Faculty and resources from institutions (BITS and other institutions) will also contribute towards these programmes and will be compensated as per guidelines (based on services offered).

Case Example

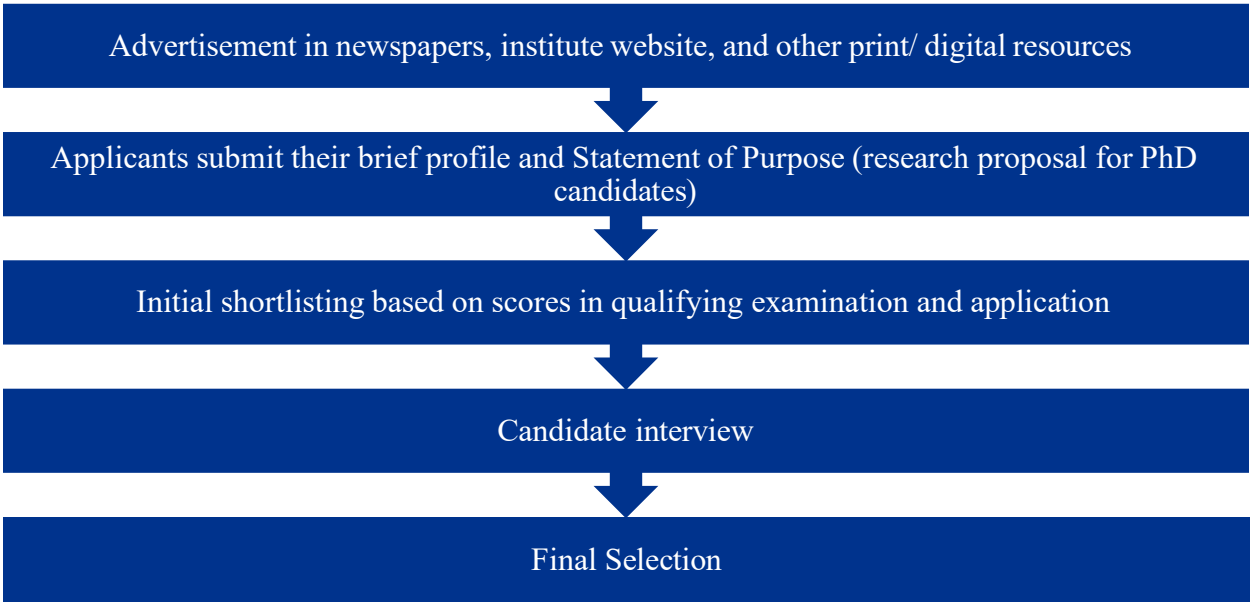
California Institute of Technology's Biotechnology Leadership Training Program is a pre-doctoral training program involving interdisciplinary research and coursework consisting of biotechnology workshops, an industrial internship, assistance with commercialization of research results, and biotechnology company site visits. The program exposes the participants to industrially relevant research questions and experimental techniques early in their graduate careers, in addition to the concerns that govern commercialization of biotechnology.

Source: California Institute of Technology website, accessed September 2020, http://trainingbiotechleaders.caltech.edu/#:~:text=An%20integrated%20training%20experience%20involving,Caltech%20students%20for%20industrial%20and

Fellowship Selection Process:

The candidates for UG, PG and PhD Fellowships shall be selected by the Academic Committee through a rigorous selection process to identify the right fit.

Figure 12: Fellowship Selection Process



Faculty Fellowship Programmes:

Six fellowships shall be offered in the first five years to faculty to engage heavily in research and teaching in the area of Bio-CPS. Their work shall complement the work being done at the TIH. The faculty shall be offered a top up fellowship amount of INR 35,000 per month. The duration of the fellowship will range from 3 months to 5 years.

Selection Process: The Academic Committee shall announce the opening of application for Fellowship faculty. Interested faculty need to submit a research proposal, along with proof of research work and teaching undertaken in areas related to Bio-CPS. The Academic Committee shall set the criteria for selection from time-to-time (as required).

Chair Professors:

The position of Chair Professor shall be targeted at eminent and experienced academicians working in areas related to Bio-CPS. Seven such positions shall be created, and a top-up salary of INR 50,000 per month shall be funded by the TIH. The responsibilities of the Chair Professor shall include:

- Advancing research in the field of Bio-CPS
- Providing inputs to launch industry relevant programmes
- Establishing mutually beneficial collaborations with other reputed institutions working in the same domain to facilitate faculty and student mobility, knowledge transfer and joint research

- Work with donor industries to identify their R&D and HRD requirements which can be addressed by the TIH

The selection of Chair Professors shall be done by the Academic Committee along with field experts. The selection shall be done on the basis of contribution to academic research and to the institute.

iii. Innovation, Entrepreneurship and Start-up Ecosystem

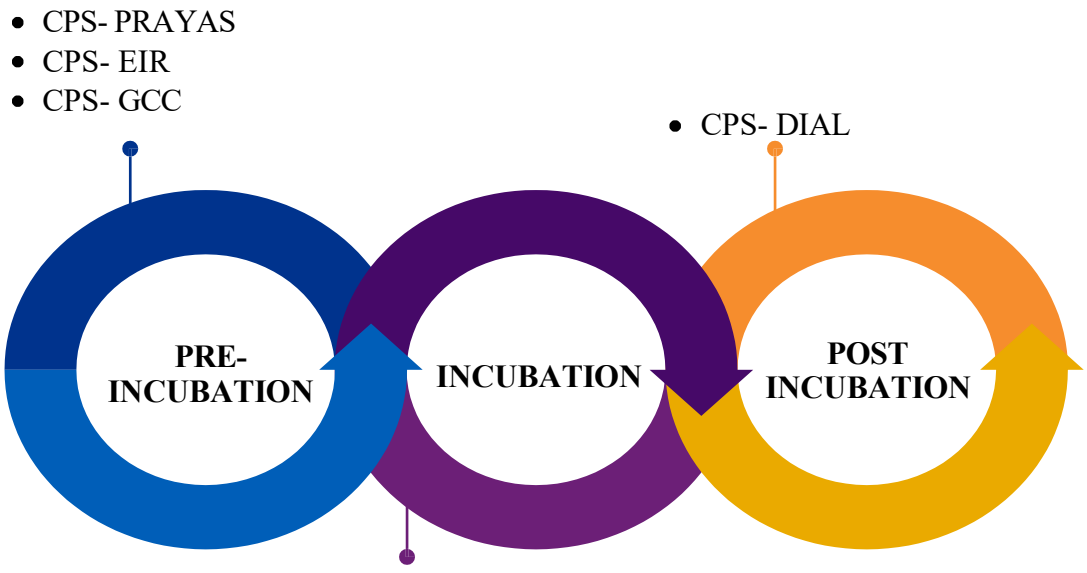
A Technology Business Incubator (TBI) shall be established within the TIH to promote startups working in areas related to Bio-CPS. The TBI shall focus on creating startups and spin-off companies in the area of Bio-CPS. The TBI will focus on all stages across pre-incubation, incubation and post incubation support.

Pre-incubation

CPS-Promotion and Acceleration of Young and Aspiring technology entrepreneurs (CPS-PRAYAS)

Under the CPS-PRAYAS program, innovators will be supported to turn their ideas in the field of Bio-CPS into proof-of-concepts. Innovators will be supported through physical infrastructure, technical guidance, business mentorship and a grant for converting their idea into a prototype. The Entrepreneurship Committee would setup a transparent screening mechanism for selecting the innovators based on relevance and the potential of the idea/ innovation. A prototype grant would be given to innovators basis the selection process.

Figure 13: Focus Areas of the TBI



- Incubation program
- CPS- SSS

The innovators shall be assessed based on the following parameters:

- Timeline for porotype development- working prototype within 18 months
- Progressing towards filing of IP or commercialization in the form of licensing or startup
- Funding/ Investment received for prototype development/ commercialization
- Expression of interest shown by manufacturers on the idea/ prototype/ product

CPS- Entrepreneur in Residence (CPS-EIR)

Around 24 entrepreneurs shall be identified over the first five years and supported through the following to convert their innovative ideas into viable businesses:

- Provide access to workspaces and university labs and other infrastructure for developing prototypes/ products and testing
- Seed support
- Consulting/ mentoring services
- Training programmes
- Operational support- marketing, legal, etc.

These EIRs will be given a stipend every month during the course of the program.

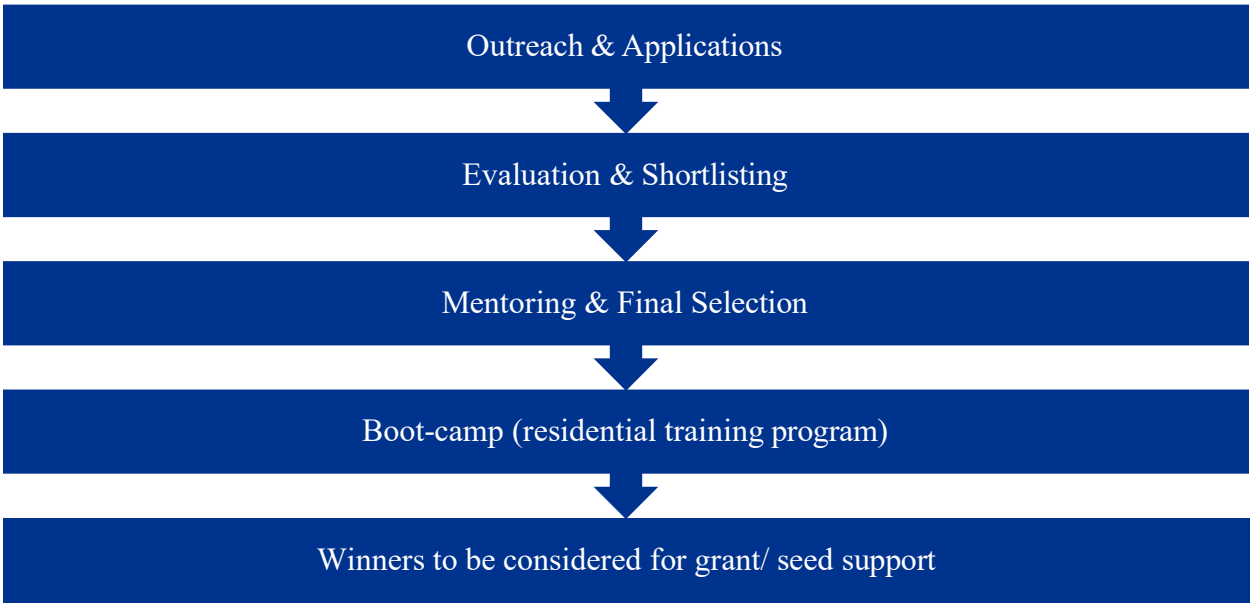
CPS- Grand Challenges and Competitions (CPS- GCC)

The TBI will organize competitions such as hackathons, ideathons, grand challenges, etc. based on a theme related to Bio-CPS every year in partnership with the industry. The grand challenges shall be aligned to the grand problems addressed by the TIH such as:

- Technologies for providing access to healthcare and real-time monitoring of patients
- Disease diagnostics and personalized medicines using advanced Bio-CPS technologies
- Technologies for venom detection and anti-venom production
- Assistive technology for the differently abled
- Technologies for improving cold chain logistics
- Technologies for improving food and water quality

These competitions shall act as a platform for the TBI to identify budding innovators who can be provided incubation support to scale up their ideas.

Figure 14: CPS-GCC Execution Process



Incubation

The TBI shall run an incubation program targeted at early stage startups. Each batch will go through a program of 18 months. The TIH targets incubating around 40 startups in the first five years. The incubation program at the TBI shall offer the following services:

Table 10: Service offering of TBI

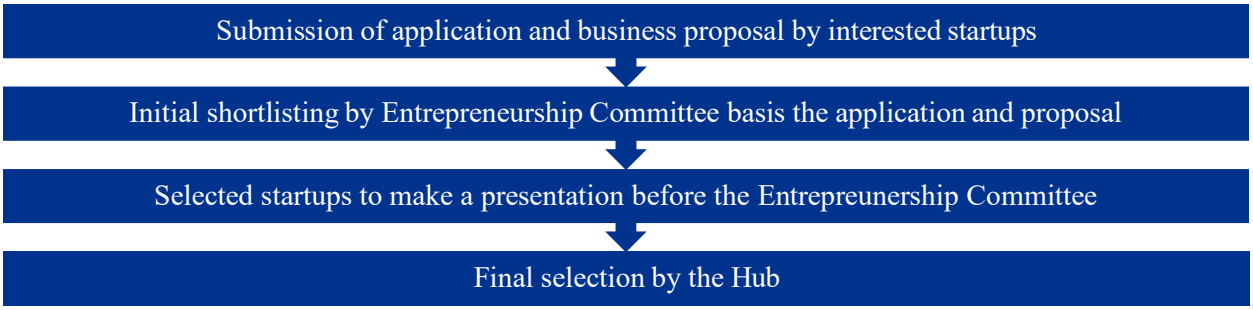
Services	Description
Infrastructure	• Individual basis: office space, computers, internet, telephone lines • Common: file server, fax machine, printer, photocopier, scanner, teleconferencing facilities, meeting/ conference room with projection equipment, library • BITS infrastructure: labs and equipment • Campus accommodation
Training programmes	• Training programmes in functional and domain areas • Experiences of successful companies- knowledge sharing platform
Funding	• Early stage grant funding • Equity stake in startups • Seed loans • Post incubation funding through a network of venture capitalists
Strategic support	• Market research, business plan and financial plan development support by BITS students • Consultancy, mentoring and coaching by BITS faculty and other professionals through BITS network
Operational support	• Corporate and legal assistance to the incubatee through internal assistance, BITS alumni or third-party involvement • Tie-ups with chartered accountants and other professional organizations as required • Links to the advertisement agencies all over India, which help the startups to advertise themselves • Discounted services such as cloud services, legal services through industry partners
Networking	• Events to help companies in networking and showcasing their technologies • Meetings with visitors of BITS Pilani (such as alumni, VCs, industry professionals) • Access to BITSAA technical network

Besides grant funding, the TBI will also have other funding instruments such as equity, royalty and soft loans. Incubatees will also pay rental charges for office space or any other services availed by them.

Selection Process:

The startups for incubation shall be selected basis a rigorous process executed by the Entrepreneurship Committee.

Figure 15: Start up selection process at TBI



Criteria for selection of startups shall include:

- Strength of product idea in terms of technology content, innovation, timelines and market potential
- Profile of core team/ promoters
- Intellectual property generated and the potential of the idea for IP creation
- Financial/ Commercial Viability and 5-year projections of P&L, Balance Sheet and Cash Flows
- Funds requirement and viability of raising finance
- Time to market
- Break-even period

There will be periodic evaluation of startups by the Entrepreneurship Committee to ensure that performance is up to the mark and targets are met.

CPS- Seed Support System (CPS-SSS)

Seed Support (INR 4–20 lakhs) would be given to deserving startups on a need basis to cater to early stage commercialization of innovations or technologies. The support shall be in the form of grant, debt, equity, or a combination of allh. The Entrepreneurship Committee shall set up a proper due diligence process to identify startups for providing seed support. The seed support shall primarily be used for the following activities:

- Product development
- Testing and trials
- Test marketing
- Consultancy/ mentoring services
- Any issues related to IPR
- Employing staff
- Any other area as deemed fit by the TBI

Post-incubation

CPS- Dedicated Innovation Accelerator (CPS-DIAL)

The Accelerator shall focus on fast tracking seed and early stage start-ups post incubation. The 3–6 month program will focus on the following objectives:

- Identification of business opportunities
- Validation of product ideas
- Identification and engagement with potential customers
- Building a scalable business model
- Product demonstration
- Team management
- Investor pitch

The startups will be provided 30–50 hours of mentoring and teaching every month. By the end of the accelerator program, start-up teams will arrive at a decision on whether to launch the product and go on to create startups that can scale. At the end of the program, the TBI will hold a demo-day wherein the participants shall be provided access to capital, networks, and customers. The Multiple stakeholders such as corporates, other higher education institutes, global experts and industry associations shall be involved by the Accelerator to support participating startups. The Accelerator shall run two batches every year with a participation of 10–15 startups in each batch. The TBI will look at best practices across the globe to run similar programs.

Through all these activities, the TIH aims to create around 9500 jobs over five years directly or indirectly.

Table 11: Job Creation by the TIH

Direct	• Manpower employed by the TIH • Research Associates working with the TIH • Employees of startups incubated at the TIH • Placement of students enrolled in academic programmes or skill development programmes offered by the TIH
Indirect	• Employment opportunities created in industries to develop products based on technologies developed by the TIH and marketing them • Employment opportunities created for operating and maintaining the tools/ devices/ systems developed by the TIH • Any other job created across the value chain in healthcare, agriculture, water and environment sectors due to the technologies developed by the TIH

4.2. Collaborations

To achieve its vision and mission, the TIH would forge collaborations with leading research and academic institutes, and industries for knowledge partnerships- international mobility and research exchange to add to its capabilities and position differently from its peers. Additionally, the collaboration with industry will allow the students to work on real time projects enhancing their learning experience.

- **Academic collaborations**

In order to consider itself as a leading innovation hub, TIH will have to gain expertise from various parts of the world. Student exchange will be facilitated to pursue collaborative research projects with the TIH. In addition to the exchange of students, partnerships will be created for faculty to be shared by the universities. The faculty will also be encouraged to pursue research opportunities with a focus to commercialize technology. Another option to consider by TIH is a partnership model of operations, knowledge sharing and academic support where the contribution and expertise of two difference institutes having diverse set of strengths come together.

- **Industry collaborations**

TIH will ensure that the along with faculty members from the academia, there will be industry members to provide practical exposure of CPS studies – they will be a part of the faculty and academic/ research council. This team will ensure continuous feedback from the stakeholders is incorporated to keep the skill development programmes relevant with the on-going trends. Industry will be invited to set up their R&D facilitates at the TIH and supported with respect to licensing, prototyping and commercialization of technology will be provided. Industry players will be able to leverage the faculty, student, infrastructure and research resources offered by the institute. Further, Industry players will be allowed to collaborate and interact with startups where they can promote, mentor and invest in the startups at the TIH incubator.

Table 12: Types of Partnerships with Academia and Industry

Type of Collaboration	Technology development	Human resource and skill development	Entrepreneurship development
Academic collaborations	• Knowledge sharing and academic support • Faculty and student exchange programme for research projects • Joint research initiatives • Joint usage of facilities	• Faculty and student exchange for research projects	• Student interns working with startups

Type of Collaboration	Technology development	Human resource and skill development	Entrepreneurship development
Industry collaborations (startups, MSMEs, large corporates)	• Programme delivery and research • Collaborative R&D • Engaging faculty for consultancy • Technology licensing • Investment in research infrastructure	• Internships/ placements to students • Upskilling of company employees • Adjunct faculty from industry • Sponsoring Chair Professors	• Investment opportunities in technology-based start ups • Mentorships

The TIH has received confirmation of partnership from the following organizations:

Table 13: Confirmed Partnerships

S. No.	Category	Name of Organization	Mode of Engagement
1	**Large corporate**	**CoreEL Technologies (I) Pvt. Ltd** #21, 7th Main, I Block, Koramangala, Bangalore 560 034 Tel: 91-80-4197 0400/2522 6775, Fax: 080- 30723638 Website: www.coreel.com	• Establish Centres of Excellence under university program umbrella with academic pricings and grants for Siemens, Ansys, Mentor Graphics and Xilinx Technology • Conduct industry and academia training programmes • Work jointly for research and patents • Brand building • Mobilize technology in the region
2	**MSME**	**Advanced Process Technology Pvt Ltd.** 23, Electronic Co. Op. Estate Ltd., Pune-Satara Road, Pune-411009. Maharashtra INDIA. **Phone:** +91 20 2422 3463 **Fax:** +91 20 2422 3461	• Protype development, equipment development, device fabrication, batch production, etc.

S. No.	Category	Name of Organization	Mode of Engagement
3	**Startup**	**Xcellence in Bio Innovations and Technologies Pvt. Ltd.** TBI Centre, BITS Pilani Hyderabad Campus, Jawahar Nagar, Shameerpet Mandal Dist, Hyderabad, Telangana 500078 https://xbitsinnovations.com/	• Lab scale validation and field trials
4	**Startup**	**Electrono Solutions Pvt. Ltd.** 513, Vinayaka Layout, Whitefield, Bengaluru, Karnataka 560066 https://electronosolutions.com/	• Design, Development, Manufacturing of Bio Automation systems such as sensors, signal conditioners, communication devices for Internet of Things, Network solutions, Digital Twin, Analytics and Software
5	**Startup**	**GnomikX Pvt. Ltd.** 222/39, Ambey Shri Colony, Adarsh Nagar, Ajmer- 305001	• Industry-academia collaboration, industry consultation and collaboration in any form within the domain of GnomikX
6	**MSME**	**Laxven Systems** Plot No. 188/A, Sector - III, Lane - 1, Phase - II, IDA, Cherlapally, Hyderabad - 500 051 http://www.laxven.com/index.html	• Design assistance • Assembly and testing assistance
7	**MSME**	**MTRC Industries** Plot no. 211/D, IDA Phase II Cheriapally, Hyderabad- 500051	• Technical support required for establishment of infrastructure • Mentor support
8	**MSME**	**CAL-ON Instruments** Phase-IV, Part Ida, Survey No 193, Cherlapally, Hyderabad, Telangana 500051 http://www.cal-on.com/	• Technical support

S. No.	Category	Name of Organization	Mode of Engagement
9	**Startup**	**SKY TechnoSolutions LLP** 3/11, Chanduri, 2nd Cross, 1st Main, Abhayadhama Road, Whitefield, Bangalore – 560066	• SDLC for Industry 4.0 Software solutions, Data Analytics, IT Infra & IT Security, Private/ Public & Hybrid Cloud solutions • Scientific inputs, technical expertise and research assistance for collaborative research Activities
10	**Startup**	**GrypTrx Solutions Pvt. Ltd.** 2-8-484, Hanamkonda, Warangal-506001	• Technical support required for establishment of infrastructure • Mentor support
11	**Startup**	**Nanobrid Innovations Pvt. Ltd.**	• Support in development of new technologies

(Consent letters are attached in Annexure 5)

Further, it is proposed that the following collaborations will be explored for the TIH:

Table 14: Proposed Collaborations

Faculty	Industry Partners	Academic Partners
Prof. Sunil Bhand	**Qmax Test Equipments Pvt Ltd.,** No 6, Qmax Building, ELCOT Avenue, IT Highway, Sholinganallur, Chennai 600119. India	1. Prof Sudhir Chandra (Coinventor in technology) Currently at Bennet University Noida 2. Prof Magnus Willander Department of Science & Technology Linköping University Sweden Email: magnus.willander@liu.se 3. Prof Bengt Danielsson Former Professor at Lund University Sweden Current Affiliation: Linkoeping University Sweden 4. Prof Paul Miller Univ of Leeds UK, Faculty of Biological Sciences Email: p.a.millner@leeds.ac.uk 5. Dr. R. Balasubramaniam Precision Engineering Division, BARC Mumbai Email: cwsbalu@barc.gov.in 6. Dr Nabarun Bhattacharyya Director, CDAC Kolkata Email: nabarun.bhattacharyya@cdac.in

Prof. Samit Chattopadhyay	1. DiagnoRite Innovative Healthcare 2. Amrita Therapeutics, Gujrat	**Existing:** 1. CSIR-IICB, Kolkata 2. CSIR-IICT, Hyderabad 3. CSIR-NCL, Pune 4. NCCS, Pune 5. Bose Institute, Kolkata 6. IIB-SP Pune University 7. NIV, Pune 8. B J Medical College (Via DiagnoRite) 9. IIT Kharagpur 10. IIT Goa
Prof. Deepak Chitkara		1. Prof. Sujata Mohanty, Stem cell facility, AIIMS, New Delhi 2. Prof. Krishna Mohan Poluri, IIT-Roorkee 3. Prof. Ram I. Mahato, University of Nebraska Medical Center (UNMC), Omaha, NE, USA 4. Prof. Harish Madhyastha, University of Miyazaki, Miyazaki, Japan
Prof. Ashis Das	1. Premier Medical Corporation, USA 2. Premier Medical Corporation Private Limited, India	**Existing:** 1. Prof. Shailja Singh, Jawaharlal Nehru University, New Delhi 2. Dr. Dinesh Gupta, International Centre for Genetic Engineering & Biotechnology, Delhi 3. Dr. Agam Singh, National Institute of Immunology, New Delhi 4. Prof. Sanjay Kochar, Sardar Patel Medical College, Bikaner 5. Prof. Arunansu Talukdar, Medical College, Kolkata **Proposed:** 1. Prof. Nirbhay Kumar, George Washington University, USA 2. Prof. John Adams, University of South Florida, USA 3. Dr. Pragyan Acharya, All India Institute of Medical Sciences, New Delhi, India
Dr. Syamantak Majumder		**Existing:** 1. Prof. Suvro Chatterjee, Anna University, Chennai, India 2. Dr. Andrew Advani, St Michael's Hospital, University of Toronto, Toronto, Canada 3. Dr. Darren Yuen, St Micahel's Hospital, University of Toronto, Toronto, Canada 4. Dr. Karina Thieme, University of São Paulo, São Paulo, Brazil

		5. Dr. Rohit Saluja, AIIMS, Bhopal, India 6. Dr. Jinjiang Pang, University of Rochester, Rochester, NY, USA **Proposed:** 1. Dr. Geun-Young Kim, National Institute of Health, South Korea 2. Dr. Masaomi Nangaku, The University of Tokyo Hospital, Tokyo, Japan 3. Dr. Imari Mimura, The University of Tokyo Hospital, Tokyo, Japan

A list of other potential organizations with which the TIH shall explore partnership are listed in the table below:

Table 15: Potential Collaborations to be explored for the TIH

Type	Organization	Location
Higher Education Institutions	Lund University	Sweden
	University of Leeds	UK
	Karolinska Institutet	Sweden
	Imperial College London	UK
	California Institute of Technology	US
	University of Virginia	US
	IIT Delhi	India
	IIT Roorkee	India
	IIT Jodhpur	India
	Indian Institute of Science	Bangalore, India
	All India Institute of Medical Science (Delhi and Jodhpur)	India
	Post Graduate Institute of Medical Education and Research	Chandigarh, India
	Jadavpur University	Kolkata, India
	University of Hyderabad	Hyderabad, India

Type	Organization	Location
R&D Institutes	SINTEF	Norway
	CSIR-Institute of Genomics and Integrative Biology	Delhi, India
	CSIR- National Institute of Oceanography	Goa, India
	CSIR- Central Electronics Engineering Research Institute	Pilani, India
	CSIR- Institute of Microbial Technology	Chandigarh, India
	CSIR-Indian Institute of Chemical Biology	Kolkata, India
	National Centre for Cell Science	Pune, India
	Raja Ramanna Centre for Advanced Technology	Indore, India
	Bhabha Atomic Research Centre	Mumbai, India
	Indian Agricultural Research Institute	Delhi, India
	National Dairy Research Institute	Karnal, India
	Centre for Development of Advanced Computing	Kolkata, India
Foundations	Piramal Foundation	Rajasthan, India
	Tata Trusts	Mumbai, India
	Bill & Melinda Gates Foundation	Delhi, India
Corporates	Biocon Ltd.	Bangalore, India
	Siemens Technology and Services Pvt. Ltd.	Bangalore, India
	Sattva MedTech	Bangalore, India
	Dr. Reddy's laboratories Ltd.	Hyderabad, India
	Tulip Diagnostics Pvt. Ltd.	Goa, India
	Molbio Diagnostics Pvt. Ltd.	Goa, India
	Birla Carbon- Aditya Birla Group	Mumbai, India
	Sun Pharmaceutical Industries Ltd.	Mumbai, India
	Cipla Ltd.	Mumbai, India

Type	Organization	Location
	Glenmark Pharmaceuticals Ltd.	Mumbai, India
	Abbott Healthcare Private Limited	Goa, India
	Serum Institute of India Private Limited	Pune, India
	Unichem Laboratories Ltd.	Goa, India
	IPCA Laboratories	Maharashtra, India
	Merck India Ltd.	Mumbai, India
	Kurade Agro	Goa, India
	Tata Consultancy Services	Gurgaon, India
	ABB	Bangalore, India
	Deccan Fine Chemicals Pvt. Ltd.	Goa, India
Government	Goa Pollution Control Board	Goa, India
	Goa Shipyard Ltd.	Goa

Hub & Spoke Model

The Hub will explore the possibility of engaging spokes to undertake collaborative research. The Hub will receive support for projects from grant making agencies and distribute among the Spokes accordingly.

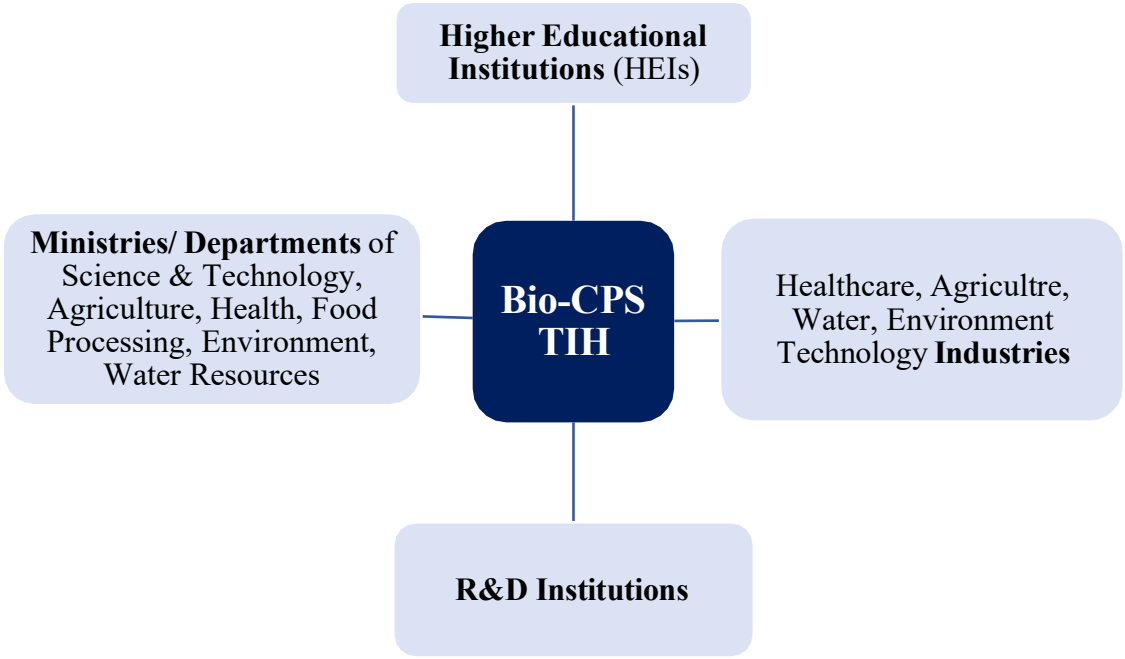
Some of the criteria to be considered for selection of spokes (institutions) are listed below:

- Institute ranking
- Faculty expertise in Bio-CPS and he related domain
- Existing research conducted in related areas
- Infrastructure availability to carry out research
- Academic and industry partnerships which can be leveraged for the project
- Proposed technology and alignment with the TIH

Targets shall be set for each spoke and their performance will be monitored through an MIS and periodic status update meetings.

NOTE: The HUB has now on boarded two SPOKES namely SASTRA deemed University and IIT Dharwad

Figure 16: TIH- Hub & Spoke Model



Further, the Bio-CPS TIH will also work with SAHs in the areas of agriculture and water, health and earth, ocean environment and pollution. It will also collaborate with other TIHs to leverage strengths and draw synergies by bringing together multifunctional experts from different institutes. Thus, the TIH at BITS will be the focal point for all knowledge creation and technology development for Bio-CPS across India

Hub-to-Hub Collaboration

The Hub will also collaborate closely with other Hubs with overlapping and complementary expertise such as IISc Bangalore etc. to accelerate the technology development The contacts has been initiated with hubs of interest.

4.3. Infrastructure Requirement

The infrastructure will comprise of lab infrastructure and academic, research and admin facilities. The facility will be of 20,000 sq. ft. out of which 10,000 sq. ft. is readily available. Further development of the facility will be undertaken based on future requirements. The TIH shall be spread across the three campuses of BITS at Goa, Pilani and Hyderabad. The Hub will comprise of 6 broad categories of facilities across the three campuses:

- Bio-CPS (Knowledge Generation and GLP facility)
- Biosensor technology platforms
- Fabrication Facility
- IoT lab and system security lab
- Bio-CPS incubation
- Printed Electronics Facility

Infrastructure for human resource development such as classrooms will be shared with BITS

Pilani.

(Detailed list of equipment is attached in Annexure 4)

5. Target Beneficiaries and Impact

The benefits of the TIH will be multifold and will create an impact across various segments, either directly or indirectly.

Figure 17: Key Beneficiaries of the TIH

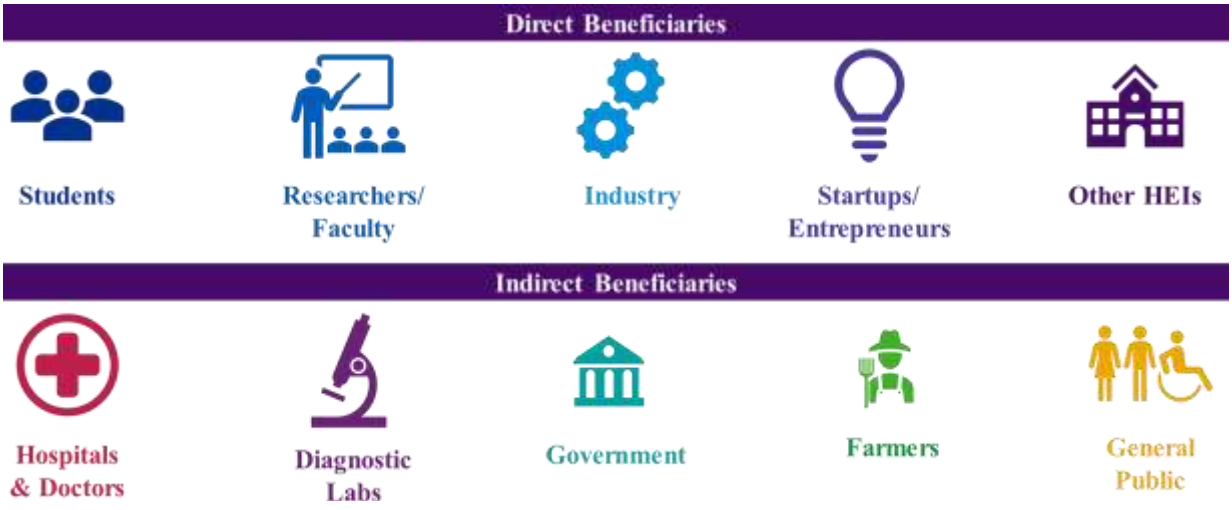


Table 16: Key Beneficiaries and their Impact

Beneficiary	Impact
	Direct
Students	• Fellowships for students to pursue UG/ PG programmes • Skill development and industry exposure in the emerging area of CPS, thereby improving their employability
Researchers & Faculty	• Fellowships for PhD students and faculty • Consultancy opportunities • Interaction and exposure to industry, enabling professional development
Industry*	• Access to the Hub's R&D centers, labs, testing facilities, etc. for research and prototype development in a cost sharing model • Opportunity to jointly bid for research projects with the university • Licensing of technologies developed by the Hub • Access to university faculty for consultancy • Availability of skilled students for internships/ work • Upskilling of company employees by the TIH • Utilization of CSR funds for the purpose of R&D • Representation in the Hub Governing Body or other sub-committees • Brand building among university community

Beneficiary	Impact
Startups/ Entrepreneurs*	• Workspaces for incubation • Access to the Hub's R&D centres, labs, testing facilities, etc. • Mentoring from Hub faculty • Incubator/ accelerator programmes • Access to investors and funds
Other HEIs (spokes/ collaborators)	• Access to the Hub's knowledge ecosystem- faculty, researchers, infrastructure, technologies, etc. • Mentoring by the Hub • Joint research opportunities • Faculty development programmes
Indirect	
Hospitals and Doctors	• Technologies for real-time, continuous and remote monitoring of patients, coupled with AI based system will enable quick decision making • Increased access to a wider range of patients • Easy access to medical history of patients • Reducing overload and exposure to healthcare workers
Diagnostic labs	• Non-invasive methods of diagnostics to improve customer experience and satisfaction • Reducing manual intervention and errors
Government	• Provide health related data to central repositories for effective monitoring • IoT based Technologies developed in the TIH will contribute towards the implementation of various building blocks of the National Digital Health Mission such as health ID, Personal Health Records, and Electronic Medical Records • Arsenic biosensor to be used to check contamination of water bodies, thereby enabling Municipal Bodies to supply clean and safe water to all households • Technologies developed and other activities of the hub to ultimately aid in achieving SDGs and other national targets
Farmers	• IoT enabled Biosensor technology platform for food safety and quality for use in various Industry sector • Creation of new start-up • Enhanced food safety and quality meeting SDG goals • Reduction of post processing losses in agriculture sector leading to food security goals

Beneficiary	Impact
	• Reduced economic losses due to quality control and hence better value to farmers' income • Detection of pesticide residues in water or crop residues in water and the development of a high throughput platform will help monitor food contamination, water contamination and also evaluate need for pesticides or dosage and hence reduce load on environment
General public	• Increased access to healthcare, especially for people located in remote areas • Timely and accurate diagnostics will influence critical therapeutic decisions, thereby altering the outcome in different health conditions • Reducing travel time and costs, especially for geriatric/ disabled patients • Access to clean and safe drinking water, which results in better health • Improved quality of life and productivity owing to general improvement in health

**Specific focus on sectors such as healthtech, pharmaceuticals, medical devices, wearables, diagnostics, clean water, food processing, etc.*

6. Legal Framework

Establishing a Section 8 Company and regulatory guidelines

The TIH will be incorporated as a **Section-8 company** (Non-profit Organization) under the Companies Act, 2013, Government of India. The TIH is proposed to be incorporated as Section-8 company primarily due to factors such as:

- proposed nature of business and services
- key benefits of being a Section-8 company, which include lesser stamp duty, optional to use suffix, separate legal identity, limited liability and no minimum capital required for incorporation, to name a few
- existing legal entities having similar nature of operations. (E.g.: IIT Delhi has formed I-Hub Foundation for Cobotics as a Section-8 not for profit company to manage their TIH)

The host institute will undertake all the necessary steps and follow the process in creation of the section 8 company. Memorandum of Association (MoA) and Articles of Association (AoA) will be prepared in alignment with the objective of the TIH and will be used for registration of the Hub.

The TIH will follow all the regulatory guidelines with reference to section 8 company requirement including but not limited to:

- formation of board and members (directors)
- preparation of financial statements and appropriate disclosures

- deploy appropriate governance mechanism and compliance with act / guidelines (as applicable)
- internal and external audit requirements
- obtain necessary forms, registrations etc. for operation of the Hub and perform its activities

A tripartite agreement shall be signed between the Section 8 company, the Mission and BITS, clearly stating the roles and responsibilities of each party.

Table 17: Proposed Roles and Responsibilities of Section 8 Company, Mission and BITS

TIH (Section 8 Company)	• Managing the overall operations and financials of the Hub • Recruitment of manpower • Housing the R&D facility • Undertaking R&D, entrepreneurship and skill development activities • Procurement of infrastructure • Signing of MoUs with collaborators or spokes
Mission	• Evaluation of the TIH against set targets and delivery • Fund dispersal
Host Institute (BITS Pilani)	• Provision of infrastructure • Any support services (such as IP office) • Student admissions and award of degree for academic programmes offered by the TIH • Monitor the operations of the Hub – as a part of the HGB • Share talent (Faculty, Students) and facilities for efficient functioning of the hub and assist in achieving the targets/ deliverables

Guideline for Intellectual Property Rights:

"**Intellectual property (IP)**" refers to creations namely inventions, literary and artistic works, symbols, names, images, and designs with potential use in commerce.

"**Intellectual Property Rights (IPR)**" refers to rights over Industrial property which includes- patents, industrial designs, know-how, trademarks over the trade names of the Institute, logos and together with fonts and colour combination, and geographical indications of sources; copyrights over literary and artistic work; integrated circuit (IC) layouts; and trade secrets which includes any confidential business information like the method and style of managing the Institute, teaching methods, sales methods, distribution methods, advertising strategies, etc.

TIH will create guidelines to protect the Intellectual Property of the Hub. In this section, we have highlighted few measures that will be taken toward IPR policy and Guidelines.

The hub will create an Intellectual Property Rights (IPR) Policy well within the guidelines, regulations and rules established by Government of India. Some of the key components of the IPR policy are listed below for reference:

- All IP should be owned by the Hub if the project is completely funded and executed by it.
- IP generated by projects at the host institution or any other entity, funded jointly by the Hub or other entities, will be jointly owned by the entities and the Hub, with revenue share of any benefits accrued from licensing or sale of such IP.
- Hub will have the exclusive right to commercialize (license, repackage or sell) the IP for the life of the IP available. The revenue share will be decided based on the nature of the IP and its translation into product or company. The revenue sharing will be transparent and decided on a case-to-case basis by the IP Committee and the Investment Committee, together with the mutual consent of the IP owners for maximizing the returns for everyone.
- Sponsored strategic research projects which fall into the roadmap decided by Hub by entities other than Hub will lead to joint ownership of IP. Hub will own exclusive rights to commercialize the IP. Participating entities can get non-exclusive rights to IP usage on a business model.
- Hub can also decide based on funding amount to give exclusive rights for IP which is time-bound to the Industry partners.
- Hub will take responsibility for the entire life cycle of the IP generated by Hub funding covering the filing for protection via patents, copyrights or trademarks and finding suitable licensees.
- In case of startup being formed out of the IP, License to IP and depending on the IP, there may be more than one startup formed and hub shouldn't favour one startup over other in access to IP. This along with ownership will be transferred to startup in lieu of equity, revenue or data sharing or a combination thereof. In case Industry partners are significantly

participating in IP creation, they can be given participation rights in the startup being formed via AI studio or Hub Venture Fund.

- If the startup who is assigned IP gets closed before funding, IP ownership and IP rights goes back to Hub, which can further license it out again.
- Hub can create special IP licensing policy for pre-existing startups in case they are collaborating in Hub projects in lieu of data sharing for innovation and research.
- In case Hub contributes significantly to IP creation along with pre-existing startup, it can take equity in lieu of transferring IP in exclusive fashion for a period of time via AI studio. Existing/prior IP at HI, in areas of relevance to the Hub, can be licensed to Hub for further commercialization with a revenue-sharing agreement on a case to case basis on the exclusive model.
- IP Policy will be updated each year by the IP committee with the approval of the Hub Governing Board.

IP relation between Host Institution and Hub:

- HI may offer any of its IP to be licensed to Hub free of charge for possible commercial exploitation.
- Any IP created by Hub (faculty from HI and staff of Hub) without any kind of intellectual contribution from Industry Partner shall be jointly owned by HI and Hub.
- Hub will have no objection regarding use of IP's owned by Hub as background IP for new IP generation which will be owned by Hub.
- Commercial exploits based upon IP owned by Hub as well as IP owned by HI will be shared equally between Hub and HI under the supervision of the Joint IP Management Committee of Hub and HI, taking into account all cost towards protection of IP and monetisation of IP.

IP relation in projects supported by mission:

IP generated from projects supported completely by the Hub with the funds provided by the Mission will be owned by Hub for commercial exploitation unless an alternate arrangement is specifically agreed upon by the parties.

IP in other conditions:

IP generated under all conditions not covered by the above clauses will be covered by the IP policy of Hub as per approvals of HGB and MGB.

(Note: These are preliminary guidelines and the Hub will constitute an expert member group to prepare/ finalize the policies of the hub. Wherever required, the Hub will seek support and services from BITS)

The Hub will set up processes to enable, review and comply ethical, bio safety, data security and privacy norms as per the guidelines of NM-ICPS. The Hub will also set up committees as and when required to understand and obtain regulatory clearances required for specific projects on a case to case basis.

7. Environmental Impact

CPS technology is soft computing in nature, hence there will not be any adverse environmental impact.

- Land acquisitions are not involved since the TIH will come up within the existing three campuses of BITS
- Environmental clearances are not involved since there will not be any construction activity
- Forestry clearances are not involved since the TIH will come up within the existing three campuses of BITS and there is no clearance of forest land
- Wildlife clearances are not involved since the TIH will come up within the existing three campuses of BITS and there is no impact on wildlife
- The Academics and Research committee will ensure that all the research undertaken are as per environment regulation of Government of India before commencing the research work

In addition, the TIH may create positive impact on the environment through the technologies developed as mentioned in the previous sections.

8. Technology

The TIH will focus on developing technologies with applications in healthcare, agriculture and environment sectors.

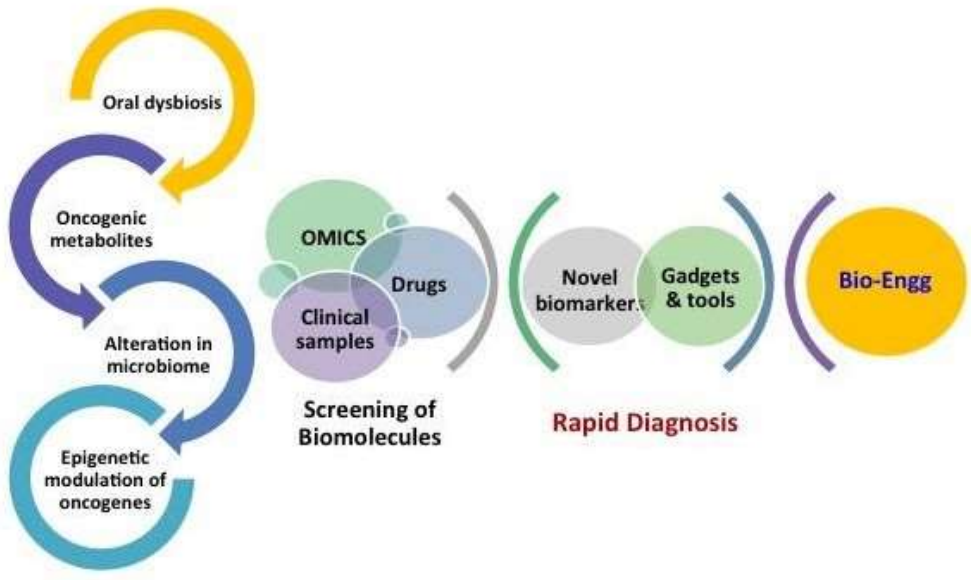
Table 18: TIH- Technologies

Area	Deliverable
Healthcare	• Novel biomolecules through Omics based approach | DNA, RNA, protein, metabolites, etc. | aptamers, antibodies, sequences • Deliver technologies / diagnostic systems/devices based on the identified novel biomolecules/sequences • Develop IoT based system for community health monitoring using antibiotic susceptibility test platform • Develop a COVID-19 diagnostic platform and identification of anti-COVID peptide and small molecule drugs • Develop IoT enabled plug-and-play smart devices focusing on better accuracy, cost-effectiveness, rapid detection, data analysis/transfer and security harnessing the core-competencies of Microfluidics, Nanoelectronics, Biology, IoT, and Security. These devices will include printed, wearable and implantable devices, point-of-care bio-diagnostic devices and environment monitoring devices • New editing technologies for diagnostics and Smart wearable sensors • New anti-cancer drug candidates for oral cancer.
Agriculture	• Demonstrate an IoT field sensor network for food supply chain monitoring for food toxin detection and reduce economic losses

	• Detection of fertilizers using sensors, resulting in reduced losses and enhanced income for farmers • Waste to wealth and increasing crop productivity with Bio-CPS component
Water and Environment	• Mapping of bio diversity such as coral reefs using under water network • Deliver an IoT based biosensor network for bacterial contamination and pesticide residue monitoring in drinking wate • Rapid detection of antibiotic residues in water • Waste management with Bio-CPS component
Startup/ innovation ecosystem	• Set up an incubator in Bio-CPS and support start-ups in the domain; leverage on BITS Pilani's startup eco-system along with network of corporate and academia collaborators • Create platforms for interaction between startups and industry for boosting collaboration and technology transfer of the innovative devices, tools and Systems.
HRD and Skill development	• Train at least 200 researchers /Scientists /Post Docs/Students in the area of Bio- CPS • Offer skilling and upskilling courses for professionals, job seekers and academia in Bio-CPS, its application and entrepreneurship • Increase awareness of issues related to Bio-CPS in the society.

These technologies shall be developed and delivered by an interdisciplinary team across the three campuses of BITS.

Figure 18: Major Subjects and Deliverables



The following list of projects have been identified to be undertaken in the next 5 years. The same shall be reviewed periodically and additional projects will be added from time-to-time.

Table 19: Proposed List of Projects to be Undertaken by the TIH

S.no.	Project Title	Description	Sector	Team	TRL Level (Start-End)
TECHNOLOGY DEVELOPMENT					
1	A field tested portable device for water pollution monitoring and use in health-sector for rapid diagnostics of bacterial infections in humans and by Real time AMR surveillance	A prototype device for detection of AMR and its validation at field level	Healthcare	**PI**: Prof. Suman Kapur, Senior Professor, BITS Pilani, Hyderabad Campus	TRL 5-7
2	Mobile/Web and AR-VR Based Cognition Tracking, Analysis and Rehabilitation for healthy and cognitively impaired people.	Development of a hybrid system and network of devices consisting of EEG, Eye tracker and Augmented Reality interfaces for able as well as differently abled members of Society. To infer mental health disorders (Autism & Dyslexia) and cognitive behaviour using eye tracker and eye movements in real time contributing to pervasive health monitoring	Healthcare	**PI**: Prof. Veeky Baths, Associate Professor, Cognitive Neuroscience Lab, Dept. of Biological Sciences, BITS Pilani K K Birla Goa Campus	TRL 3-7

3	Isolation of white blood cells in a microfluidic device with applications to Point-of-care diagnostics	The outcome of the work will be a fully functional micro-device for leucocyte (WBC) and plasma separation in point of care setting integrated a sensing platform for analysis of sepsis	Healthcare	**PI:** Dr. Siddharth Tripathi, Assistant Professor, Dept. of Mechanical Engineering, BITS Pilani K K Birla Goa Campus, Goa Co PI: Prof. Sunil Bhand, Senior Professor, Department of Chemistry, BITS Pilani K K Birla Goa Campus, Goa	TRL 2-6
4	Technology for detection and analysis of Aflatoxin M1 in milk and milk products	A biochip for testing of AFM1 in milk at dairy/central laboratory ii. Field trials of the developed technology with stake holders	Agriculture	**PI:** Prof. Sunil Bhand, Senior Professor, Department of Chemistry, BITS Pilani K K Birla Goa Campus, Goa **Co PI**: Dr. Gautam Bacher, Asst Professor Dept. of EEE&I BITS Pilani KK Birla Goa Campus, Goa	TRL 5-8
5	Biosensor platform for detection of Aflatoxin B1 in groundnut	A biosensor platform for detection of Aflatoxin B1 in groundnut will be further developed to make it field deployable for detection of AFB1 in groundnut/animal feed at storage site. Subsequently it will be integrated in to IOT and sensor network to provide decision support system	Agriculture	**PI:** Prof. Sunil Bhand, Senior Professor, Department of Chemistry, BITS Pilani K K Birla Goa Campus, Goa **Co PI:** Dr. Gautam Bacher, Asst Professor Dept. of EEE&I BITS Pilani KK Birla Goa Campus, Goa	TRL 3-7

6	Development of Prototype Biosensor for detection of bacteria (E. coli/ Shigella and Salmonella spp.) in drinking	To develop a highly specific and sensitive biosensor for detection of selected pathogens in potable water. The focus will be on establishing the protocols and its validation	Environment	**PI:** Prof. Utpal Roy, Senior professor, Biological Sciences, I BITS Pilani KK Birla Goa Campus, Goa **Co PI:** Prof. Sunil Bhand, Senior Professor, Department of Chemistry, BITS Pilani K K Birla Goa Campus, Goa; Dr. Gautam Bacher, Asst Professor Dept. of EEE&I BITS Pilani KK Birla Goa Campus, Goa	TRL 3-5
7	Novel field biosensor for detection of urea in agricultural runoff water	A novel field biosensor for detection of urea in agricultural runoff water will be developed. This in turn will be coupled to the reuse of water with known urea values. An IOT enabled sensor network will be developed to integrate the sensors with decision support system	Agriculture	**PI:** Prof. Sunil Bhand, Senior Professor, Department of Chemistry, BITS Pilani K K Birla Goa Campus, Goa **Co PI:** Dr. Gautam Bacher, Asst Professor Dept. of EEE&I BITS Pilani KK Birla Goa Campus, Goa	TRL 3-6
8	A novel transistor based biosensor for analysis of BPS in water	To develop and demonstrate a field effect transistor (FET) based biosensor for sensitive detection of Bisphenol S (BPS) in surface/ground water.	Environment	**PI:** Dr. Gautam Bacher, Asst Professor Dept. of EEE&I BITS Pilani KK Birla Goa Campus, Goa **Co PI**: Prof. Sunil Bhand, Senior Professor, Department of Chemistry, BITS Pilani K K Birla Goa Campus, Goa; Prof. Abhijit Pethe, Associate professor, Dept. Of EEE, BITS Pilani-K.K.Birla Goa Campus	TRL 3-6

9	Development of Solar Powered Cloud Based IoT Device for Agriculture Application.	To Develop (or adapt) a solar powered user-friendly cloud-based device capable of receiving and transmitting multiple sensor data. Solar Powered IoT system for agricultural application capable transmitting pH and Moisture date to cloud will be demonstrated.	Technology Platform-Agriculture	**PI:** Nitin Sharma, Associate Professor EEE, BITS Pilani-K.K.Birla Goa Campus **Co PI:** Prof. Sunil Bhand, Senior Professor, Department of Chemistry, BITS Pilani K K Birla Goa Campus, Goa	TRL 3-5

S.no.	Project Title	Description	Sector	Team	TRL Level (Start-End)
10	Design and development of a portable Bio-Cyber Physical System based microfluidic cell culture platform	To develop a standalone and integrated Lab-On-Chip (LoC) microfluidics-based system for cell and tissue culture studies. Development and integration of the following three subsystems: Culture Environment Regulation Subsystem, Microfluidic Cell Culture Devices with Integrated Detection capabilities. To Validate the developed system for establishing co-cultures and evaluating their response under different conditions (drug toxicities)	Healthcare	**PI:** Prof. Sanket Goel, Professor, Department of EEE, BITS Pilani, Hyderabad Campus	TRL 2-7
11	Cyber-Physical System Enabled Integrated platform with Microfluidic biofuel cell and Supercapacitor for powering and monitoring biomedical implants.	Development of a high-performance, reliable and miniaturized Microfluidic Enzymatic Bio-Fuel Cell (M-EBFC), to serve as an interruption-free power source for low-power devices leveraging nanostructured carbon materials functionalized bio-electrodes for enhanced enzyme stability leading to better performance than the existing systems.	Healthcare	**PI:** Prof. Sanket Goel, Professor, Department of EEE, BITS Pilani, Hyderabad Campus	TRL 3-7
12	Development of Underwater Acoustic Sensor Network for Monitoring of Coral Reef	Develop underwater sensor network for monitoring the regional coral reef non_intrusively Study of upwelling effect in Ocean and Observation of marine life	Environment	**PI:** Dr. Sarang C. Dhongdi, Asst. Prof., Dept of EEE, BITS Pilani K K Birla Goa Campus, Goa **Co PI:** Prof. K R Anupama, Prof., Dept of EEE, BITS Pilani K K Birla Goa Campus	TRL 3-5

13	Integrated Microfluidic/Miniaturized Electrochemical Sensing Platform for multiple bio-analytes	Develop a miniaturised platform for estimation of three important renal bio-analytes or biomarkers, namely – Urea, Uric Acid and Creatinine in blood and urine samples and to incorporate IoT based architecture for secure data availability to all involved stake holders for enhanced diagnosis or timely preventive measures.	Healthcare	**PI:** Dr. Satish K Dubey, Asst. Professor, Department of Mechanical Engineering, BITS Pilani, Hyderabad Campus **Co PI:** Prof. Sanket Goel, Professor, Department of EEE, BITS Pilani, Hyderabad Campus	TRL 3-7
14	A Multimodal and Cost-Effective Framework For Medical Diagnostic And Robotic Surgery Devices	To develop a multi-model and cost-effective framework, that can be used by medical device vendors to in turn develop a large variety of innovative medical diagnostic and robotic surgery devices (or products). The proposed hardware-software-sensor reference framework (which can also be called a platform) will be intended to be used by existing and new players in the medical device industry	Healthcare	**PI:** Dr. Kunal Korgaonkar, Assistant Professor, Computer Science and Information Systems (CSIS) Department, BITS Pilani, KK Birla Goa Campus, Goa **Co PI:** Prof. Vinayak Naik, Professor, Computer Science and Information Systems (CSIS) Department, BITS Pilani, KK Birla Goa Campus, India	TRL 3-6

S.no.	Project Title	Description	Sector	Team	TRL Level (Start-End)
KNOWLEDGE CREATION					
15	A thin film transistor biosensor for detection of endocrine disruptive compounds	To identify a transistor structure and suitable analyte candidate to measure the concentration of 17β-estradiol in surface water bodies .	Environment	**PI:** Prof Abhijit Pethe, Associate Professor, EEE, BITS Pilani K K Birla Goa Campus **Co PI:** Prof. Sunil Bhand, Senior Professor, Department of Chemistry, BITS Pilani K K Birla Goa Campus, Goa	TRL 1-3
16	Exosome cargo in severe malaria infections: Prognostic markers for severe disease/ Markers for detection of infection	To isolate exosomes from body fluids like plasma or urine from Plasmodium spp infected persons and investigate the protein or nucleic acid cargo for novel prognostic biomarkers.	Healthcare	**PI:** Prof. Ashis Kumar Das, Senior Professor, Department of Biological Sciences, BITS Pilani, Pilani campus **Co PI:** Prof. Anupama Mittal (Associate Professor, Department of Pharmacy, BITS Pilani, Pilani campus Prof. Shilpi Garg (Associate Professor. Department of Biological Sciences, BITS Pilani, Pilani campus	TRL 1-2
17	Bio-CPS Device Security	A lightweight cryptographic solution that will suit the Bio-CPS devices which is resource efficient and secure. The proposed approach is expected to safeguard the device against MITM attacks and counter replay/spoofing attacks.	Healthcare	**PI:** Prof. Chittaranjan Hota, Professor, Department of Computer sciences, BITS Pilani, Hyderabad Campus **Co PI:** Dr. Sameera Muhamed Salam, Assistant Professor, Department of Computer sciences, BITS Pilani,	TRL 1-2

				Hyderabad Campus	
18	Methylated cfDNA as a pathological biomarker for the development of a CRISPR/Cas based molecular diagnostic tool	cfDNA methylation status as a molecular marker for the progression of diabetes mellitus. The project will deliver novel sequences which will be tested for specificity to deliver a prototype novel Biosensor devices	Healthcare	**PI:** Dr. Deepak Chitkara, Associate Professor, Department of Pharmacy, BITS-Pilani, Pilani campus **Co PI**: Prof. Sunil Bhand, Senior Professor, Department of Chemistry, BITS Pilani K K Birla Goa Campus, Goa Prof. Ashis Kumar Das, Senior Professor, Department of Biological Sciences, BITS Pilani, Pilani campus	TRL 1-4
19	Identification of novel biomarkers in ovarian cancer and design of appropriate prognostic probes	To develop a cognitive deep learning model through machine learning that can predict treatment response in ovarian cancer patients. A probe to detect luminescence of Aggregation Induced Emission (AIE)-based compounds when bound to specific targets molecules is also under development.	Healthcare	**PI:** Prof. Rajdeep Chowdhury, Associate Professor Biological Sciences, BITS-Pilani, Pilani campus **Co PI:** Prof. Inamur R Laskar, Professor, Department of Chemistry, BITS-Pilani, Pilani campus, Prof. Shibasish Chowdhury, Professor, Department of Biological Sciences, BITS-Pilani, Pilani campus, Prof. Kamlesh Tiwari, Professor, Department of Biological Sciences, BITS-Pilani, Pilani campus	TRL 1-3
20	De Novo designed peptides scavenge SARS-CoV2 Spike-protein	Pre-clinical characterization of peptide-based ligand targeting the Spike protein of SARS-CoV2 for therapeutic intervention.	Healthcare	**PI:** Prof. Samit Chattopadhyay, Senior Professor, Department of Biological Sciences, BITS Pilani K K Birla Goa Campus, Goa **Co PI:** Dr. Subhrangsu Chatterjee, Associate Professor, Bose Institute, Kolkata, India.	TRL 2-4

21	Quick detection of early stage oral cancer by signature metabolites using Bio-CPS modules: Small molecule intervention with anticancer activities for oral cancer	Pre-clinical studies on Small molecule SCS-OCL-381, which stabilizes tumor suppressor pathways SMAR1/BANP, for developing it as an oral cancer drug. Screening for Saliva based metabolites as Biomarkers for Oral cancer for developing rapid diagnostics.	Healthcare	**PI:** Prof. Samit Chattopadhyay, Senior Professor, Department of Biological Sciences, BITS Pilani K K Birla Goa Campus, Goa **Co PIs:** Dr. Partha Chakrabarty, MD, Ph D; Scientist: CSIR-IICB, Kolkata; Dr. Srivari Chandrasekhar, Secretary, DST, Former Director, CSIR-IICT, Hyderabad; Prof. Sanket Goel, Department of EEE, BITS Pilani, Hyderabad Campus; Dr. Manas K Santra, NCCS, Pune	TRL-2-4
22	Development of detection system of pre-validated salivary biomarkers to determine the stages and type of cardiovascular disease	To optimize the detection system (aptamer or probe based) to measure the quantity of specific CVD biomarker in saliva followed by development of a portable prototype to detect the probe based measurement of biomarkers in biological samples	Healthcare	**PI:** Dr. Syamantak Majumder, Associate Professor, Department of Biological Sciences, BITS Pilani, Pilani campus **Co PIs:** Prof. Shibasish Chowdhury, Professor Department of Biological Sciences; Prof. Inamur R Laskar, Professor, Department of Chemistry; Dr. AR Harikrishnan, Assistant Professor, Department of Mechanical Engineering, BITS Pilani, Pilani campus	TRL 1-3
23	A Scalable Cloud and Edge-based Framework to Ease The Deployment of IoT-based Applications	Design and Develop a scalable backend framework, APIs for optimized data transfer and storage in the edge and the cloud and an administrator dashboard to monitor the resource consumption of the IoT based application deployed on cloud.	Healthcare Platform	**PI:** Prof. Vinayak Naik, Professor, Dept. of CSIS, BITS Pilani K K Birla Goa Campus, Goa Co PI: Dr. Arnab Kumar Paul, Assistant Professor, Dept. of CSIS, BITS Pilani K K Birla Goa Campus, Goa	TRL 1-3

24	Developing novel biomarker based test for Rapid diagnosis of Malaria infection as better alternate to current approaches	To develop proof of concept for two novel bio-markers specific to Plasmodium species and genus and develop an assay probes for detection and diagnosis of Malarial parasites	Healthcare	**PI:** Prof. Vishal Saxena, Professor, Department of Biological Sciences, BITS Pilani, Pilani **Co PI:** Dr. Sanjay K. Kochar, Professor, Dept. of Medicine, S. P. Medical College, Bikaner	TRL 1-3

(The Table above presents the key information on the identified strategic research projects from Host Institution and the details are attached in Annexure 2. The list of proposals shortlisted for support as outsourced activity to the two identified spokes are also included under Annexure 2)

9. Management

9.1. Governance

The TIH shall be governed by the **Hub Governing Body (HGB)**. The HGB will be the Apex body for the TIH providing overall supervision, control, directions and course correction in the implementation of the TIH. It shall be delegated with administrative, technical and financial powers. Functions of HGB include:

- Provide guideline for implementation and operation of the TIH
- Re-appropriation of the budget within the ceiling of sanctioned budget
- Hiring appropriate manpower as per industry standards
- Signing of Memorandum of Understanding (MoU) with international institutions and approving foreign visits for collaboration
- Establishing partnerships with industry and other academic/ R&D institutions
- Receive/support for projects in bio CPS to academic institutions, R&D institutions, industry, other funding agencies
- Create new TBI
- Create / Appoint subcommittee from time to time and mandate them on specific tasks of the TIH
- Strategic planning for the functions and growth of the Hub
- Coordination between the TIH, Host Institute and the Mission/ DST
- Ensure financial sustainability of the Hub, including attracting CSR funds
- Monitor/ review the performance of the TIH against set targets
- Represent the Hub in public forums
- Provide approvals for the following:
    - Processes and policies for the smooth functioning of the TIH
    - Infrastructure development
    - Any large-scale equipment procurement
    - Launching new courses or programmes
    - Selection process of students for granting Fellowships
    - Selection of startups for incubation and funding
    - Requests received from corporates/ startups to license the technologies developed by the Hub

The composition of the HGB is presented below:

Table 20: Composition of HGB

Vice Chancellor, BITS Pilani	Chairman
Academic representatives (not less than 2)	Members
Industry representatives (not less than 3)	Members
Mission Director (or representative), Mission Office, DST	Member
CEO, TIH	Member-Secretary

- The HGB members may appoint nominees to perform the above-mentioned functions from time to time
- The HGB members shall meet as often as required and at least once in 6 months
- HGB may appoint executives for the day to day operations of the TIH as per guidelines and policies
- HGB may nominate the Chairman of the board to take / change any decision and provide approvals on key / urgent requirements of the TIH and shall ratify the same on the subsequent board meeting

Sub-Committees

The HGB can appoint sub-committees from time-to-time and assign and/or mandate them appropriate technical streams or tasks for efficient implementation of the TIH. Some of the sub-committees that shall be formed are:

Figure 19: Proposed Subcommittees for the TIH

The functions and composition of these proposed sub-committees are detailed below.

Table 21: Functions and composition of proposed sub-committees

Finance Committee
Functions: • Provide recommendations to the HGB in ensuring financial sustainability and exploring new revenue streams • Prepare annual budgets of the TIH • Manage cash flow planning and ensure funds availability for financial sustainability • Maintain custody of all finances and ensure proper handling and dispersion of funds • Evaluate capital expenditure requirements and suggest strategies to secure them • Maintain up to date financial information in the PFMS system and follow the EAT module for expenditure monitoring and utilization • Ensure periodic audit of the Hub's accounts • Preparation of annual financial statements • Define finance related KPIs for the Hub to monitor and drive the financial performance • Conduct periodical review of the financial plans and budgets • Oversee procurement activities of the TIH • Oversee day-to-day financial activities such as general ledger, accounts payable and receivable, fixed assets, monthly and year-end closing, etc. • Periodic reporting of financial position to the HGB

- Oversee the preparation of annual reports, investor pitch packs and any other market facing collateral carrying financial information
- Identify institutional/ individual donors to attract funding

Composition:

- CEO, TIH
- CFO, BITS
- Core faculty team (any 2 members)

Academics and Research Committee

Functions

Academics

- Drafting selection criteria for Fellowships
- Evaluation of student applications for Fellowships and preliminary shortlisting
- Assessing market potential for launching new programmes
- Periodic evaluation of student performance to ensure quality standards
- Draft curriculum for new programmes
- Onboard adjunct faculty from industry or other reputed academic/ R&D institutes
- Identification and coordination with spokes/ other collaborating institutes for student and faculty exchange programmes
- Tracking of academic and research outcomes to ensure that targets are met
- Periodic reporting of R&D and academic activities to the HGB

Research proposal evaluation and Support

- Evaluate the research proposals submitted by faculty and shortlisting
- Evaluate proposals received from industry to set up their R&D in the TIH
- Assistance in preparation of grant specifications and bids including new proposals
- Support in applying for funding including costing, contract negotiation and liaison with partners
- Identification and coordination with spokes/ other collaborating institutes for joint research
- Analyse the ethical, environment and other regulatory impacts related to the project and suggest mitigation measures

Technology Transfer

- License negotiation and administration
- Assistance to research teams in filing for patents

Outreach

- Seek out for consultancy opportunities in the area of bio-CPS
- Assess the market potential of technologies developed by the Hub
- Marketing of these technologies to license to industry

- Coordinate with BITS Placement Cell to secure internship/ employment opportunities for graduating students
- Work with industry partners to identify their skilling needs in the field of Bio-CPS and design skill development programmes
- Organize knowledge dissemination events such as workshops, seminars, etc.
- Conduct faculty development programmes in the area of Bio-CPS
- Develop research publicity and promotion strategy via various print and online platforms
- Develop best practices through involvement in appropriate forums at national and international level

Composition:

- Faculty Coordinators of TIH
- Core faculty team (any 2 members)
- Dean Sponsored Research and Consultancy
- Dean: Academic- Undergraduate Studies
- Dean: Academic- Graduate Studies & Research
- Industry experts (2)
- CEO, TIH

Entrepreneurship Committee

Functions

Training and Monitoring

- Coordinate between incubates and BITS faculty to provide consultancy/ mentorship opportunities
- Performance evaluation of incubates
- Periodic reporting of entrepreneurship activities to the HGB

Entrepreneurship Support

- Evaluate applications from startups for incubation and preliminary shortlisting
- Identify funding opportunities for the incubates
- Work with BITS Placement Cell to assist startups in recruiting student interns/ employees
- Work with institutional partners to secure discounted services for startups such as IT, legal, etc.
- Tracking of entrepreneurship outcomes to ensure that targets are met

Outreach

- Organize training programmes for incubates
- Coordinate with the Industry Collaboration team at BITS to bring valuable industry connections to the TBI
- Organize innovation challenges and competitions
- Marketing and branding of the TBI, including event management

Composition:

- CEO, TIH
- Core faculty team (any 2 members)
- Head TBI
- Industry experts (2)

Infrastructure Committee

Functions:

- Infrastructure development planning
- Evaluate proposals from research team for equipment and supplies
- Ensuring complete utilization of spaces
- Managing the rental lease of co-working spaces
- Procurement management of equipment/ supplies
- Inventory management
- Evaluation and onboarding of vendors for construction
- Monitoring of construction activities to ensure adherence to budget and timelines
- Periodic review of infrastructure, equipment and supplies to ensure good working condition
- Periodic reporting to the HGB

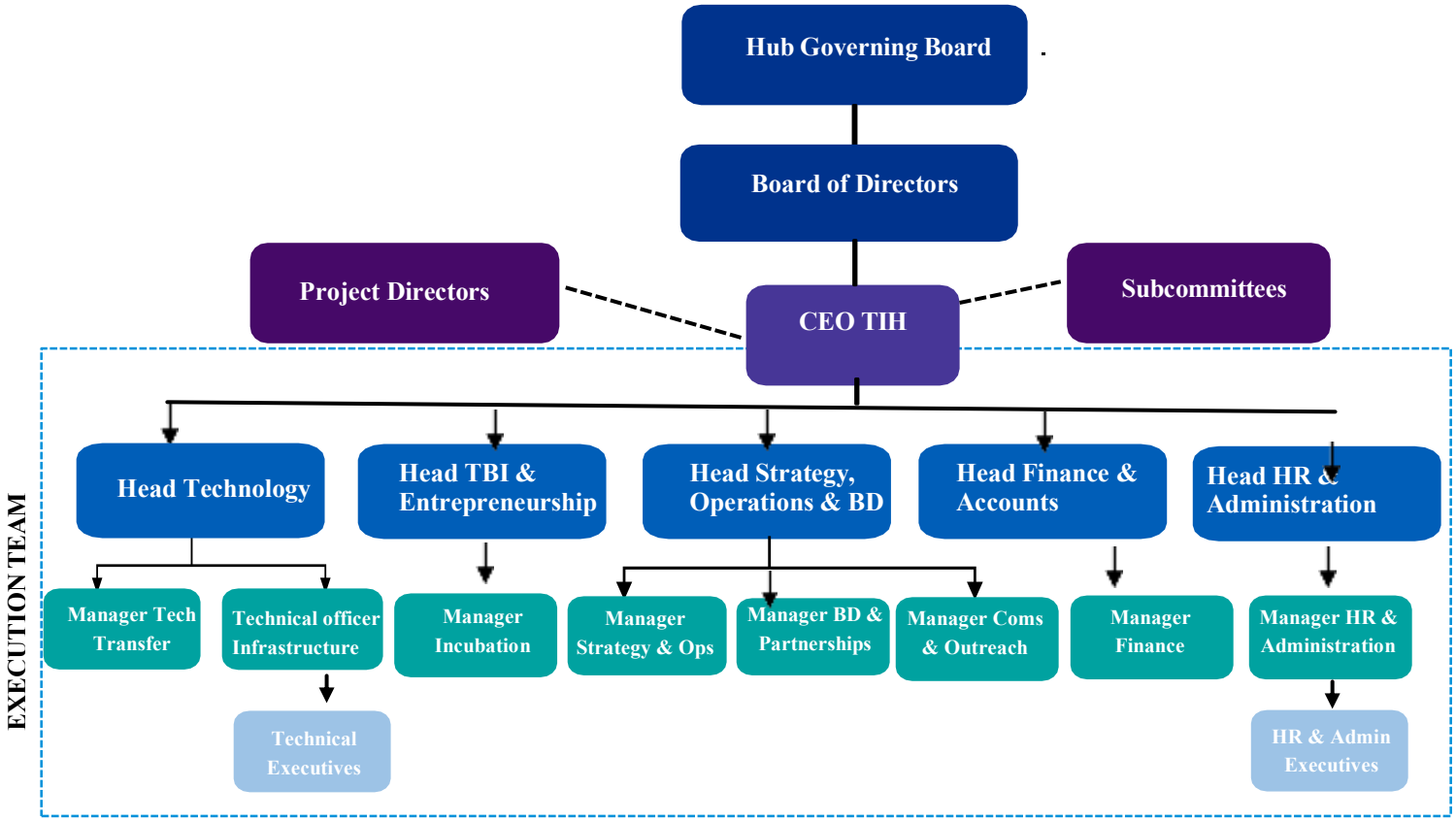
Composition:

- CEO, TIH
- Core faculty team
- Directors – Pilani, Goa & Hyderabad campuses of BITS Pilani
- Dean Administration, Pilani, Goa & Hyderabad campuses of BITS Pilani

9.2. People Requirement

The TIH shall be managed by an Execution Team reporting to a Core Faculty team as illustrated below:

Figure 20: TIH Proposed Execution Structure



Core Team: BITS BioCyTiH Foundation

Board of Directors:

1. Professor Souvik Bhattacharyya, Vice Chancellor, Chairman
2. Professor S K Barai
3. Professor G Sundar
4. Professor Suman Kundu

Project Directors:

5. Professor Sunil Bhand, Coordinator (Engineering)
6. Professor Samit Chattopadhyay, Coordinator (Biological Sciences)
7. Professor Syamantak Majumder, Coordinator

Executive Team:

8. Dr. Satya Prakash Dash, CEO,
9. Dr. Saishyam Narayanan, Chief Manager Strategy, Operations and BD
10. Dr. Sandeep Raut, Manager Incubation

Core Faculty Team

The Core Faculty Team will comprise of the following members:

Table 22: Details of TIH faculty team

#	Name	Designation	Dept.	Area of Expertise	Dedicated Faculty (Y/N)	Young Faculty (Y/N)	Fellow of Academy (Y/N)
1	Prof. Sunil Bhand	Professor & Dean, Sponsored Research & Consultancy	Chemistry	Micro/nano Biosensors, Diagnostics, IOT based sensors, agri and environment tech.	Y	N	N
2	Prof. Samit Chattopadhyay	Sr. Professor and Chair Professor	Biological Sciences	Healthcare, Cancer detections, HIV, Immunomodulator discoveries	Y	N	J C Bose National Fellow, TWAS, FNA, FNAsc, FASc, FAScT, FMASc
3	Prof Ashis K. Das	Professor	Biological Sciences	Malaria, Diagnostics	Y	N	N
4	Prof Vinayak Naik	Professor	Computer Science & Info Systems	IOT devises, wireless sensor networks	N	Y	N
5	Prof Abhijit Pethe	Associate Professor	EEE & EI	Microelectronics, devices	N	Y	N
6	Prof Anil Gaikwad	Associate prof	Pharmacy	Drug delivery	Y	Y	N
7	Dr Syamantak Majumdar	Asst. Professor	Biological Sciences		Y	Y	N
8	Dr Gautam Bacher	Asst Professor	EEE & EI	Biosensors, devise fabrication, instrumentation	Y	Y	N
9	Prof Sanket Goel	Associate Professor	EEE & EI	Micro/nano fabrication, MEMS devises	N	Y	N
10	Dr Nitin Sharma	Asst. Professor	EEE & EI	Wireless Sensors, instrumentation	N	Y	N
11	Dr Siddhartha Tripathi	Asst Professor	Mechanical Engg.	Microfluidics and MEMS based sensors	Y	Y	N
12	Dr. Deepak Chitkara	Asst. Professor	Pharmacy		Y	Y	N

Summary of roles and responsibilities of all team members

Table 23: Roles & Responsibilities of Core Faculty Team

S. No.	Name of Team Member	Area of Expertise	Roles/ Responsibilities
1	Prof. Sunil Bhand	Biosensors and devices	Overall implementation of project and Coordination of Interdisciplinary Engineering & Technology projects.
2	Prof Samit Chattopadhyay	Healthcare, Bioinformatics, diagnostics and biomarkers of cancer, COVID and other diseases, etc.	Overall implementation of project and monitoring the progress of all Knowledge generation projects
3	Prof Ashis Das	Malaria Diagnostics	Implementation of project on knowledge generation and facility creation at Pilani
4	Prof Anil Gaikwad	Proteomic and Genomics	Implementation of facility creation and knowledge generation at Pilani
5	Dr Syamantak Majumdar	Omics	Implementation of facility creation and knowledge generation at Pilani
6	Dr Dipak Chitkara	Gene Delivery, miRNA, CRISPR/ Cas system, nanotechnology	Implementation of facility creation and knowledge generation at Pilani
7	Prof Abhijit Pethe	Micro Nano devises	Implementation of facility creation for fabrication and prototyping at Goa
8	Prof Sanket Goel	Microfabrication, devices	Facility creation and implementation of prototyping and devise fabrication facility at Hyderabad
9	Prof Vinayak Naik	IoT and sensor networks	Implementation of IOT facility and sensor network team for cyber physical systems development
10	Dr Gautam Bacher	Biosensors and devices	Implementation of sensor development facility for sensors
11	Dr Nitin Sharma	EEE	Implementation of IOT facility and sensor network team for cyber physical systems development
12	Dr Siddhartha Tripathi	Mechanical Engineering	Implementation support for prototyping facility development

Execution Team

The Execution Team shall be headed by the CEO, who will be supported by a Technical Officer. The TIH will be organized into three facilities- Generic, Fabrication and TBI. Senior Technicians will be managing the technical facilities and will be reporting to the Technical Officer. TBI will be managed by a Head reporting to the CEO.

Table 24: Execution team responsibilities and qualification

Role	Description	Qualification
CEO, TIH	• Monitor performance of the TIH against set targets • Oversee all activities to ensure the desired goals are achieved and consistent with overall vision and mission of the TIH • Identify new revenue generation opportunities • Conduct periodical review of the budgets • Oversee the day-to-day operations of the TIH and ensure productivity and operational efficiency • Undertake business development activities for the hub to ensure continuous projects and operation • Set up processes and policies for Hub operation • Coordinate call for research proposals, startup applications and fellowship applications • Supervise manpower recruitment process • Supervise and guide the Execution Team and evaluate their performance • Maintain awareness of recent developments in the field of Bio-CPS • Establish and maintain deep rooted partnerships/build relationships with industry, corporates and leading global educational institutes • Represent the TIH in public forums • Identification of potential investors/ donors and formulation of business plans to attract funds	• Master's degree • 12+ years of relevant experience, with minimum 3 years in a leadership role • Prior experience in a research role in academic/ R&D institutes or industry (preferred) • Entrepreneurial mind set • Outstanding analytical, negotiation, communication and interpersonal skills

Role	Description	Qualification
	• Make periodic status update report to the Hub Governance Body on the operation and progress against deliverables	
Technical Officer	• Planning and procurement of equipment and arranging the installation including site readiness with the vendor • Make plan of recruitment of technicians for running knowledge generation/Fabrication facility • Supervision of technician, supervise/ coordinate tasks execution of device fabrication and knowledge generation facility • Overall commissioning, accreditation of the labs (NABL, ISO etc.) • Coordinate with CEO/MD for business processes with Industry/MSME • Provide technical support to startups for their activities on TIH lab facilities • Overall maintenance and sustenance of experimental facility and other labs of the HUB • Coordinate financial reporting to CEO/MD/HGB	• ME or M Tech in Engineering with at least 5 years of relevant experience in maintenance of central R&D facility or Industry experience in maintenance/execution of Sophisticated instrumentation facility • Industry experience will be preferred
Head Strategy, Operations and Business Development (SO&BD)	• Identifying, qualifying, and securing business opportunities and coordinating business generation activities • Building business relationships with current and potential clients • Identify potential clients for technologies developed by BITS and assist in marketing and license negotiation • Identify consultancy opportunities for the faculty associated with the TIH • Identify and approach potential donors such as foundations, CSR funds, alumni, etc. • Lead acquisition and conversion for offering skill development programmes	• Bachelors in any field; MBA is preferred • Overall 8 to 10 years of experience in B2B sales and developing marketing strategies • Excellent communication and interpersonal skills and must have an intimate knowledge of B2B Sales process

[51] *To be hired in Year 3*

Role	Description	Qualification
	• Identify potential clients such as industry and MSMEs for infrastructure monetization and testing services • Organize visibility exercise such as seminars, networking events, etc. • Creating informative presentations; presenting and delivering information to potential clients at client meetings, industry exhibits, trade shows, and conferences • Represent the Hub in public appearances and in local organizations; develops professional relationships with other HEIs, corporates and other channel partners driving partnerships with the TIH	
Head TBI	• Designing and managing incubation and accelerator programs • Develop and implement new service offerings for the incubatees • Oversee day-to-day administrative and operational functions of the TBI • Monitor the progress and performance of startups against set targets • Build and maintain strong working relationships with startups, entrepreneurs, mentors, investors, etc. • Undertake brand building activities for the TBI • Manage outreach communications such as website, social media, newsletter, etc. • Coordinate between BITS, TIH and the TBI to offer coaching, training and mentorship services to the incubatees • Organize events to facilitate collaborations, technology tie-up, business development	• Engineering graduate with MBA • 3-4 years' experience working in an entrepreneurial environment
Project Coordinator	• Oversee and plan interdisciplinary work with experience in translation research • Conceptualization, ideation, implementation with innovative ideas related to the subjects of the project	• PhD in Natural Sciences and Engineering with Post-doctoral experience in biological science • Experience and vision in productization,

Role	Description	Qualification
	• Help in teaching and training in healthcare related programs	infrastructure development and regulatory matters • Long term experience in innovation and start-up culture
Senior Technicians	• Participate in installation, servicing and commissioning of equipment • Oversee day to day operation of the fab lab and maintenance of equipment in the lab • Supervise and mentor students and users of the lab, provide technical assistance to users • Ensure that equipment and software in the lab is properly maintained and is in proper working condition • Provide routine maintenance of equipment in the lab • Repair equipment as needed and maintain inventory of consumables • Assist in projects of users, provide guidance in development of the projects and direct them to appropriate tools and resources • Review, modify and rewrite existing processes to optimize and adapt to fit new requirements	• BE / BTech with 5 years of experience (or) ME / MTech with 3 years of work experience • 2 years of experience in setting up, operation and maintenance of fabrication facility
Admin Executive/ Executive Staff TBI	• Perform clerical duties such as mailing, placing orders and answering calls • Assist in preparation of any documents (budget, presentations, newsletters, etc.) as required by the HGB or sub-committees • Arrange meetings by reserving rooms and managing refreshments • Maintain accurate records and enters data • Assist with organizing events when necessary • Aid with guest/ visitor reception	• Bachelor's degree in any field • 1-2 years' experience in a related field • Good mathematics skills • Proficiency in Microsoft Office

Role	Description	Qualification
	• Organize and maintain office common areas • Organize travel by booking accommodations and reservations needs as required • Maintain office equipment • Resolve office-related malfunctions and respond to requests or issues • Count, sort and check in incoming supplies and verify against requisitions, shipping notices or invoices • Handle and manage stock of supplies in an organized manner and maintain inventory records • Check inventory periodically to determine reordering needs	

10. Finances

The Hub will receive a funding of INR 125 crores over five years from the Mission. A major part of this funding will be utilized for non-recurring expenses (~60%) in procuring and establishing R&D infrastructure. The other key area where the funding will be utilized is for the recurring expenses / opex (~40%) which includes technology development / research related expenses, training related expense and other overheads. The Hub will take up various revenue generating activities across the verticals of R&D, human resource development and entrepreneurship to ensure financial sustainability on the longer run and has charted out a plan. Additionally, the hub is eligible to receive gifts or donations by tapping into CSR funds, donor funding, etc. to scale up operations in the later years.

Key financial estimates of the hub are presented below which are calculated for the first five years of operation of the TIH.

10.1. Sources and Application of Funds

Grant from DST is a significant source of funds till Y5. However, it is estimated that the Hub will attain financial sustainability in Y6-Y7. Around 60% of the funds are deployed for non-recurring expense (capex) and around 40% for recurring expenses (operational expenses deficit). The projected sources and application of funds for the proposed TIH is presented in the below table.

Table 25: Estimated sources and application of funds for TIH for first 5 years (INR Crore)

Budget Head	Budget in INR Crore					
	Y1	Y2	Y3	Y4	Y5	Total
Recurring Expenses	7.25	12.5	19.75	12.5	7.75	**59.75**
Non-Recurring Expenses		17.5	20.25	17.5	10.00	**65.25**
Total	**7.25**	**30.00**	**40.00**	**30.00**	**17.75**	**125.00**

10.2. Revenue estimates

The total estimated revenue for the TIH is growing from around INR 1.8 crores in Y2 to around INR 14 crores in Y5. The major sources of revenue are trainings to human resources, revenue from start-ups, asset monetization, consultancy, sponsored projects and testing services. The TIH is also eligible to receive gifts or donations from CSR funds, donor funding, etc. The year on year revenue of the hub in shown below:

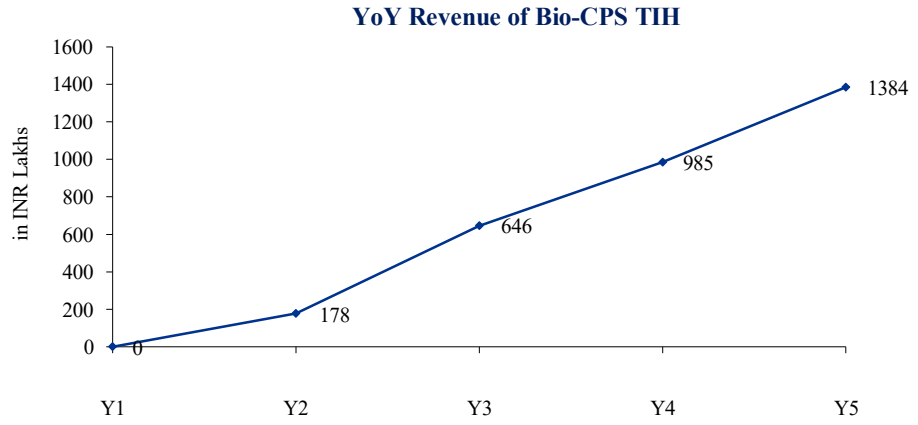


Figure 21: YoY TIH Revenue (Y1-Y5)

The hub will leverage its resources and talent for the revenue creation. The hub will explore / undertake the following revenue options for the financial sustainability in the longer run.

- **Human Resource Development:** The TIH will conduct short-term or long-term skill development/ training programmes in online/ in-person/ blended mode from Y1 onwards targeted at industry professionals, students, faculty, entrepreneurs, etc. The hub will undertake the services of the host institution and other experts for delivery of the training program. There will be a revenue sharing agreement, or a fee arrangement will be made on such cases.
- **Revenue from start-ups:** The revenue from start-ups incubated at the Bio-CPS TBI shall be of three types as mentioned below. The returns from start-ups have a longer gestation period and benefits will be realised from Y7 onwards.
    i. ***Equity stake in start-ups***
    ii. ***Rent for availing space or services: Market rate rental*** will be charged for availing space or other support services

iii. ***Seed loans:*** Interest income on seed loans provided to startups (proposed at 6% p.a.)

- **Monetization of TIH's assets**: The TIH can monetize its assets, i.e. technologies and equipment. Some of the ways are as follows:
    - **Technology commercialisation –** Royalty Charges. Hub Governance Committee will determine the share between the parties involved in technology development / commercialisation
    - **Usage charges will be levied on equipment usage** from internal users, external academic users and start-ups, external users from government R&D labs and MSMEs, and industry. The equipment will be primarily used for identified projects, however, will also be utilised for other stakeholders' requirement outside the hours of regular operations (as permissible in the guidelines). The charges will be determined by the committee for various types of users from time to time
- **Consultancy and sponsored projects:** The revenue from consultancy is expected to be generated from consulting/ mentoring services provided by TIH's faculty and expert. The Hub may also apply for other sponsored projects funded by government schemes (such as by DBT, ICMR) or foundations. Further, the TIH will look to partner with large industry players to undertake joint research projects within the TIH and provide technical assistance for the same.
- **Testing services:** The TIH will offer testing services to industry players with its lab facilities and equipment.
- **Grants:** The TIH is expected to generate funds from other sources such as tapping CSR funds, donor funding etc.
- **Other revenue:** This will include registration fees, participation fees etc. for any events conducted by the hub such as project exhibitions, seminars, conferences, symposiums, etc.

The share of the various revenue sources in Y5 is illustrated below:

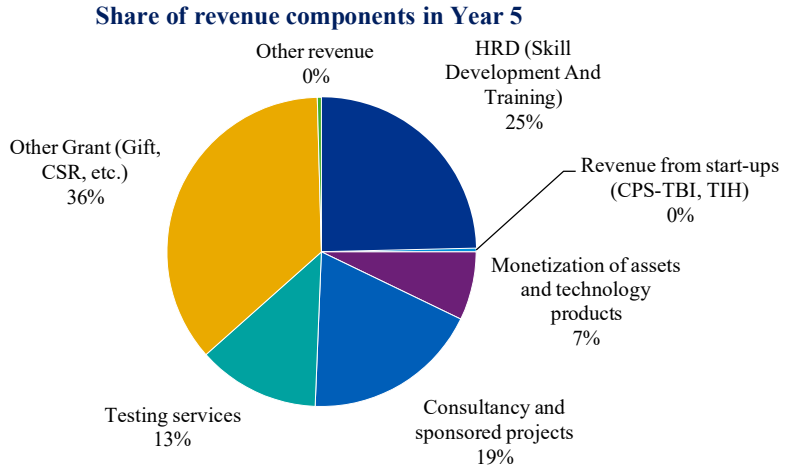


Figure 22: Revenue Sources in Y5

10.3. OPEX estimates

The total operational expenses for TIH is increasing from INR 7.25 Crore in Y1 to around INR 19 Crore in Y5. The major sources of operating expenses include manpower, training cost, grants for fellowships and EiRs, collaboration, external projects and other overheads. The year on year estimates of operating expenses in shown below:

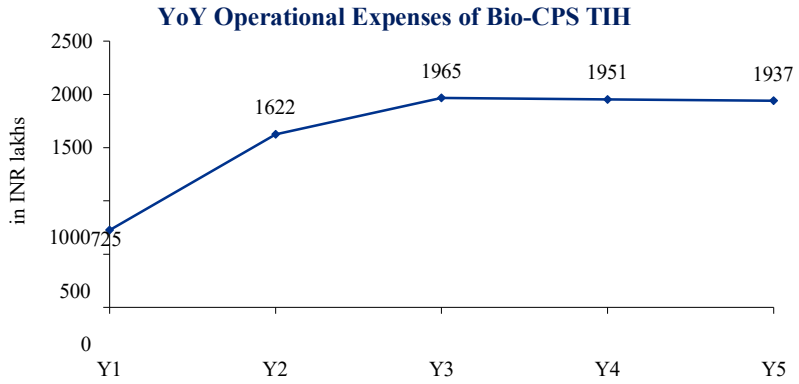


Figure 23: YoY Operating expenses of the TIH (Y1-Y5)

Some of the key heads of operational expenses of the hub are as follows:

- **Manpower expenses:** The manpower expenses of the hub consist of:
  - Project / Hub personnel: This includes the salary for the positions within the Hub including CEO, Head-TBI, Senior technicians, project staff etc.
  - External experts: Hub will appoint need based subject matter experts from academia and industry for activities of the hub
- **Human resource development (Skill Development and Training cost):** Cost associated in creating and delivering skill development programmes including trainer cost, training and technology expenses.
- **Grants for fellowships and EiRs:** This includes- (i) fellowships offered for graduate, postgraduate, doctoral, faculty and Chair Professors, (ii) a stipend for EiRs
- **Collaboration expenses:** This refers to the expenses related to partnering with institutions / organisations in India and abroad
- **External projects:** This includes expenses associated with call for proposals in the identified areas of the TIH. The hub will ensure a mechanism to track the expenses of the spokes (institutions) and the deliverables in such cases
- Project related expenses: This is one of the key expenses head of the Hub and comprises of:
  - **Prototyping and technology development costs:** This includes expenses for development of technology and related products
  - **Technology projects related cost:** This refers to the costs associated with the projects identified by the TIH. This includes consumables, field study, outsourcing costs etc. for the projects
- Overheads and other expenses:

- **General administration and facility management expenses:** This includes general and administrative expense, building space and equipment maintenance, power and utilities, and consumables.
- **Other costs:** These include travel costs, marketing / visibility expenses and any other miscellaneous expenses.

The share of the various operating expenses in Y5 is illustrated below:

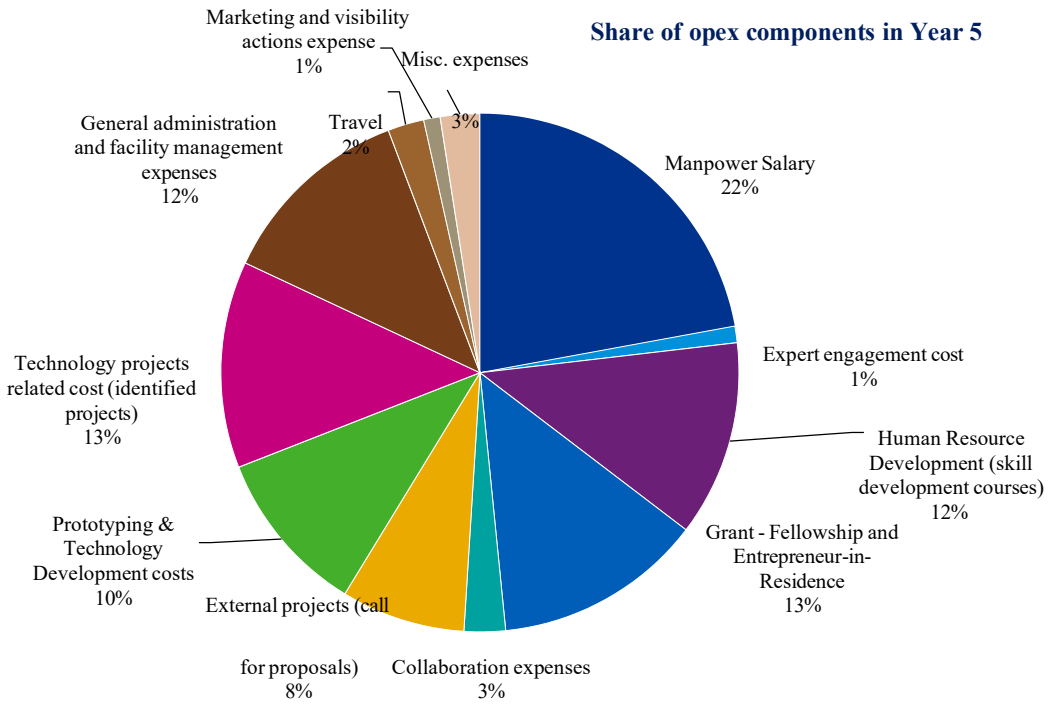


Figure 24: Share of Operating expenses of the TIH in Y5

10.4. CAPEX estimates

The total capital expenditure (non-recurring expenses) proposed for the TIH is estimated to be in the tune of approximately **INR 74.92 crores** for the period of 5 years for lab R&D infrastructure, Technology Business Incubator and other research / training / entrepreneurship facilities set to achieve the objectives of the hub**.**

Table 26: Summary of CAPEX estimated for TIH (in INR lakhs)

Key facility / CAPEX	**Cost (INR lakhs)**
Bio-pharma equipment (Knowledge Generation)	2225
Bio facility (Knowledge Generation)	1200
Biosensor Technology Platforms	425
Fabrication facility (incl. prototyping)	2135
IOT Lab and System security lab	250

Key facility / CAPEX	**Cost (INR lakhs)**
Bio-CPS Incubation facility	437
Addition/ replacement of equipment	395
Start-up (Entrepreneurship)	425
TOTAL	**7492**

11. Time Frame

The TIH will start functioning from the day the fund, released by DST, is received by BITS Pilani. The key activities which needs to be undertaken by the TIH over 5 years is provided below:

Table 27: TIH- Implementation Plan

S.no.	Work Area	List of Activities	Y1 Q1	Y1 Q2	Y1 Q3	Y1 Q4	Key Milestones
1	Entity Formation	Formation of Section 8 company	1				1. Submission of application for incorporation of Section-8 company 2. Appointment of Directors 3. Tripartite agreement
		Appointment of Directors		2			
		Signing of tripartite agreement between Mission, TIH and BITS Pilani		3			
2	Infrastructure	Refurbishment of infrastructure		1			1. Completion of infrastructure development 2. Completion of procurement 3. Leasing of space
		Procurement of equipment				2	
		Leasing of space for setting up industrial R&D/ startup incubation				3	
		Maintenance of infrastructure and ensuring 100% utilization				4	
3	Finances	Finalization of financial indicators / targets to be achieved by the TIH	1				1. Finalization of financial targets 2. Annual budget 3. Quarterly review of financial performance 4. Annual financial statements
		Release of funds by DST					
		Preparation of annual budget	2			2	
		Identification and pitching to potential funding sources (institutional/ individual)					

S.no.	Work Area	List of Activities	Y1 Q1	Y1 Q2	Y1 Q3	Y1 Q4	Y2	Y3	Y4	Y5	Key Milestones
		Periodical review of financial position of the TIH	3								
		Monitoring and managing cash flow									
		Preparation of annual financial statements				4					
		Update financial information in the PFMS system									
4	**Performance Monitoring**	Review of Hub performance against targets and milestones	1								1. Quarterly performance review
		Reporting to MGB and SAC as and when required									
3	**Governance & HR**	Finalize Governance and Execution Team structure (JD, Roles, KPIs)									1. Constitution of HGB and other committees 2. HGB meetings 3. Process and polices document
		Identification of resource internally (if possible)									
		Recruitment Strategy - Budgeting, selection of recruitment agency, Briefing with the agency									
		Recruitment process									
		Nomination of external members for HGB and other committees									
		Appointment of positions and onboarding	1								
		HGB meetings	2		2		2				
		Preparation of processes, policies and SoPs		3							

S.no.	Work Area	List of Activities	Y1 Q1	Y1 Q2	Y1 Q3	Y1 Q4	Y2	Y3	Y4	Y5	Key Milestones
4	Branding & Communication	Design of brand elements (such as logo)		1							1. Finalization of brand elements 2. Website launch 3. Marketing collaterals
		Website development		2							
		Preparation of marketing collaterals, investor pitch packs		3			3				
5	R&D	Finalization of projects to carry out research in Bio-CPS									1. Project selection 2. R&D activities and outcomes (such as patents, publications, etc.)
		Call for proposals from industries to set up R&D facility within the TIH or for joint research with faculty									
		Evaluation of proposals and selection				1	1				
		Negotiation with industry/ startups for technology licensing									
		Release grants based on proposal evaluation									
		Tracking of research outcomes					2				
6	Entrepreneurship	Set up TBI			1						1. Set up of TBI 2. Set up of Seed Support Fund 3. Onboarding of startups/ EiRs 4. Program launch 5. Periodic review 6. Grand challenge
		Set up Seed Support Fund			2						
		Call for proposals from startups									
		Evaluation of proposals and selection of startups/ EiRs for incubation or acceleration				3					
		Acceleration/ incubation program launch					4				
		Performance review of incubatees					5				

S.no.	Work Area	List of Activities	Y1 Q1	Y1 Q2	Y1 Q3	Y1 Q4	Y2	Y3	Y4	Y5	Key Milestones
		Launch Grand Challenge							6		
7	**Academics**	Finalization of selection criteria and process for fellowships									1. Fellowship launch 2. Skill development programmes 3. Selection of faculty for fellowship 4. Selection of faculty for Chair Professorship
		Finalize Academics Committee									
		Design of skill development programmes for faculty/ industry employees based on client needs									
		Call for UG/ PG/ PhD fellowships and selection			1		1				
		Skill development programme launch					2				
		Selection of faculty for Fellowship				3	3				
		Selection of Chair Professor				4	4				
8	**Collaborations**	Identification of potential partners and mode of collaboration (academic and industry)									1. Signing of MoUs with partners
		Initial discussion with potential partners									
		Define roles and responsibilities of both parties and identification of SPOC									
		Signing of MoU				1					

12. Cost Benefit Analysis

The cutting-edge technologies developed by the Hub will lead to various economic benefits for the industries in the sectors of healthcare, agriculture, water and environment. In addition to this, various other stakeholders in the value chain such as hospitals, diagnostic labs, farmers, etc. are also set to benefit from these technologies. The focus of this TIH is to make these technology products affordable to all, thereby economically benefiting the end consumer as well.

Apart from the economic benefits, the TIH shall also provide various tangible and intangible benefits directly or indirectly through its activities. The unique nature of R&D also indicates that while the cost for technology development needs to be incurred upfront, their benefits may not be realized for several years and the impact may be created in several unrelated areas. The following matrix gives an indication of the non-financial benefits of the TIH:

Table 28: Benefits of the TIH

		Benefits	
		Tangible	**Intangible**
Beneficiaries	**Direct**	• Patents, copyrights • Technology products • Gene bank submissions • Publications • Startups • Job creation • Fellowships awarded (students/ faculty) • Awards and rankings for participating institutes	• Knowledge generation • Skill development • Better brand image for all participating institutes/ companies
	Indirect	• Attend to high number of patients for hospitals/ doctors through remote monitoring • GDP growth through innovation and jobs • Better healthcare indicators in the country through timely and accurate diagnostics • Reduced travel time and costs for patients • Access to safe food and water • Better performance in SDGs and other global indices	• Better patient experience through minimally invasive techniques • Improved health and quality of life

13. Risk Analysis

Implementation of the TIH comes with its set own set of challenges and risks due to the uncertain nature (both internal and external) of research and development activities. The following are some of the risks that can be foreseen and the mitigation measures to address them:

Table 29: Risks & Mitigation Measures

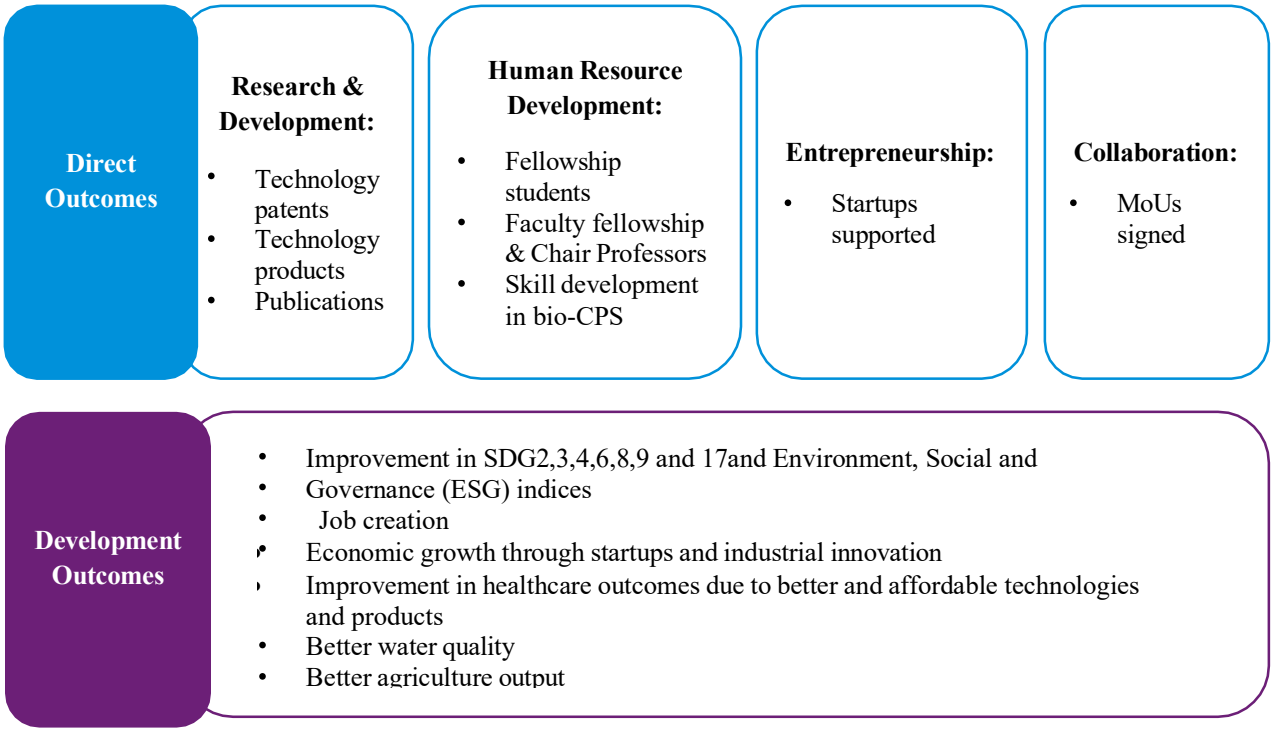
Type of Risk	Description	Mitigation Measures
Legal/ contractual risk	• Risks related to management of intellectual property and data privacy, especially while working with partners	• Drafting of process and policy documents related to IP and data privacy • Appointment of Legal Officer to handle disputes related to IP
	• Failure to maintain proper financial records/ other compliance documents related to the Section 8 company	• Appointment of an independent auditor to audit the financials of the Section 8 company • Oversight by HGB to ensure legal compliances
Environmental risk	• Any hazards arising out of due to equipment failure • Pollution caused by waste generated in the labs	• Adequate measures will be put in place in maintaining the equipment and labs as per standards • Proper process will be followed for waste disposal
Financial risk	• Technology/ product development may turn out to be costlier than was anticipated	• Finance Committee and R&D Committee to monitor the costs periodically and raise red flags in case of cost overrun
	• Product developed maybe commercially unsuccessful or dwarfed by competing technology, resulting in loss of revenue	• R&D Committee to scan the market periodically to understand competition and bring in market insights of both successful/ failed products of similar nature • Product testing and market research to be conducted with the help of external agencies before product launch
	• Failure in meeting targets, resulting in funding cut off by the MGB	• Periodic review of targets by the HGB and course correction based on results
	• Failure to attract enough funds or generate revenue to ensure self-sustainability of the TIH after five years	• Tapping into BITS alumni network, CSR funds and industry partner for funding and other revenue generating activities such as skill development programmes
	• Technology/ product development may turn out	• Well planned and strict criteria, two-tiered scrutiny by R&D /

Type of Risk	Description	Mitigation Measures
	to be more difficult or unwieldy or even fail	Entrepreneurship Committees and HGB for evaluating proposals from faculty/ industry partners/ startups to ensure that only viable projects are taken up • Periodic evaluation of progress
Project management risk	• Poor maintenance of infrastructure or any disaster resulting in damage to property and loss of productivity	• Infrastructure Committee to ensure proper maintenance and utilization of infrastructure
	• Inadequate / Failure of deliverables by spokes and other collaborators	• Clear targets and evaluation mechanism laid out for spokes/ collaborators in the MoU • Periodic evaluation to ensure that targets are met
Regulatory risk	• Change in government policies or priorities resulting in loss of funding for the Mission	• Clear plan for the TIH to be self-sustainable in five years without the support of government funding

14. Outcomes

The TIH will produce outcomes across the verticals of research and development, human resource development, entrepreneurship, and collaborations. Apart from the direct outcomes from these verticals, the TIH will have an overall impact on the country's development across the sectors of healthcare, agriculture, water and environment.

Figure 25: TIH- Outcomes



Targets and estimated achievement

The minimum targets, to be achieved against the indicative grant of INR 125 crore for the period of 5 years, of the TIH are estimated to be achieved in a phased manner. The details of TIH activity wise minimum targets and year on year estimated achievement is depicted in table below:

Table 30: TIH activity wise target vs estimated achievement

Particulars	Target defined in ToR	Total estimated achievement	YoY estimated achievement				
			Y1	Y2	Y3	Y4	Y5
Technology Development							
No. of Technologies	23	23	-	2	5	7	9
Technology products	18	18	-	3	4	5	6
Publications, IPR and other Intellectual activities	54	60	-	8	10	18	24
CPS Research base	75	80	-	12	18	25	25
Entrepreneurship Development							
CPS-Technology Business Incubator	1	1	-	1	-	-	-
CPS-Start-ups & Spin-off companies	38	42	-	5	10	12	15
CPS-GCC - Grand Challenges and Competitions	1	1	-	-	-	1	-
CPS-Promotion and Acceleration of Young and Aspiring technology entrepreneurs (CPS-PRAYAS)	1	1	-	-	1	-	-
CPS-Entrepreneur in Residence (CPS-EIR)	23	24	-	2	5	7	10
CPS-Dedicated Innovation Accelerator (CPS- DIAL)	1	1	-	-	1	-	-
CPS-Seed Support System (CPS- SSS)	1	1	-	1	-	-	-
Job creation	9,375	9,500	-	750	2,000	3,000	3,750

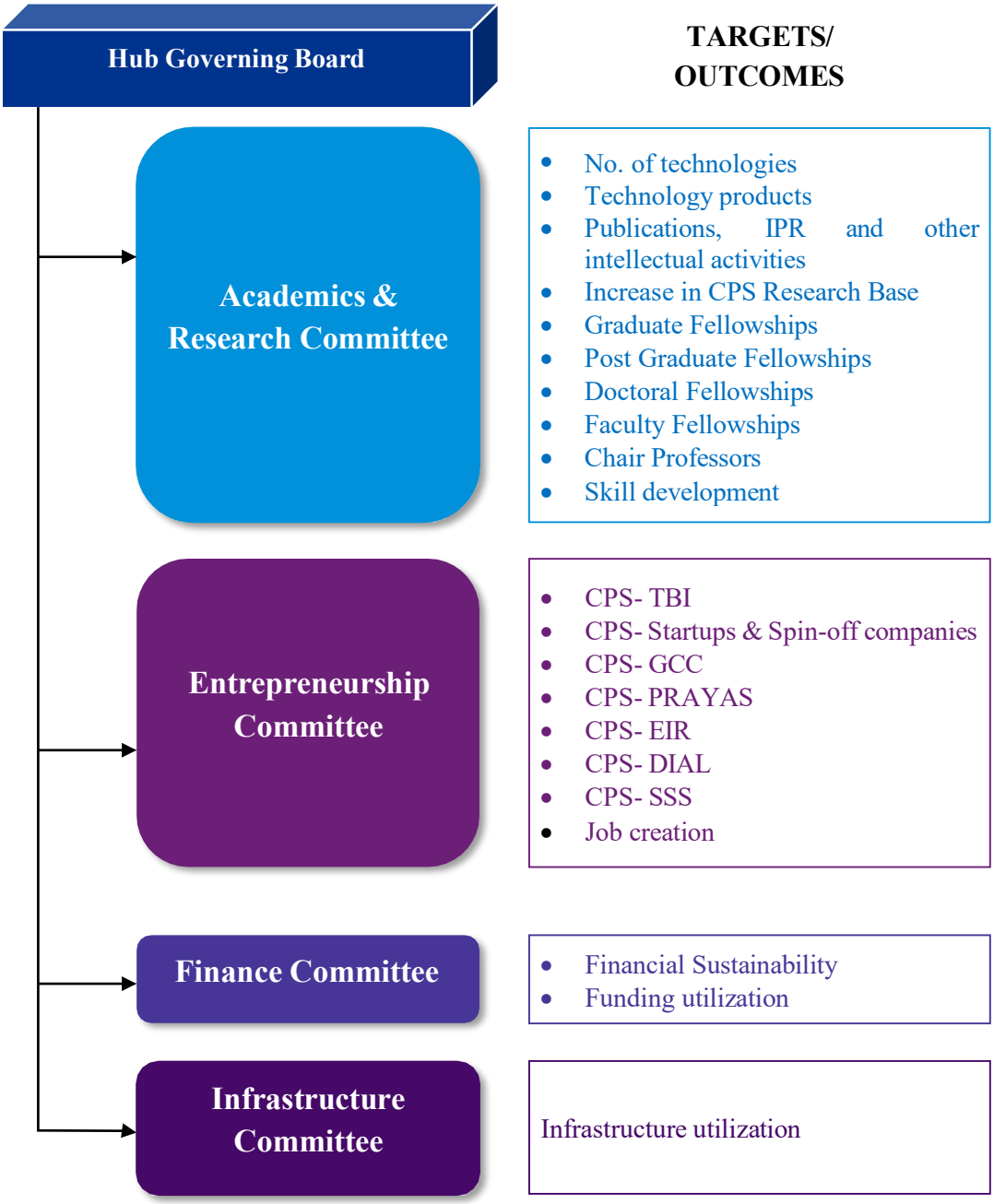
Particulars	Target defined in ToR	Total estimated achievement	YoY estimated achievement				
			Y1	Y2	Y3	Y4	Y5
Human Resource Development							
Graduate Fellowships	250	261	24	27	60	60	90
Postgraduate Fellowships	48	62	11	11	11	14	30
Doctoral Fellowships	24	25	25	25	25	25	25
Faculty Fellowships	4	6	-	1	2	2	1
Chair Professors	4	7	-	2	3	1	1
Skill Development	450	4,888	-	722	1,306	1,380	1,480
International Collaboration							
International collaboration	**1**	**2**	-	1	-	1	-

15. Evaluation

The output of the TIH shall be monitored by both internal and external stakeholders to ensure that the targets are on track.

- **Internal evaluation:** The sub committees shall keep a track of the respective verticals and periodically report the activities and outcomes to the HGB. The HGB shall ensure that all targets are met in a timely manner.

Figure 26: Internal Evaluation Mechanism of the TIH



- **External evaluation:** The TIH will be evaluated and monitored against the set targets and delivery by the Mission Governing Board (MGB) and Scientific Advisory Committee (SAC). The Inter-ministerial Coordination Committee shall facilitate connecting the Mission and Hub to stakeholders. A Coordination Committee chaired by Secretary, DST and comprising heads of all Hubs will ensure better outcomes of research activities and assist in development of collaborative solutions.

Checks and balances will be put in place to ensure that the TIH's progress is tracked periodically and corrective actions are taken in a timely manner:

- An MIS shall be set up for the HGB and the subcommittee members to periodically track all outcomes on a real time basis
- The TIH Execution Team and the core faculty team shall brief the respective sub committees about the progress on a fortnightly basis
- The HGB shall convene once in every quarter to discuss the progress and develop strategies for the future.

ANNEXURES

Annexures

1. Innovation Ecosystem at BITS Pilani

The Centre for Innovation, Incubation and Entrepreneurship (CIIE) coordinates the incubation activity at the three Indian Campuses in Pilani, Goa and Hyderabad.

Existing Incubators

Table 31: BITS- Existing Incubators

S. No.	Name of TBI	Funding Agency with Scheme name	Funding (INR Cr)	Year Established	Domain	No. of Innovators Supported
1.	Pilani Innovation and Entrepreneurship Development Society (PIEDS)	BITS Pilani & DST, DeiTy support MeitY TIDE 2.0 HDFC CSR grant	3 Cr (BITS Pilani) 3.1 Cr 0.25 Cr	2013	Electronics, Health, Automation	60
2	BITS Pilani Hyderabad TBI Society	BITS Pilani and NSTEDB	5 Cr (NSTEDB) 2 Cr (BITS Pilani)	2012	IT in Healthcare, Biotech, Pharma, IoT, MEMS, Gaming	60
3	BITS BIRAC BioNEST Incubator, Goa	BITS Pilani and DBT BIRAC	2.9 Cr (BIRAC) and 0.55 Cr (BITS)	2017	Healthcare, environment	10

TBI, BITS Pilani, Pilani Campus

Technology Business Incubator (TBI) at Pilani Campus was set up in 2004 by BITS Pilani with grant support from Department of Science and Technology (DST) (Govt. of India) and support from BITS Alumni. The Scheme was sanctioned by the DST vide their letter No. 22/15/2002-NEB dated 5th March 2004. On 16th September 2013, **"Pilani Innovation and Entrepreneurship Development Society (PIEDS)"** was established under "The Rajasthan Societies Registration Act, 1958". All activities done under TBI, BITS Pilani in the context of incubation and seed fund support, mentoring etc. were passed to Pilani Innovation and Entrepreneurship Development (PIED) Society.

Grants received

- DST sanctioned **INR 191.35 L** vide letter No. 22/15/2002-NEB dated 5th March 2004. Total non- recurring grant and recurring grant envisaged from DST in the project was INR 138.35 L and INR 53 L, respectively.
- The Technology Incubation and Development of Entrepreneurs (TIDE) grant was sanctioned to TBI at BITS Pilani vide approval dated Feb 23, 2012. The total grant sanctioned was **INR 155 L** and it included INR 30 L for capital expenditure to upgrade incubation facilities at Goa (Rs 20 L) and Pilani (Rs 10 L) campuses; balance Rs 125 L was towards seed funding support to incubating companies.
- Total amount of CSR grant received: Rs 25 L (HDFC).

Present Status and achievements of TBI at BITS Pilani, Pilani Campus

- Space available for incubation: 4255 Sq. ft
- Number of Start-ups that can be accommodated at a time: 18
- Total number of start-ups incubated till now at Pilani Campus: 46
- Total no. of start-ups funded till now through government sponsored scheme: 12
- Total number of start-ups funded by BITS '75 batch: 3
- Total no. of start-ups supported through CSR grant: 1
- **Areas of focus:** Information and communication technology (ICT), VLSI & Embedded systems, Electronics, Education Sector, technology-based product/service.
- **Processes streamlined:** Incubation process, Legal & IPR Support process, Funding process (Legal contract documents and policies & guidelines are well placed)

Pilani TBI, Physical Infrastructure: TBI is now fully functional with the following hardware/software design facilities already procured.

1. Office space, 1 meeting room, 1 Pre incubation Cell, 1 Seminar Hall, 35 cabins for individual startups
2. EDA tool suite from **MAGMA, MENTOR GRAPHICS, CADENCE, TANNER** ---A complete package for RTL to GDSII solution
3. Sun Ultra 2 Enterprise Servers, Number of Powerful SUN machines as License servers and SUN THIN Clients as nodes
4. UPS for the complete laboratory
5. Microcontroller Development Systems, FPGA proto-boards, DSP Development Systems, Testing Tools, Testing and Measuring Equipment
6. Round the clock Internet access and email facility

7. Institute library with a collection of approx. 2 lakh volumes of books and journals, and more than 550 e-journals in various disciplines
8. Specialized laboratories to strengthen R&D efforts. in various disciplines

Total startups for Pilani campus are as follows:

- Startups supported with seed fund - **16**
- Current Incubatees - **11**
- Startups incubated without funding - **44**

Imparting Entrepreneurship Education: Flagship Course-New Venture Creation (NVC)

New Venture Creation is a unique course being offered at BITS Pilani that enables students to graduate as job givers than job takers. The purpose of this course is not to teach entrepreneurship but to create entrepreneurs. The course enables the student start-ups, mostly technology based, to grow by providing the building blocks for creating an enterprise using the lean start up method. By providing students with the tools to take their ideas to the market this one semester course is able to convert more than 10% of the ideas to real start-ups.

The course collaborates with large number of BITSian entrepreneurs as well as several non-BITSian entrepreneurs and investors for lecture and mentorship. It is their selfless support that forms the key to the success of this course. Prof. Mridula Goel is currently the Faculty in charge of the course.

In order to create a successful startup, student teams are required to address various issues in startup creation: market research, competitor analysis, customer development, technology viability, product development, marketing & sales strategy, team formation, legal compliance and fund raising. Interactive sessions with entrepreneurs across the globe are supplemented with faculty facilitated hands-on workshop and feedback sessions to create deliverables like elevator pitch, business model canvas and minimum viable product. Offered through the special telepresence Classroom facility connecting all BITS Pilani Campuses the sessions are able to connect virtually with speakers across the globe.

Companies from where Invited Speakers/Mentors were sourced in the last 3 years: redbus.in, Cubito.in, Petasense, Gharpay, Krishi Star, Postman, map my India, Localoye, Exotel, Nayi disha, Housing.com, UrbanClap, Phyzok, Knolskape, Helion Ventures, Tap Chief, Lead Angels, Venturenursery, Eduguild, Sattva, Snapdeal, Freecharge, Framebench, Zippr, etc.

Each team is assigned an experienced entrepreneur as mentor who guides them through the semester and beyond. The teams compete with each other and the top teams are awarded seed fund to pursue the business idea for incubation after the completion of the course and eventually to launch the business.

TBI, BITS Pilani, Hyderabad Campus

The role of technology business incubator is to proliferate overall entrepreneurial process and thus increasing the completeness and bring about sustain development to an innovative idea till formation of a successful venture. A Technology Business Incubator (TBI) can ably support such an environment by nurturing technical bents of mind and innovations. TBIs are, a desirable link, in the present context between manifesting the potential of technical innovations and New Enterprise Creation & Growth. The essence of economic development lies in the pace of entrepreneurship development. TBI, BITS Pilani, Hyderabad Campus (TBI-BPHC) aim to promote and sustain startups with intimate private sector engagement. Funds will be utilized for various purposes to facilitate the incubate companies and creation of facilities for rapid growth and sustenance of start -up ventures. Against this backdrop BITS Pilani, Hyderabad Campus has promoted a Technology Business Incubator. The Incubator is supported by National Science and Technology Entrepreneurship Development Board, DST, Govt. of India.

The Technology Business Incubator at BPHC aimed at fostering technology/knowledge based entrepreneurial start-ups by:

- Nurturing them at an early-stage and helping them overcome limitation trough low cost services
- Idea validation by industry experts
- Creating an enabling innovation ecosystem for entrepreneurs to prototype creation, venture and angel funds, etc.
- Offer value added services viz. legal, financial, technical, IPR, mentoring, business networking (National and international) etc. to incubates
- Providing business environment for operation with well-equipped infrastructure support
- Commercialization of technologies and nurturing any such business collaboration for
- profitable business
- Strengthening business skills/ knowledge startups and making them more enterprising
- Skill development in the region in terms of innovation and Entrepreneurship and creating job opportunities.
- Creating a sustainable ecosystem with multiple stakeholders for enterprise creation.

Core Competence (Thrust Area)

Biotech and Cleantech: Strong Departments of Biological Sciences, Pharmacy and Chemical Engineering are working very closely with TBI and are mentoring our start-ups and giving access to cutting edge equipment. TBI is well placed to develop companies in the area of human healthcare (vaccines, therapeutics, diagnostics, etc.), biofuels, etc.

- ICT for healthcare: Strong Electrical Engineering and Mechanical engineering faculty are assisting to drive the development of smart phones/tablets for mobile diagnostics. Mechanical engineering faculty members have expertise in developing miniature sensors,

circuits and devices for healthcare.

- Internet of Things (IoT): TBI, along with electrical engineering, mechanical and computer science researchers, has a strong f focus on IoT. TBI has helped BITS setup a "IoT sandbox" where students may develop devices for everyday use such as smart appliances and other common items which communicate with each other using low cost communications technologies.
- 3D printing: A team at TBI has already been funded INR 35Lakhs for a 3D printing idea. TBI, faculty from Chemical Engineering and students from Electrical
- Engineering and Mechanical Engineering were the ideators. TBI has a high-end polyjet3D printer and an indigenous FDM printer and plans to further develop capabilities in this high-impact area.
- E-commerce, Social Media and Gaming: The above four areas, with the possible exception of 3D printing, are mostly suited for experienced researchers and entrepreneurs. TBI gets several applications from BITS (and other) students with start-up ideas in the areas of E-commerce, Social Media and Gaming- areas suited from youngsters, and deserving of TBI's support. TBI has developed a strong enabling network for such start-ups.
- MEMS Clean Room: a state-of-art micro-electromechanical systems (mems) cleanroom, which is a joint contribution of the Institute, Hemair Systems and Department of Science and Technology, government of India. The MEMS cleanroom with the existing equipment can support microfabrication of basic sensors and actuators completely. The MEMS facility started accepting project proposals from Startups and gearing up to becoming one of the busiest laboratories in the campus

Physical Infrastructure

- A 4,500 SFT office space with 11 individual cabins/offices, 35 individual work- stations, meeting room and conference room
- 2000 SFT biotech/pharma lab, with 5 individual lab spaces and a 1000 SFT common area
- Common equipment is industrial grade centrifuge, tabletop centrifuges, mammalian cell culture room, 3D printers, CNC machine, Lathe etc.
- A 1200 SFT "ICT for Healthcare" lab has smart phones for app development and diagnostics applications, high-end servers etc. A 2650 SFT microelectromechanical systems (MEMS) lab is being set up in partnership with a private company. Common equipment is high–end circuit design software, silicon wafer processing equipment such as spin coater, wet bench, probe station, thin-film depositor, etc.

Start-ups nurtured and spun out as an independent company by the institute

Table 32: BITS Startups

S. No.	Company	Product detail	Status
1.	**Bridle IT Solutions Pvt. Ltd.**	A company started by the students of BITS Pilani, by name Bridle IT is already launched. Product launched School Mate. It helps schools in updating parents about their kids' status at school over mobile phones. http://www.schoolmate.in/index.html, www.bridleit.com	Graduated
2.	**Open Source Pilani**	Source Pilani is a rural BPO company based in the rural back drop of Pilani, Rajasthan that provides high quality and low-cost back office services to domestic as well as international clients. They are the first and only rural BPO in India that provide medical transcription services to international clients while maintaining a 99% quality record. http://www.sourcepilani.com/	Graduated
3.	**Red Bus**	RedBus is India's first organized bus ticket booking service. It has services in 15 states, sales offices in 6 locations and daily departures in 2800 routes. They are India's largest aggregator of bus tickets. Team has Sudhakar Charan from BITS-Pilani, Bangalore. http://www.redbus.in/:	Graduated
4.	**Mobile Medics**	It is a traveling healthcare service for rural India. Mobile Medics would provide private sector, high quality, and affordable medical care through mobile clinics to paying villagers in India. Patients' databases are collected and transferred to the doctor sitting at a faraway place for further examination. This database is being also used in developing software for identifying prevalent disease along with at different places based on which efficient strategies for fighting those diseases are being devised.	Graduated
5.	**Sanat Technologies**	Product relates to development of modules of data storage appliances that attached to the network	Graduated
6.	**QA Infotech**	Product relates to development of Online Test Case Manager and Dashboard Tool for Reporting Test Results. It is a utilities/programs for online test automation.	Graduated

S. No.	Company	Product detail	Status
7.	**Imconfuzed**	Imconfuzed.com's mission is to enrich the high school students with every possible reliable information about a college they would want to know. They would be providing accurate, reliable data whether it be the labs, the library, the placements and even hangouts of an undergraduate college.	Graduated
8.	**Veta Peracta**	Vita Peracta is an early stage venture providing neuropsychology solutions in the Human Resources domain. They are developing products to explore new market avenues for innovative products that might be built using the Vita Frame-worklike web-based Neuro profilers and virtual interaction environment	Graduated
9.	**Nextgen Pms Ltd.**	NEXTGEN PMS Pvt Ltd. aims at performing feasibility studies for organizations to assess their earning potential in carbon credits. It calculates carbon footprints of organizations, certifies them as carbon neutral or carbon positive and gives them an action plan to turn carbon neutral. NextGen PMS Pvt. Ltd. plans to develop Energy Management Systems, an IT application tool, which will allow the user to calculate his footprint and simulate the changes in energy and economic costs with changes in inputs.	Graduated
10.	**CDS Solutions**	Given that there is a growing demand for an efficient delivery system and the vast market remains unexplored, Hence, there is potential to build a profitable business around their content delivery model. CDS Solutions aims at providing customized, cost-effective and highly efficient content delivery systems (CDS) to academia and corporate for Live and web-based content.	Graduated
11.	**Anaya Media**	To provide software development and consultancy solutions for the Media and Entertainment industry through our services: Software development based on client's request giving him better software control & understanding and freedom of customization. (This may include making Video Editing packages or Simulation engines for 3D software.) Support for adapting existing software packages to suit them to studio specific	Graduated

S. No.	Company	Product detail	Status
		workflows. Software implementation solutions (redesigning software pipeline) to help our client achieve his goal with minimum labor and superior quality.	
12.	**Parivartan Foundation**	Parivartan gets the dynamism and energy of youth to the development of villages and engages initiatives at the grass root level by treating the community where it works in as equal partners in progress. Our mantra is "*Teach people how to fish rather than giving them the fish*". By key initiatives such as e-commerce, Information and Communication Technology, we aim to create a sustainable difference.	Graduated
13.	**Gray Orange Robotics**	Specialized robotics, automation & embedded systems workshops for university & High school students. We are also developing a robotics-based curriculum in collaboration with ROBOTIS Inc for school students; to increase their interest in STEM related courses in CBSE/ICSE Schools.	Graduated
14.	**Innovese**	Provide IT solutions for all needs, expertise in website development, software development, web applications, graphic design, identity design and other business solutions. Development is based on clients' request giving them better control & understanding and freedom of customization.	Graduated
15.	**Smartec**	Smartec aims to change the manual identification system prevalent in the education sector today with a digitalized system. The service would be making the attendance system prevalent right now completely electronical by the use of smart cards and RFID technology.	Graduated
16.	**Teevra cycles**	The customized human powered vehicle to cater to the need of eco- friendly and efficient mode of private transportation is what the team is going to deliver at the initial phase and later getting into the mass scale production of this efficient vehicle and battery operated stylish mode of transportation.	Graduated
17.	**Tune patrol**	Tune Patrol is a social music discovery platform to promote independent music artists. With Tune Patrol artists will be able to upload their songs onto the site and let	Graduated

S. No.	Company	Product detail	Status
		listeners explore and buy their songs in an engaging game like experience.	
18.	**SHArP Edge Learning Pvt. Ltd.**	**SHArP Class** is a technology platform for engineering students which seamlessly integrates the traditional chalk & talk method with smart classrooms based on cognitive learning. It enables Professors to use digital resources such as educational animations, assessments and diagrams to make classroom more interactive creating multi-sensory learning for students and help improve their academic performance.	Presently incubating
19.	**MyTiTechnetronics Pvt. Ltd.**	MyS (My Slate) is an interactive Linux based utility tablet aimed at making paper-free environments, especially classrooms & offices. It plays multiple roles as a notebook, textbook, report card & other stationary while containing all powerful features of a laptop for videos, interactive educational content etc. It contains natural reflective display that is easy on eyes. The device will have unique capability of digitizing notes written on any paper or on the screen keeping in mind that transition from paper to tablet will take a few years to be fullyadopted.	Presently incubating
20.	**SnapChai Productions Pvt. Ltd. (Oodio)**	Snapbook (www.getsnapbook.com) is an application/website that creates a multiple image Photo book in less than a minute. It facilitates the user to select the best images in the phone, tablet and computer to create a memorable experience for their friends and family. The process has been designed to keep in mind speed and efficiency. User selects photos on the application in their phone. This gets processed on the server side, and sent directly tothe printing facility where the book is printed, bound and shipped within 24 hours	Presently incubating
21.	**3D-IP Semiconductors Private Limited**	*3D-IP Semiconductors Pvt Ltd* is a Bangalore-India based IC design company offering semiconductor chips such as Memory, Analog & Digital Intellectual Properties (IP's) for Low Power & High-Speed applications for IOT, automotive electronics and processors applications	Presently incubating
22.	**Techture**	The startup aims to deliver technological services in the	

S. No.	Company	Product detail	Status
	Structures Pvt. Ltd.	Civil Engineering, Architecture and Construction industry. These services encompass a wide variety of disciplines including Architecture, Structure, Mechanical, Electrical and plumbing for the building industry.	Graduated
23.	**Piquor Technologies Pvt. Ltd.**	Piquor developed an automated digital Photo Booth that combines traditional photo booth with in-image branding & social sharing making it a powerful marketing tool.	Virtual
24.	**WeMakeScholars**	WeMakeScholars is an artificial intelligence data driven company in the domain of International education having over 2.5 million unique users from 200+ countries, of which 400K is registered.	Presently incubating
25.	**Paxport Webservices**	Online 2 Offline Authentication Services.	Presently incubating
26.	**Tapchief**	Expert consultancy Platform	Graduated
27.	**Drakle**	Healthcare services	Graduated
28.	**Dexter**	Artists Collaborative portal	Graduated
29.	**Aspire**	Career social platform	Graduated
30.	**Gaitx**	AI to understand consumer behaviour	Graduated
31.	**Phyzok Learning Solutions LLP**	Company develops technology to help teachers bring concepts alive in the classroom. The USP of the Company is creating virtual teacher customized to the real teacher of the student that also provides interactivity and assessment. The market served: Schools in tier 1 and tier 2 cities.	Graduated
32.	**I Dream Education**	Education is a social impact startup founded with a vision of facilitating enjoyable learning to the underserved masses in the country via mobile and tablet devices. Have set up Tab Labs at rural govt schools via CSR and govt. projects, and affordable private schools	Graduated
33.	**Amber Warehouse Solutions**	Technology product for monitoring the food grain's health stored in a warehouse	Graduated
34	**HUMIT**	Discover and share music with people	Graduated

Recently incubated startups:

1. Neoncube Solutions Pvt Ltd
2. Nawgati Tech Pvt Ltd
3. Urbantrack Pvt Ltd
4. Greynight Pvt Ltd
5. Soheal
6. Paddy Stubble
7. Forganic
8. Pepper Global LLP
9. HelloVoRld
10. Elixar Systems
11. Gnomik Pvt Ltd
12. Turtlelearn

Hyderabad TBI Incubatees

Table 33: BITS Hyderabad- Incubatees

#	Company name	Category	Product details	Status	Current/ Graduate
1	WOGi	Infra	Customizable cabins for open Workspace	Prototyping	Current
2	Acubiosys	Pharma	Oral insulin formulation and Patch for Diabetic foot ulcer	Product	Current
3	Almac Protech	Clean technology	Waste management technology	Product Development	Current
4	Insilia Therapeutics	Healthcare	Development of Therapeutics for metabolic disorder	Product Development	Current
5	Yogee'S BioInnovations	Healthcare	preclinical drug discovery and diagnostics covering a span of therapeutic areas	Product Development	Current
6	Indibots	Robotics	Solar panel cleaning robot	Product Development	Current
7	Cogentibs	ICT	Facial encryption for Email and data communication	Product Development	Current
8	Drugplus	ICT	Online marketplace and knowledge bank, Database for Generic	Idea	Current
9	SandMed	AI	Artificial intelligence for CVD	Idea	Current
10	Vinnan	Robotics	Robot for room sterilization and Navigation	Product Development	Current
11	LookBy	Ecommerce	Market place for small vendors and retail stores	Idea	Current

#	Company name	Category	Product details	Status	Current/ Graduate
12	Fastcarv	Food app	App for highway dhaba and highway experience	Idea	Current
13	Dhruva Space tech	Nano satellite	Sector agnostic Nano Satellite	Product Development	Current
14	Kasura	Electronics	Simulation for chip designing and IoT	Product Development	Current
15	RoDeSO	Robotics	Autonomous robot for COVID19	Product Development	Current
16	BAIID	IoT	IoT enabled smart face mask COVID19	Funding stage	Current
17	Netsips.in	Online	Online content aggregation/ Software/ Consumer Application	Product Development	Graduated
18	Bracket Biz	Online	Website for business and Marketplace		Graduated
19	DronesHub	Drone	Hub securely park, wireless charge, scan for the physical damages, get deploy & be ready for the next mission		Graduated
20	Mr Ritwik Das (f20180515)	AI /Chatbot	create a platform to help college students with their day-to-day life with chatbots using AI		Graduated
21	Rlyable	Blockchain	creating a timeless, immutable, transparent, anonymous, and secure ledger of artwork and collectible records		Graduated
22	Pradicto	Social media	Online tool and App for opinion		Graduated
23	Aidea	Optics	Handheld smart dental devise for visualization of Dental pulp chamber and canal orifice		Graduated
24	Romp (Branciau Technology)	Social media	social commerce platform aiming at disrupting the retail industry		Graduated
25	Dainik Shram	App	Application to hire skilled labours in rural and semi urban Area		Graduated
26	ALPYUS	Medical tourism	healthcare service customized and tailored for every individual as per their needs and expectations		Graduated
27	Know Your treatment	AI	AI interface/app for daily medicine and Clinical research		Graduated
28	Dr Ramesh	Sensor	Development of sensors for industrial usage		Graduated

#	Company name	Category	Product details	Status	Current/ Graduate
29	WCB	Robotics	Window cleaning robot		Graduated
30	Hasiee	Social venture	We at Hasiee aim to connect donors to NGO using a combination of both online-offline technologies		Graduated
31	Naturlich Global Beverages	Food tech	Naturlich Global beverages, a health drink company non-alcoholic novel functional Beverage		Graduated
32	Best Price Dude	Ecommerce	Comparison of the price of all ecom sites		Graduated
33	AEGIS	AI	intelligent traffic management system		Graduated
34	Medisec	App	A simple approach to save Medicines		Graduated
35	SmartCampus	App	Connecting service providing cashless transactions for college services and events.		Graduated
36	Vaibhab Aggarwal	AI	AI and Neural Network for Health Care		Graduated
37	EdgeFX	Skill based	STEM education to higher education has helped us immensely to incorporate design thinking in building our products.		Graduated
38	Nature's Velvet	Nutraceutical	Natural herbal products		Graduated
39	SSK Bio	Biotech	SSK Bio is developing novel drugs in collaboration with a Brazilian University		Graduated
40	Naturlich Global Beverages	Nutraceutical	Prebiotic beverages from fermentation of beneficial microorganisms		Graduated
41	Idea3D	3D printing	Environmentally friendly, biological origin filaments for 3D printing		Graduated
42	Paxport Web Services	Hardware	Software and hardware solutions for retail authentication and anti-Counterfeiting		Graduated
43	Digipartment	Digital marketing	Personal and corporate digital marketing		Graduated

#	Company name	Category	Product details	Status	Current/ Graduate
44	xBITS Pvt Ltd	Biotech	Technologies for inexpensive antibiotic susceptibility testing and blood sugar detection		Graduated
45	Bonegraft Technologies	Biotech	Bone substitute powders and implants		Graduated
46	MLPA Technologies	Biotech	Device for inexpensive diagnosis of copy number disorders		Graduated
47	WeMakeScholars EdTech Pvt Ltd	Web based	Search and discovery platform for higher ed scholarships		Graduated
48	PSRP Technologies	3D printing	Custom 3D printed prosthetics made of composite materials		Graduated
49	GeneSys Biologics	Biotech	Economical microbial origin bio-Therapeutics		Graduated
50	Innovar research	Med tech	Medical and mechatronic device		Graduated
51	Nabler Web solution	Big Data	internet data analytics		Graduated
52	Applytics InnovativeSolutions	AI	Anti-counterfeiting of drugs and other retail merchandise		Graduated
53	Trippify	Social media	Social media for tech-enabled collaborative travel		Graduated
54	Kloudisk	HRM	Work-flow management tool for Design		Graduated
55	lnc42	Media	Social media for entrepreneurs to network in innovation Ecosystems		Graduated
56	AcadCloud	Skill based	Learning Management Toll for schools and colleges		Graduated
57	Starluxe Electrochrom	Manufacturing	Starluxe electrochromic works in the field of electrochromic glasses, films, mirrors and Displays		Graduated
58	SmilieMiddle	Online	Online Platform for portrait and arcticians		Graduated

BITS BIRAC BioNEST, BITS Pilani – K. K. Birla Goa Campus, Goa

BITS BIRAC BioNEST at K. K. Birla Goa Campus was set up in 2017 by BITS Pilani K.K. Birla Goa Campus with grant support from the BioNEST scheme of Biotechnology Industry Research Assistance Council (BIRAC), Department of Biotechnology, Government of India.

The scheme was sanctioned by the BIRAC with reference to Grant-In-Aid Letter Agreement Reference No. BT/BIRAC/BI-BITS Goa/2016 dated 3rd March 2017.

With a vision of 'Enabling Innovation in healthcare and environment for a better tomorrow', BITS BIRAC BioNEST at BITS Pilani K. K. Birla Goa Campus aims to:

- Create an ecosystem that will enable innovation and knowledge-based entrepreneurship to improve quality of life.
- Promote sustainable development while taking the innovations from lab to land.
- Encourage the concept of techno-entrepreneurship, enable creation and sustainability of viable Bio & Healthcare enterprises.

On February 18, 2020, **"BITS Goa Innovation Incubation & Entrepreneurship Society (BGIIES)"** was registered under the "Societies Registration Act, 1860 (Central Act 21 of 1860)". All activities done under BITS BIRAC BioNEST, BITS Pilani K. K. Birla Goa Campus in the context of incubation and seed fund support, mentoring etc. will be passed to BITS Goa Innovation Incubation & Entrepreneurship Society (BGIIES) in due course.

Funding received (Goa Campus):

- Department of Biotechnology- Biotechnology Industry Research Assistance Council (DBT-BIRAC) sanctioned **Rs.296.64 L** with reference to Grant-In-Aid Letter Agreement No. BT/BIRAC/BI-BITS Goa/2016 dated 3rd March 2017.

Present Status and achievements of BITS BIRAC BioNEST at BITS Pilani – K. K. Birla Goa Campus:

- Space available for incubation: 3500 Sq. ft
  Office Space: 1500 sq. ft. (7 individual Office spaces, Conference Room, Common Area)
  Innovation Lab: 2000 sq. ft. (Individual Workbenches, common working platforms and 6 specialized laboratory rooms.
  Number of Start-ups that can be accommodated at a time: 20+
- Total number of start-ups in incubation at Goa Campus: 10
- Total no. of start-ups funded till now through government sponsored scheme: 2
- Total number of start-ups funded by BITS '75 batch: Two (Sattva Medtech and Thinkerbell Labs)
- **Areas of focus:** Healthcare & Environment
- **Processes streamlined:** Incubation process, Purchase Process, Collaborative networks established, Legal & IPR Support process
- **High end Equipment:** Autotitrator, Biosafety Cabinet BSL II B2, Fermenter, Gel Documentation system, Inverted fluorescence Microscope, Lyophilizer, RT-PCR, Spray dryer, TOC Analyzer, etc.

BITS BIRAC BioNEST Goa Incubatees

Table 34: BITS Goa Incubatees

Sr. No.	Incubate Name	Name/Description of Product / Technology	Status
1.	Sattva MedTech	Fetal Lite- Next-gen fetal heart rate & uterine contraction monitor	Associated
2.	Bactreat Environmental Solutions LLP	Wastewater treatment (On site project)	Resident
3.	Zycon Biosciences	Enzymes from Agricultural Waste	Resident
4.	Soares Healthcare LLP	Cancer care service provider	Associated
5.	Magellan Life Sciences	Zero caloric natural protein Sweetener	Resident
6.	Epione Swajal Biosolutions India LLP	Domestic appliance grey water recycling	Resident
7.	Ms. Preethi Poduval	Bioremediation using lectin	Associated
8.	Mr. Taaha Nizam	Piezo-electric sole for Diabetics	Pre-incubate
9.	Goa Health Monitoring Services	SeDI Bin -SelfDisinfecting Bin	Associated
10.	Dr. Roshan Naik	Rapid Cortisol Diagnostic Kit	Resident

* The above list of startups includes both resident and Associated incubatees.

2. List of Strategic Projects to be Undertaken by the TIH at Host Institutes

1. A field tested portable device for water pollution monitoring and use in health-sector for rapid diagnostics of bacterial infections in humans and by Real time AMR surveillance

Team:
PI: Prof. Suman Kapur, Senior Professor, BITS Pilani, Hyderabad Campus

Proposal Duration: 18 months

Budget: INR 60.00 Lakhs

Human Resources: 2 (1 RA & 1 Field Worker)

Proposal Summary:

Integrated Water Resource Management (IRWM). IWRM is a comprehensive tool for managing and developing water resources in a way that balances social and economic needs, and that ensures the protection of ecosystems for future generations. Water's many different uses—for agriculture, for healthy ecosystems, for people and livelihoods—demands coordinated action. The proposal aims to use the existing RightBiotic platform for point of testing of water pollutants and determining the presence of antibiotic resistant pathogenic bacteria in surface and ground water samples. The pollutants proposed by CPCB will guide the development of test strip and rapid testing

for bacterial ID and AST. Experience of Dr. Suman Kapur will be utilised for superbug and bacterial resistome determination. Hendriksen et al (2019) used metagenomic analysis of untreated sewage to characterize the bacterial resistome. AMR gene abundance strongly correlates with socio-economic, health & environmental factors. Global AMR gene diversity and abundance vary by region, and that improving sanitation and health can potentially limit the global burden of AMR. Analysis shows AMR was directly responsible for an estimated 1.27 million deaths worldwide, and associated with an estimated 4.95 million deaths, in 2019. HIV/AIDS and malaria have been estimated to have caused 860,000 and 640,000 deaths, respectively, in 2019. The platform is intended to be: Portable, Affordable, Accessible and IOT enabled for real time data transfer and surveillance. Integrating environmental surveillance across surveillance programs can inform policy.

Objectives:

- Standardize the strip design and procure reagents
- Standardize the strip design for dry format assay
- Field testing for developed strip based tests
- Data Analysis and report writing

Deliverables:

Mature field tested technology for licensing and commercializing

2. Mobile/Web and AR-VR Based Cognition Tracking, Analysis and Rehabilitation for healthy and cognitively impaired people

Team:

PI: Prof. Veeky Baths, Associate Professor, Cognitive Neuroscience Lab, Dept. of Biological Sciences, BITS Pilani K K Birla Goa Campus

Proposal Duration: 18 months

Budget: INR 24.46 Lakhs

Human Resources: 3 (1 JRF, 1 RA and 1 Project Assistant)

Proposal Summary: Cognitive impairment (mild, moderate and severe) is rapidly growing worldwide, however there is no pharmacological cure for the same at the moment. Research though has established that rehabilitation and early detection of cognitive impairment can minimize the progress of the impairment and also aid in maintenance of cognitive abilities to live independently. Technology, has a huge role to play in contributing to both rehabilitation and early detection. Through our project we wish to target two things:

1. Development of a theoretical framework which can potentially guage the cognitive performance of a person across the life-course, and then develop a product that translates this framework into action.

2. Development of non-invasive methods to detect the cognitive status of a person (through VR-based serious games) and also to assist them in rehabilitation by engaging in VR-space based activities

Objectives:

1. Assessment and evaluation of current evidence on lifestyle, demographic, socio-economic, and psychological well-being on confusion/memory loss in adults.
2. Study and assesses the lifestyle of people across different age groups and measures their cognitive performance in different domains: A mixed method approach and proof-of-concept development for cognition tracker.
3. Development of a prototype of cognitive tracker which collects and analyses the user data and piloting it.
4. Piloting the VR-based cognitive testing and rehabilitation among patients with cognitive impairment at NIMHANS.

Deliverables:

Pilot testing may be finished and we will work on advancing the functionalities of the proposed product. Secondly, a proof-of-concept for cognitive tracker and analyser is planned for the duration

3. Isolation of white blood cells in a microfluidic device with applications to Point-of-care diagnostics

Team:

PI: Dr. Siddharth Tripathi, Assistant Professor, Dept. of Mechanical Engineering, BITS Pilani K K Birla Goa Campus, Goa

Co PI: Prof. Sunil Bhand, Senior Professor, Department of Chemistry, BITS Pilani K K Birla Goa Campus, Goa

Proposal Duration: 18 months

Budget: INR 24.869 Lakhs

Human Resources: 2 (1 JRF and 1 RA)

Proposal Summary: WBCs or leukocytes contain genetic materials and are responsible for host of physiological functions. Leukocytes are potential biomarkers for blood-based diagnostics of various pathological conditions, such as heart disease, cancer, HIV and other pathological disorders. To obtain relevant clinical and diagnostic information from WBCs their separation/isolation from other blood cells becomes imperative. Conventionally, WBCs are separated using density based centrifugation technique, RBC lysis, FACS and immunomagnetic cell sorting. Though commonly applied, these methods require large amount of blood sample, are labour intensive, require trained personnel and result in compromised sample purity. The drawback associated with the conventional process of WBC isolation can be addressed using microfluidic technology. Our survey indicates that though several microfluidic devices have been reported in literature, there still remain several limitations and challenges which need to be addressed. There exists an unmet and urgent need to develop and innovate an efficient microdevice for WBC isolation. This research project aims towards designing, fabricating, testing and developing a novel passive

microfluidic device which can effectively separate leukocytes or white blood cells using small quantity of human blood. Our microfluidic design will employ hydrodynamic methods for separating WBCs. Using this microfluidic device WBC analysis will be made much simpler and efficient. Further, the separated WBCs will be utilized to check their phagocytic ability and enable disease diagnostics at Point-of-care setting. For example, isolated WBCs will be used to assess Immunodeficiency disorder (Chronic Granulomatous Disease) by detecting the superoxide ions using the on-chip platform

Objectives:

- Design and fabricate various microdevices to understand WBC dynamics in microchannel of simple geometry.
- Experimentation with few initial designs, identifying governing parameters responsible for separation of white blood cells and reporting separation efficiency and purity of the WBCs
- Based on the understanding from the experiments, propose an optimized design for testing
- Perform biological quality checks on the separated WBCs i.e. activation, viability and detection of bio-markers on separated WBCs
- Utilizing separated WBCs and testing their phagocytic ability

Deliverables:

The outcome of this work will be a working microfluidic device for separation of white blood cells using a small amount of human blood. The device will be simple in construction and will not require cell labelling or application of any external forces for its operation. The outcome of the work will be a fully functional microdevice for leucocyte separation. This study is relevant for bio-medical community and will open new avenues in field of single cell research, clinical disease diagnostics and therapeutics related to immune cell functionality.

4. Technology for detection and analysis of Aflatoxin M1 in milk and milk products

Team:

PI: Prof. Sunil Bhand, Senior Professor, Department of Chemistry, BITS Pilani K K Birla Goa Campus, Goa
Co PI: Dr. Gautam Bacher, Asst Professor Dept. of EEE&I BITS Pilani KK Birla Goa Campus, Goa

Proposal Duration: 18 months

Budget: INR 59.952 Lakhs

Human Resources: 2 (1 JRF & 1 RA)

Proposal Summary:

A large population is impacted due to presence of Aflatoxin M1 (AFM1) in milk and milk products. AFM1 is declared a class 1 carcinogen as per International Agency for Research on Cancer IARC. A huge amount of milk and milk product are rejected or declared unfit for consumption due to presence of AFM1 in commercial products above permissible limits. This is impacting both human lives of consumers due to over exposure of AFM1 contamination and also significantly impacting economy of the country due to rejection of milk powder and milk products. These losses are of significant economic value. The

Permissible limits for AFM1 recommended by European Union are very stringent at EU 50 ng/L. In India FSSAI has recommended permissible limit of 500 ng/L milk similar to USFDA at 500 ng/L. The milk is procured from multiple supply sources and collected at collection center. Any single milk source results in contamination of a whole batch brought by the tanker to the milk processing plant/diary where it stays about 4 hr prior to processing. Currently there are no affordable technologies that can enable rapid detection of AFM1 in milk meeting the regulatory stringent levels of 50 ng/L for exports or meeting FSSAI standards of 500ng/L at processing plant or event at milk collection center. The proposed biosensor chip technology will enable both rapid detection of AFM1 in milk meeting FSSAI And EU standards at milk collection center as well as processing plant. Current technologies use LC-MS/MS or HPLC Cobra cell method which are not affordable to industry and take a long analysis time (more than 6 to 8 hrs) and are not field deployable. The project will focus mainly on the batch fabrication of the sensor chip and the establishment of Bio-chip development protocols to meet the desired levels of reproducibility and sensitivity for AFM1 detection in milk. Subsequently the sensor will be taken for user feed back (dairy or other milk processing unit)

Objectives:

- Undertake the technology development specific to
    - establishing batch production and performance of the AFM1 bio-sensor chip meeting regulatory standards (FSSAI/USFDA/EU)
    - establish inter batch and intra batch reproducibility using certified reference materials (CRM) followed by analysis of unknown milk samples.
- Undertake user feedback involving NDRI /CIPET Ludhiana and reintegrate in to user protocol.
- Packaging of the sensor chip for USB interface, IoT enablement and for data processing & analytics

Deliverables:

Biosensor chip validated at user site for sample analysis and IoT enabling, decision support systems and USB interfacing performed

5. Biosensor platform for detection of Aflatoxin B1 in groundnut

Team:

PI: Prof. Sunil Bhand, Senior Professor, Department of Chemistry, BITS Pilani K K Birla Goa Campus, Goa

Co PI: Dr. Gautam Bacher, Asst Professor Dept. of EEE&I BITS Pilani KK Birla Goa Campus, Goa

Proposal Duration: 18 months

Budget: INR 39.951 Lakhs

Human Resources: 2 (1 JRF & 1 RA)

Proposal Summary:

Many grains and foodstuffs, including corn, peanuts, cottonseed, cereals, beans, and rice, have been found to be contaminated with aflatoxins. Moreover, humans are exposed to aflatoxins either directly by eating contaminated grains or indirectly via animal products. The contamination generally occurs in the field, during harvest and transportation, and during storage, under conditions where mold is allowed to grow. FB1 is found in abundant and is classified as a carcinogenic substance of group 1 by

the International Agency for Research on Cancer (IARC) The Permissible limits for AFB1 recommended are EU 2ug/Kg. In India FSSAI has recommended permissible limit of 30ug/Kg slightly above USFDA recommended 20ug/Kg MRL. The Agricultural and Processed Food Product Export Development Agency (APEDA) Govt of India wide its Trade Notice No: APEDA/PPP/Q/2021 Dated 05/07/2021 has made it mandatory for each export consignment of groundnut to have aflatoxin analysis and compliance certificate through accredited laboratories. It states "The Government of India, Ministry of Commerce and Industry, Department of Commerce vide Notification No. 28 (RE-2012)/2009-2014 dated 3rd January, 2013 issued under Section 5 of the Foreign Trade (Development & Regulation) Act, 1992 as published in the Gazette of India conferred powers to APEDA permitting export of groundnuts (peanuts) subject to registration with APEDA along with controlled aflatoxin level certificate issued by laboratories.to have. The recommended methods are vary time consuming and expensive and cannot be performed at the export dock. Currently there are no affordable and field deployable technologies that can enable rapid detection of AFB1. Contamination of groundnut/peanuts and similar class of pulses get spoiled due to AFB1 contamination. The proposed biosensor technology will enable both rapid detection of AFB1 in groundnut /peanut meeting FSSAI and EU standards. The project will develop a sensor to test AFB1 contamination at field level. The sensor will be tested involving the users feedback (including recognized R&D labs)

Objectives:

- Undertake the technology development specific to
    - establish the performance standards for AFB1 bio-sensor to achieve regulatory standards (FSSAI/USFDA/EU)
    - establish sampling protocols for contaminated groundnut/peanut
    - undertake inter batch and intra batch reproducibility using certified reference materials (CRM) followed by analysis of filed samples.
- Undertake validation involving CIPET Ludhiana and reintegrate in to user protocol.
- Filed trials at storage site

Deliverables:

The biosensor technology for AFB1 detection will be validated using standard methods as well as through user feedback involving CIPHET Ludhiana and other relevant ICAR lab. Further refinements will be integrated and a field trial will be conducted for analysis of samples from food storage units.

6. Development of Prototype Biosensor for detection of bacteria (E. coli/ Shigella and Salmonella spp.) in drinking

Team:

PI: Prof. Utpal Roy, Senior professor, Biological Sciences, I BITS Pilani KK Birla Goa Campus, Goa

Co PI: Prof. Sunil Bhand, Senior Professor, Department of Chemistry, BITS Pilani K K Birla Goa Campus, Goa

Dr. Gautam Bacher, Asst Professor Dept. of EEE & I BITS Pilani KK Birla Goa Campus, Goa

Proposal Duration: 18 months

Budget: INR 22.62 Lakhs

Human Resources: 1 (RA)

Proposal Summary:

A rapid and specific detection of pathogens is of great importance from public health viewpoint as well as from economic perspectives. The sensor based on sequence specific detection of Escherichia coli /Shigella/Salmonella would facilitate significant improvements in rapidity and specificity over traditional or conventional microbiological methods. The sensing probe would be developed to a prototype smart biosensor for the rapid and specific for detection of in spiked and environmental water samples.

Objectives:

- To design novel probes for specific detection of Shigella sp. and Salmonella
- To develop a sensitive biosensor for pathogen detection in potable water

Deliverables:

A novel bacterial biosensor for early and rapid detection of E. coli/Shigella sp/Salmonella in drinking water with integrated sensor network for community level water monitoring

7. Novel field biosensor for detection of urea in agricultural runoff water

Team:

PI: Prof. Sunil Bhand, Senior Professor, Department of Chemistry, BITS Pilani K K Birla Goa Campus, Goa
Co PI: Dr. Gautam Bacher, Asst Professor Dept. of EEE&I BITS Pilani KK Birla Goa Campus, Goa

Proposal Duration: 18 months

Budget: INR 39.60 Lakhs

Human Resources: 2 (1 JRF & 1 Research Assistant)

Proposal Summary:

The demand forcast for urea in India (2017-18) and (2021-22) stood at 33,754 (000,tonnes) and 36,808 (000 tonnes) as per the working report for 12th five year plan. The large amount application of nitrogen fertilizer has made great contribution to satisfy the continuously increasing food demand. However, the loss of nitrogen fertilizer from soils of farmland via runoff, leaching, and ammonia volatilization, etc. not only results in the low nitrogen use efficiency (NUE) and high production cost, but also increases environmental risk, since large amounts of nitrogen from agricultural fields may deposit in neighboring ecosystems and lead to acidification and eutrophication of natural ecosystems. Specifically, Govt of India is providing a high subsidy to the farmers on urea fertilizers. Thus enhancing the NUE, recovery of these valuable resources need to be significantly optimized via minimization of losses in run-off waters in agricultural fields.

One such opportunity is to develop sensors for monitoring urea content in run-off water and integrate precision farming systems via use of sensors in the SMART farms. This in turn will monitor dose and utilization of urea. Hence, development of novel biosensors (indigenous) will facilitate precision farming systems that in tun will enhance NUE from urea application in the farm via recycling of the dissolved urea in water. The project will develop a urea biosensor and will test its feasibility at farm level by integrating sensor in the irrigation system

Objectives:

- Develop a novel biosensor for detection of urea in agricultural runoff water.
- Integration of urea sensor in farm irrigation system (feasibility study through pilot demonstration) and evaluate urea content in the run-off water.
- Develop an IoT based communication system providing decision support for dosing and reuse of urea in runoff water**.**

Deliverables:

An indigenous low cost miniature biosensor integrated with IoT for SMART farming.

8. A novel transistor based biosensor for analysis of BPS in water

Team:

PI: Dr. Gautam Bacher, Asst Professor Dept. of EEE&I BITS Pilani KK Birla Goa Campus, Goa
Co PI: Prof. Sunil Bhand, Senior Professor, Department of Chemistry, BITS Pilani K K Birla Goa Campus, Goa; Prof. Abhijit Pethe, Associate professor, Dept. Of EEE, BITS Pilani-K.K.Birla Goa Campus

Proposal Duration: 18 months

Budget: INR 39.951 Lakhs

Human Resources: 2 (1 JRF & 1 RA)

Proposal Summary:

The regulations on Bisphenol A (BPA) leads to an increase in the production and use of alternative chemicals for replacement. Bisphenol S (BPS) is the most extensively used as alternative substances for BPA in the production of epoxy resins and polycarbonate plastics (Ye et al., 2019). The contamination of bisphenol S (BPS) in many commercial products has attracted tremendous attention for its adverse impact on animals, human health, and environment. As one of the widely used chemical and raw materials for producing epoxy resins and some polycarbonate polymers, BPS is exposed through plastic and paper industries in many respects in the daily lives of human beings. Studies have reported the occurrence of Bisphenols (BPs) other than BPA in diverse environmental matrices which includes surface water and ground water. BPS has toxic potential, including endocrine disruption, cytotoxicity, genotoxicity, reproductive toxicity, neurotoxicity, and dioxin-like effects, similar to or even higher than BPA and can cause lymphocyte proliferation, affect brain development and damage the reproductive system (Segovia-Mendoza et al., 2020). Many countries in the world have strict regulations for use of BPS but in India we do not have policies and regulations for BPS usage. According to the European Food Safety Authority (EFSA), Tolerable Daily Intake (TDI) amount for BPA is 4 μg kg−1 body weights per day (Niu et. al., 2015) and as per EU guidelines the Specific migration limit (SML) for BPS is 0.05 mg/kg. Thus, rapid and low-cost techniques for the determination of BPS with high sensitivity are urgently needed. Although many methods have been exploited for BPS detection, including Liquid chromatography-mass spectrometry (LC-MS) (Gély et al., 2021), ultrahigh-performance liquid chromatography-tandem mass spectrometry (UHPLC-MS/MS)(Vela-Soria et al., 2014), enzymelinked immunosorbent assay (ELISA)(Lin et. al., 2019), and surface-enhanced Raman spectroscopy,(Roschi et al., 2021), these techniques are not portable, expensive, and time consuming. Recently, various types of transistor based biosensors have been developed in combination with specific

molecular recognition using enzymes, antibodies and nucleic acid. The advantages of transistor based biosensors are large-scale integration of multiple sensors and miniaturization of the sensing area because advanced semiconductor technologies can be used for fabrication and production. An array-based sensor chip with 32 SiNWs was fabricated using nanoimprint lithography, anisotropic wet etching, and photolithography methods (Rani et al., 2018). Liu et al. have reported DNA-functionalized graphene field effect transistors for the detection of BPA. There is a need to develop low cost devices for sensitive and reliable for the detection of BPS in surface/ground water. Hence, under this project we will develop and demonstrate a field effect transistor (FET) based biosensor for sensitive detection of BPS in surface/ground water

Objectives:

- Design, Fabrication and development of novel FET device.
- Detection and analysis of BPS in spiked sample and recovery studies.
- Analysis of real sample and field validation of developed BPS biosensor

Deliverables:

Envisaged a prototype of the BPS biosensor for field trials

9. Development of Solar Powered Cloud Based IoT Device for Agriculture Application

Team:

PI: Nitin Sharma, Associate Professor EEE, BITS Pilani-K.K.Birla Goa Campus

Co PI: Prof. Sunil Bhand, Senior Professor, Department of Chemistry, BITS Pilani K K Birla Goa Campus, Goa

Proposal Duration: 18 months

Budget: INR 30.00 Lakhs

Human Resources: 2 (1 JRF and 1 Research Assistant)

Proposal Summary:

Though our country has taken giant strides from being a food grain deficient state in 50's & 60's to a present surplus state, agriculture sector is showing worrying signs of stagnation in recent past. Declining the size of land holdings without any alternative income is resulting in fall in agriculture income causing distress among farming community. It is estimated that nearly 120.72 million hectare of land is degraded so far due to soil erosion and about 8.4 million hectare has soil salinity and water logging problems. Huge quantities of nutrients are lost during crop production cycle. About 8% of GDP is spent on fertilizer subsidies.

The agri-marketing in India is showing 18 to 25% losses in the entire supply-chain. High dependence on oil and non-renewable sources of energy are making the agriculture sector more risk prone and less

profitable. The productivity of factors of production in agriculture sector is very low compared to the international standards. It is observed that the annual growth rate for land productivity has risen from 2.6 % to 3.1 % and labor productivity rose from 2.2 % to 4.8 % during 1997-98 to 2012-13.

It is estimated that the demand for food grains would be 355 million tons in 2030 and to meet this demand, production of food grains needs to be increased at the rate of 5.5 million tons annually. The demand for high value commodities such as horticulture, dairy, livestock and fish is expected to increase by more than 100% and these commodities are perishable and require infrastructure for handling, value-addition, processing, storage and marketing. In such a scenario, where over dependence on traditional fertilizers are a serious drain on farm productivity, quality of produce and also exchequer, it is imperative that we look towards other alternative technological inputs to raise productivity. Internet of Things (IoT), Cloud Computing and Edge Com based applications can be used to collect real time data to monitor various parameters related to soil health and environment. The processed information can be used to either control the quantity of various parameters automatically using actuators and/or can display the analysis results along with suggestions to the end users.

The Cloud Computing has several advantages such as lower cost, efficiency, scalability and reliability. However, when dealing with multiple sensors generating massive amount of data it may face some challenges. Some of the major issues encountered are, higher latency, higher bandwidth and energy requirement, data loss, etc. For consistent results Cloud based system need steady and low latency connectivity which is difficult in agricultural fields. Edge Computing is an emerging area where data processing occurs near proximity of sensors. Edge computing enables low latency, real-time interaction, support for mobility, improvement of security, efficiency, and conserving network bandwidth. The proposed system will mainly have following four sections: Solar Power module, Sensor module, Edge Computing module and Radio/Transmission module. This will enable the device to use solar energy to recharge the chargeable battery that will be used to power sensors, edge devices and other communication systems. This will theoretically enable this device to be deployed at any remote location.

Objectives:

- Design and implement a solar powered IoT based automated agricultural system using off-the-shelf sensors and related component
- Implement edge computing solutions and a cloud-based dashboard for real-time control and monitoring of the automated farm
- Build anomaly detection models to alert farmers and to store data for future analysis and prediction models. Evaluate performance of the sensors and communication system in lab

Deliverables:

A Solar Powered IoT system for agricultural application capable transmitting pH and Moisture date to cloud will be demonstrated

10. Design and development of a portable Bio-Cyber Physical System based microfluidic cell culture platform

Team:

PI: Prof. Sanket Goel, Professor, Department of EEE, BITS Pilani, Hyderabad Campus

Proposal Duration: 18 months

Budget: INR 21.98 Lakhs

Human Resources: 1 (JRF)

Proposal Summary:

The rapidly increasing demand to develop new therapeutics, test new drugs and develop a deeper understanding of the biological processes have led to significant developments in cellular biology. This increased interest has also led to the need for human and animal-based models. However, experimental investigations involving animal models are sophisticated, expensive and very often impossible to mimic the ideal effects. Therefore, it is prudent to develop an automatic, robust, less-expensive system, amenable to high-throughput analysis, compatible with the data analysis, and preferably requires minimal human intervention. Microfluidics based organ-on-chip (OoC) platforms have emerged as a promising solution to the challenges. Microfluidics based OoC incorporated modified approached of cell and tissue culture techniqies. In the current framework surrounding cell and tissue culture, certain peripheral equipment are critical: biosafety cabinet, incubator, fluid handling systems such as pipettes or pumps and microscopes. This proposal aims to develop a standalone and integrated Lab-On-Chip (LoC) microfluidics-based system for cell and tissue culture studies. The project is aimed toward the development and integration of the following three subsystems: Culture Environment Regulation Subsystem, Microfluidic Cell Culture Devices with Integrated Detection capabilities. The validation for the developed system will be performed by establishing co-cultures and evaluating their response under different conditions (drug toxicities).

Objectives:

- Development of a Portable & Standalone Environmental Control Chamber
- Development of a Microfluidic Device for Co-Culture of Cells
- Identification & Development of Characterization Methodology for Cell Growth
- IoT/Remote Monitoring Integration and Validation of Developed System

Deliverables:

- An independent prototype system would be available for cellular evaluations, which will not require any ancillaries.
- The developed prototype would find relevant applications in various domains such as drug development research employing organ-on-chip models, cellular biology-based academic and industrial R&D, etc.
- The system being cost-effective and requiring minimal capital expenditure would enable further penetration of cell culture-based experimentation to even resource-limited laboratories.

11. Cyber-Physical System Enabled Integrated platform with Microfluidic biofuel cell and Supercapacitor for powering and monitoring biomedical implants

Team:

PI: Prof. Sanket Goel, Professor, Department of EEE, BITS Pilani, Hyderabad Campus

Proposal Duration: 18 months

Budget: INR 24.98 Lakhs

Human Resources: 1 (JRF)

Proposal Summary:

Improved accessibility to quality healthcare, even in cases of chronic disorders due to sedentary lifestyle or otherwise, has led to significant growth in wearable and implantable diagnostic and therapeutic systems. Continuous glucose monitors (CGMs), insulin pumps, pacemakers, neurological monitoring, and aiding systems, etc are some of the examples of wearable or implantable systems currently in popular use. Significant improvements have been done to improve these systems in terms of miniaturization and ergonomics. One major aspect which limits their deployments in a truly 'plug and forget' format of use is the dependency on batteries as power sources. Significant work has been done to reduce power consumption and improve the longevity of battery sources (to a few weeks at most). The need for a continuous power source with proven reliability for wearable and implantable systems is not yet addressed satisfactorily. We propose the development of a high-performance, reliable and miniaturized Microfluidic Enzymatic Bio-Fuel Cell (M-EBFC), to serve as an interruption-free power source for low-power devices. The M-EBFC system is proposed to be developed by leveraging nanostructured carbon materials functionalized bio-electrodes for enhanced enzyme stability leading to better performance than the existing systems. The proposed system aims to power and monitors the functioning of biomedical implants and wearable devices remotely using the self-powered property. The proposed system comprising of an efficiently designed miniaturized EBFC finds application as an energy source for implantable aids such as a pacemaker, CGMs, brain stimulators, insulin generators, etc. To ensure that these devices are supplied with power continuously, a bio supercapacitor is proposed to act as an EBFC and a short-duration power storage unit for interruption-free operation, meeting the requirements of hot-swap operations in existing systems as well. The possible integration with existing systems for hot-swap operation further improves the commercialization potential of the proposed system. Further, a suitable cyber-physical system with an IoT low-energy communication architecture is proposed to be integrated with the M-EBFC system to facilitate the use of the developed systems with real-time monitoring and the point-of-care diagnostic approach, which is the future of the healthcare industry.

Objectives:

- Designing a miniaturized flexible glucose biofuel cell (M-EBFC)
- *in vivo* characterization of the developed M-EBFC for powering implantable biomedical devices with the harvested power
- Integration of wireless devices for real-time health care applications.
- Storage of the harvested power using the fabricated bio supercapacitor (EBFC)

Deliverables:

- A high-performance, reliable, and miniaturized MEBFC, with optimized design and fabrication, to serve as a power source for implantable devices such as insulin pumps, CGMs, etc.
- Enhanced enzyme stability by leveraging nanostructured carbon materials functionalized bioelectrodes leading to better performance than the existing devices.
- Platform technology to monitor the functioning of biomedical aids remotely using the self-powered property of the developed system
- Storage of the harvested power using the fabricated bio supercapacitor (EBFC).

12. Development of Underwater Acoustic Sensor Network for Monitoring of Coral Reef

Team:

PI: Dr. Sarang C. Dhongdi, Asst. Prof., Dept of EEE, BITS Pilani K K Birla Goa Campus, Goa
Co PI: Prof. K R Anupama, Prof., Dept of EEE, BITS Pilani K K Birla Goa Campus

Proposal Duration: 18 months

Budget: INR 34.86 Lakhs

Human Resources: 1 (RA)

Proposal Summary:

Coral reefs are a very important environment that maintain a great variety of life forms and are indicators of ocean health. Currently coral reefs are monitored using divers and researchers have been collecting data periodically on environmental conditions. The current system does not provide real-time data through all seasons. In addition, it is invasive in nature. The main objective of the proposal is to develop an underwater acoustic sensor network which can be deployed for monitoring the regional coral reef non-intrusively and through all seasons. For deployment of this network, series of underwater nodes would be developed with the capability of sensing, communication, data processing and networking. Using these nodes an ad hoc self-configuring underwater acoustic sensor network will be built to monitor various parameters ocean environment using oceanographic sensors.

Objectives:

- To develop an underwater acoustic sensor node
- To test the point to point communication among the nodes underwater
- To design network architecture and develop networking protocols for UASN
- To implement the networking protocol, stack in simulation and on hardware test-bed set-up.

Deliverables:

- An underwater node with the following capabilities

- Acoustic Communication and Networking
- Plug and Play Multi-sensor configuration
- Data processing and storage

- Underwater ad hoc acoustic sensor network and its protocol stack with the following features

- Dynamic and Limited Scalability
- Real time data acquisition and analysis.

- Sensing Technology for study and documentation of coral reef flora and fauna using acoustic network through automation.

13. Integrated Microfluidic/Miniaturized Electrochemical Sensing Platform for multiple bio-analytes

Team:

PI: Dr. Satish K Dubey, Asst. Professor, Department of Mechanical Engineering, BITS Pilani, Hyderabad Campus

Co PI: Prof. Sanket Goel, Professor, Department of EEE, BITS Pilani, Hyderabad Campus

Proposal Duration: 18 months

Budget: INR 18.48 Lakhs

Human Resources: 1 (JRF)

Proposal Summary:

Renal health, often addressed as a kidney health, is one of the most critical indicators of over human-body function. The kidneys and associated organs, collectively forming the renal system, have the important function of regulating toxins in the body. It is an established fact that prolonged ailments like elevated blood pressure, diabetes etc., generally affects renal health. Thus, timely evaluation of renal health is essential in most medical conditions. Also, various contributory factors have led to an increase in chronic kidney diseases (CKD) over the past few decades. CKDs also require close monitoring of renal health which is cumbersome in the current framework. Renal health is evaluated using few biomarkers and the analysis of quantitative difference in biological fluids. Creatinine, Urea and Uric acid are three important biomarkers in estimating renal health. The absolute values in blood and urine help in establishing other parameters associated with renal health such Glomerular Filtration Rate (GFR) and creatinine clearance. The current techniques involved in estimating these critical parameters are dependent on availability of complex laboratory equipment, skilled personnel, high operational costs. The current techniques are lab dependent, leading to a higher turnaround time. Through this proposal, a portable electrochemical sensing platform for multiple analytes associated with renal health is being developed to address the challenges associated in the clinical settings. The aim is to bring down the complexity and improve affordability in renal health assessment by developing the portable system as has been done for glucose monitoring systems. Along with assessment, the proposal aims to incorporate IoT based architecture for secure data availability to all involved stake holders for enhanced diagnosis or timely preventive measures.

Objectives:

- Fabrication of the miniaturized Electrochemical device for quantification the renal biomarkers
- Electrochemical characterization techniques for the detection and Miniaturized Platform
- Machine learning (ML) and Internet of Things (IoT) based integration of the devices for detection
- Validation of the System

Deliverables:

Point-of-Care Renal Heath Assessment System with IoT enables Remote Diagnostics Capabilities

14. A Multimodal and Cost-Effective Framework For Medical Diagnostic And Robotic Surgery Devices

Team:

PI: Dr. Kunal Korgaonkar, Assistant Professor, Computer Science and Information Systems (CSIS) Department, BITS Pilani, KK Birla Goa Campus, Goa

Co PI: Prof. Vinayak Naik, Professor, Computer Science and Information Systems (CSIS) Department, BITS Pilani, KK Birla Goa Campus, India

Proposal Duration: 18 months

Budget: INR 21.9 Lakhs

Human Resources: 2 (1 RA and 1 Research Assistant)

Proposal Summary: The proposal project caters to the current and future demands of the medical diagnostic and robotic surgery device industry. Given the fast-paced advancements in computing technologies such as computer architectures (Custom-CPU, GPUs, FPGAs, etc.) [1] and algorithmic advancements in machine learning [2] (e.g. deep learning, image processing, robotic algorithms), we foresee that it will be difficult for the small and medium scale enterprises (including startups) in the Indian medical diagnostic and robotic surgery device industry to keep pace and maintain a competitive advantage against their international counterparts.

As a solution to this grand challenge, we intend to develop a multi-model and cost-effective framework, that can be used by medical device vendors to in turn develop a large variety of innovative medical diagnostic and robotic surgery devices (or products). The proposed hardware-software-sensor reference framework (which can also be called a platform) will be intended to be used by existing and new players in the medical device industry in India (especially, SMEs) to innovate faster and better, thereby enabling them to serve the large and booming domestic and international market.

We intend to go to field trials by 18 months or sooner. We will be developing the platform in the coming 18 months and getting it ready for field trials with a set of target SMEs. We foresee that some of these SMEs will in turn become our initial customers. Acceptance by them will be a key milestone and this will set the course for the future progress of the project.

Objectives:

- Prototype 1
- Prototype 2
- Start of field trial
- End of first field trial

Deliverables:

A complete sensor, data processing and visualization pipeline will be built and demonstrated. Demonstrate how the same framework can be used for both medical devices (Ultrasound Diagnostic Medical Device (ultrasound sensor), and Endoscopy Diagnostic Medical Device (image sensor)

15. A thin film transistor biosensor for detection of endocrine disruptive compounds

Team:

PI: Prof Abhijit Pethe, Associate Professor, EEE, BITS Pilani K K Birla Goa Campus
Co PI: Prof. Sunil Bhand, Senior Professor, Department of Chemistry, BITS Pilani K K Birla Goa Campus, Goa

Proposal Duration: 18 months

Budget: INR 41.976 Lakhs

Human Resources: 2 (1 JRF and 1 Research Assistant)

Proposal Summary: Endocrine disruptive compounds (EDC) constitute a wide group of environmental pollutants, which are able to antagonize or mimic the effect of endogenous hormones such as estrogens, androgens and testosterones. The presence of these class of compounds in surface water poses a serious threat to the endocrine systems of both human and wildlife populations. Among these EDCs, 17β-estradiol is an endogenous estrogen, whose presence in contaminated waters can lead to dysfunction, gynaecomastia and rise in the probability of cancer among humans. A cheap, fast, sensistive and reliable sensor will be essential to quantify concentrations of these in surface water bodies which can eventually be used to track and prevent discharge of these compounds. The sensors need to sensitive and reliable while measuring concentration of the endocrine secretion over the normal physiological range. Indium gallium zinc oxide (IGZO) field –effect transistors are a promising technology that are currently commercialized in displays. They have relatively high electron mobilities, and can be processed at low temperatures that are compatible with flexible substrates. The back channel in the FET devices may be functionalized using coupling agents. Self-assembled monoloayers (SAMs) based on Polyhydroxyalkanoates (PHA) have been used to immobilize enzymes in previous work. the interaction of the agent with the enzyme leads to concentration-dependent changes in the FET electrical response.

Objectives:

- Demonstration of IGZO films using a aqueous process: metals salts will be procured and process will be developed for film creation and deposition. Material analysis will be done along with establishing process windows to map out the manufacturability of the flow. Film deposition will be demonstrated on both glass and kapton substrates.
- Demonstration of back-gated transistor on glass substrates – two/three mask flows will be developed and transistor action demonstrated on aqueous processed semiconductor films. Electronic mobility in the range of 2.5-5cm2/Vs needs to be demonstrated.
- Integration of analyte on the transistor and sensitivity demonstration – The analyte required for sensing the EDC needs to be integrated onto the back gate followed by a demonstration of

modified electrical performance of the transistor. Measurement of sensitivity will be carried out over the wide range of experimental conditions like temperature, light conditions, solution medium etc.

- Passivation technique demonstration: Establish a passivation technique to ensure that ambient does not impact device performance once the solvent has been introduced. The response time needs to be kept to below 1 ms.

Deliverables:

Identify a transistor structure and suitable analyte candidate to measure the concentration of 17β-estradiol in surface water bodies. This may be then licensed to flexible electronic manufacturers to build IoT devices for live monitoring in the field.

16. Exosome cargo in severe malaria infections: Prognostic markers for severe disease/ Markers for detection of infection

Team:

PI: Prof. Ashis Kumar Das, Senior Professor, Department of Biological Sciences, BITS Pilani, Pilani campus

Co PI: Prof. Anupama Mittal (Associate Professor, Department of Pharmacy, BITS Pilani, Pilani campus

Prof. Shilpi Garg (Associate Professor. Department of Biological Sciences, BITS Pilani, Pilani campus

Proposal Duration: 18 months

Budget: INR 50.918 Lakhs

Human Resources: 2 (JRF and Lab Assistant)

Proposal Summary:

Extracellular vesicles produced by various cell types have become the subject of extensive investigations in recent times. We intend to isolate exosomes from persons infected with Plasmodium spp, who exhibit either uncomplicated disease or severe disease viz. hepatic dysfunction, renal failure, etc. The objective would be to isolate exosomes from body fluids like plasma or urine and investigate the protein or nucleic acid cargo in them. These would be compared with exosomal cargo seen in uninfected control plasma or urine. This discovery project could provide signature nucleic acid sequences or proteins, which then could be used as the basis of procedures and devices for disease prognosis or pathogen detection.

Objectives:

- Collection and Processing of samples Isolation of Exosomes
- Extraction of Protein and RNA content of Exosomal cargo
- Transcriptomic and Proteomic analysis

Deliverables:

The proposed outcome of this project would be the effective isolation of EVs/ Exosomes from both plasma and urine samples of malarial patients followed by the analysis of the contents of the cargo. We aim at finding unique proteins or nucleic acids belonging to the parasite as the indicator of infection or parasite/host as prognostic markers of disease severity. This would enable future procedure and device development to further detection or prognosis.

17. Bio-CPS Device Security

Team:

PI: Prof. Chittaranjan Hota, Professor, Department of Computer sciences, BITS Pilani, Hyderabad Campus

Co PI: Dr. Sameera Muhamed Salam, Assistant Professor, Department of Computer sciences, BITS Pilani, Hyderabad Campus

Proposal Duration: 18 months

Budget: INR 34.9 Lakhs

Human Resources: 3 (1 JRF & 2 Research Assistants)

Proposal Summary:

A Wireless Body Area Network (WBAN) is a wireless network made up of a collection of microscopic biomedical nodes that are dispersed around the human body's surface, inside the body, in the clothes or next to it. WBAN, also known as Wireless Body Sensor Network (WBSN), is a specific kind of Wireless Sensor Networks (WSNs) that is defined in IEEE 802.15.6 (IEEE, 2012). With a wide range of data transmission speed to suit various application types, IEEE 802.15.6 offers dependable communications across short distances. The incredibly low power sensor nodes can track the body's critical physiological indicators, and some of them may even administer a dose of medication directly into the body. A distant server or a sink node will receive real-time readings of the body's bio-signals from wearable devices and Implantable Medical Devices (IMDs). Depending on the kind of node, the monitored signals can include electrocardiogram (ECG), electromyogram, blood pressure, respiration measurement, heart rate, and blood glucose levels (EMG) etc. The high rate of death caused by various chronic diseases such as heart disease, diabetes, Parkinson, asthma, and various other fatal diseases can be predicted with early detection using sensors on the patient's body. Fig.1 shows an example of a WBAN. Monitoring these physiological factors in older people or people with chronic illnesses gives them more freedom and flexibility and enables prompt intervention when necessary.

The main issues preventing the widespread implementation of WBANs are security and privacy concerns. Sensitive and extremely important data is sent by sensor nodes. Any compromise would violate the patients' right to privacy and even put their lives in danger. To address potential security weaknesses, security countermeasures range from conventional security solutions like authentication and encryption to Intrusion Detection Systems (IDSs) and Trust Management Systems (TMSs). Keeping in mind wide usage of WBANs and its security implications, our research focuses on the following key research gaps:

- The security solutions that were designed for WSNs may not be suitable for WBANs because of the resource constraints associated with Bio-CPS devices. Hence a low power, energy efficient cryptographic techniques are required to secure these devices from malicious attacks.
- Once the data is captured, this is transmitted to the nearest sink node. The sink node analyzes this data. It becomes important to ensure that this data does not have any irregularities. So removing the anomalies from the generated data is currently one of the other important challenges researchers are facing.

Objectives:

- Literature Review
- Design a PUF based light weight authentication scheme and multi factor authentication approaches to secure wearable devices
- Provide security solution to counter replay/spoofing attacks on implantable devices
- Design of an anomaly detection framework

Deliverables:

- A lightweight cryptographic solution that will suit the Bio-CPS devices which is resource efficient and secure. The proposed approach is expected to safeguard the device against MITM attacks and counter replay/spoofing attacks.
- An anomaly detection framework that can detect anomalies from the data generated from the Bio-CPS devices using different machine learning techniques which will be trained on the existing datasets.

18. Methylated cfDNA as a pathological biomarker for the development of a CRISPR/Cas based molecular diagnostic tool

Team:

PI: Dr. Deepak Chitkara, Associate Professor, Department of Pharmacy, BITS-Pilani, Pilani campus

Co PI: Prof. Sunil Bhand, Senior Professor, Department of Chemistry, BITS Pilani K K Birla Goa Campus, Goa

Prof. Ashis Kumar Das, Senior Professor, Department of Biological Sciences, BITS Pilani, Pilani campus

Proposal Duration: 18 months

Budget: INR 36.712 Lakhs

Human Resources: 2 (1 JRF and 1 RA)

Proposal Summary:

CRISPR (clustered randomly interspaced short palindromic repeats) was discovered in 2012 by Doudna and Charpentier (received a Nobel prize in 2020) [4] as a defence system in the bacteria and archaea against the

viruses which invaded them[5]. Till then it has evolved very fast and become the mainstream gene editing tool for its site-specificity and precise gene editing ability. Since early 2018, our lab is working on CRISPR therapeutics and exploring its role as a new therapeutic approach. Interestingly, CRISPR therapeutics become the most attractive area as it is unwrapping or solving the bigger questions in the field of science [6]. The pandemic situation created by the COVID-19 infection pressurized the researchers to develop some novel methods of diagnosis. As a result, significant outcomes were observed where CRISPR was employed to develop biosensors that can detect the viral genome in the patients' samples [7-9]. The technology attracts researchers to work on it and till now different Cas effectors [10] (33 subtypes, each with distinct abilities) have been discovered and some of them are explored in the field of diagnosis [11]. The nucleic acids such as DNA, RNA, miRNA, cell-free DNA, lncRNA, etc are one of the potential biomarkers whose expression levels get modulated in biological fluids such as serum/plasma/urine [12]. The expression level of these nucleic acid biomarkers is strongly correlated to the onset of diseases condition in the body. However, the amount of these biomarkers in the body fluid is very low (sometimes even < 10 ng/ml) [13] and it is very challenging to detect them using the existing technologies. CRISPR biosensors have been reported for their ability to detect nucleic acid at the femtomole level with high accuracy and precision and therefore could be a potential method to detect the aforementioned nucleic acid biomarkers. Therefore, in the current proposal, we aim to utilize the novel Cas effectors i.e Cas12a for developing a biosensor that could detect chronic diseases via multiple nucleic acid sensing at an early stage. The successful completion of the work results in the development of a ready-to-use kit that could reveal the actual status or onset of the disease through a digitalized device using predetermined mathematical correlations and statistics.

Objectives:

- Expression, purification, and characterization of Cas effector proteins
- Identification, selection, and validation of nucleic acid biomarker associated specifically with a disease progression
- Design and synthesis of crRNA for the target nucleic acid
- Optimization and validation of CRISPR reaction using predetermined nucleic acid biomarkers

Deliverables:

A final prototype ready-to-use packed kit that will be out for feedback trial from selected clinicians working in the diagnostic field

19. Identification of novel biomarkers in ovarian cancer and design of appropriate prognostic probes

Team:

PI: Prof. Rajdeep Chowdhury, Associate Professor Biological Sciences, BITS-Pilani, Pilani campus
Co PI: Prof. Inamur R Laskar, Professor, Department of Chemistry, BITS-Pilani, Pilani campus,
Prof. Shibasish Chowdhury, Professor, Department of Biological Sciences, BITS-Pilani, Pilani campus,
Prof. Kamlesh Tiwari, Professor, Department of Biological Sciences, BITS-Pilani, Pilani campus

Proposal Duration: 18 months

Budget: Rs. 34.66 Lakhs

Human Resources: 2 (JRFs)

Proposal Summary:

Today one of the biggest unmet gynecological challenges in women's health, in India is ovarian cancer (OC). It is considered to be the third most common and one of the most lethal gynecological cancers in India, mainly because of its inadequacy in being detected at early stages and frequent recurrence. In this context, we assume that an effective, yet sensitive approach towards OC prognosis above the conventionally used procedures can enable effective management of this dreadful disease. Current methods of disease detection rely on the levels of Cancer Antigen- 125 (CA- 125) or HE4 protein in blood. Although widely used, the accuracy of detection using these biomarkers is questionable as CA125 is not elevated in 50% of Stage-I and 30% of more advanced OCs. Also, CA125 is often found in serum of individuals without cancer, increasing the probability of false positive results. Moreover, it is important to note that there are no approved markers for prediction of chemotherapy response in OC. This highlights the inappropriateness of the current monitoring approach for OC. No wonder it is amongst the top gynecological cancers in India. Despite an aggressive treatment regime involving surgery and chemotherapy, a high percent of women with ovarian cancers often show recurrence. This increasing risk of ovarian cancer burden in India provide compelling reasons to address this issue. High percentage of recurrence of cancer in advanced stage patients, is usually corroborated to resistance to chemotherapy. A lot of molecular markers for chemo resistance have already been reported, but have not been translated to the clinics. In our proposed study we plan to explore gene signature for prediction of resistant features in OC. In this context, cancer cells are known to secrete exosomes, which are involved in tumor progression, metastasis and invasion. This can be regulated by the macromolecules present in the exosomes which also alter various signaling pathways involved in bringing about resistance to chemotherapy. Following an extensive database search wherein we filter patient and cell line datasets using key gene filtration, we hope to shortlist macromolecules which can be potential markers for prediction of drug response. The expression of these markers shall be validated in ovarian cancer cell lines. Furthermore, exosomes shall be isolated from drug treated cells and explored for the presence of these selected markers. The exosomes serve as a suitable platform to understand the evolutionary dynamics of a disease through minimal invasive procedures. The presence of the identified marks from OC cells and exosomes will then be validated in ovarian cancer patient samples. Thereafter, based on the parameters obtained from the aforementioned studies, we propose to develop a cognitive deep learning model through machine learning that can predict treatment response in ovarian cancer patients. Herein, our initial studies on key gene filtration of datasets obtained from the publicly available databases have provided us with lead to signatures associated with drug treatment. Some protein biomarkers such as Lung Resistance Protein-1 (LRP-1), P-glycoprotein (PGP), Vascular Endothelial Growth Factor (VEGF), Excision repair cross complementation group 1 (ERCC-1) amongst many others are known to be differentially regulated in presence of chemotherapeutic drugs like Cisplatin, Carboplatin, Paclitaxel in advanced ovarian cancer. Some protein molecules such as Prostasin (PRSS8), GSTT1, FOLR1, KLK6, KLK7, and ALDH1 have also been reported to show increased specificity and sensitivity for early detection of OC. There are increasing number of reports on presence of lncRNAs in exosomes as well. Taking into consideration the existing and the newly identified marks, we further plan to design an effective probe for detection of the molecular markers. In collaboration with Chemistry department, we have so far analyzed different Aggregation Induced Emission (AIE)-based compounds which are capable of emitting color in response to presence of specific target molecules. Herein, we expect to deliver a probe that can in future act as a single point of care device which will allow us to detect the luminescence of AI compound bound to specific target molecules. This might be of tremendous importance in

context to improved disease management in future, impacting overall women health and reducing mortality.

Objectives:

- In silico analysis and putative identification of a signature of biomarkers; initiation of in vitro validation
- Biomarker validation and Exosome isolation and characterization.
- Design, synthesis, structural characterization and analysis of specificity of AIE based nanoprobe. In parallel, analysis of sequencing.
- Validation of the probe in biological samples and development of the cognitive model

Deliverables:

Complete biomarker discovery phase and make advancements toward next phase

20. De Novo designed peptides scavenge SARS-CoV2 Spike-protein

Team:

PI: Prof. Samit Chattopadhyay, Senior Professor, Department of Biological Sciences, BITS Pilani K K Birla Goa Campus, Goa
Co PI: Dr. Subhrangsu Chatterjee, Associate Professor, Bose Institute, Kolkata, India.

Proposal Duration: 18 months

Budget: INR 70.00 Lakhs

Human Resources: 1 (RA)

Proposal Summary:

COVID-19 has emerged as a pandemic affecting almost all the countries of the globe, resulting in 567,372,876 getting infected and over 6,387,270 deaths worldwide as of 17th July 2022 according to WHO. Several vaccines are available in the market that offer a range of protection against SARS-CoV2. Despite the unprecedented scale of vaccination drive throughout the world, we are in dire need of anti-COVID-19 drug molecules to mitigate the healthcare overwhelming situation currently being faced by many countries around the world. The Spike protein of SARS-CoV2 mediates the attachment and entry of the virus within human cells by utilizing the human Angiotensin Converting Enzyme 2 (ACE2) as a receptor. These receptors are present in the epithelial cells of the upper respiratory tract as well as the lungs. The glycosylated Spike protein has been well characterized using structural and biochemical techniques and its association with the human ACE2 receptor has been elucidated structurally. These studies have given us the opportunity to develop this novel therapeutic peptide that specifically target the Receptor Binding Motif (RBM) within the Receptor Binding Domain (RBD) of the Spike protein. Our research team has been working in the development of anti-Covid agents which can be useful as nasal drop and inhaler/nebulizer to combat SARS-CoV2 infections. One of our molecule exhibited anti-COVID-19 activity against patient derived strain in VeroE6 cells with 98% inhibition for 10µM concentration of the molecule (work done at ILS, Bhubaneswar, DBT Institute, Govt of India). This molecule is characterized by non-cell permeability and high miscibility in water and found to be stable in human saliva for 18 hrs. The cell cytotoxicity assay and animal model cytotoxicity (complete blood profile and tissue histopathology lung, liver,

kidney, spleen, heart) have been performed and found to be safe for administration (with animal ethical clearance). Our molecule offers a low cost, simple, reliable, and efficient solution to combat the virus. Our proposal aims to target the Spike protein of SARS-CoV2 by selective peptide-based ligand for therapeutic intervention

Objectives:

- Serum stability assay
- Formulation
- Toxicity studies in GLP accredited laboratories
- Other experiments to check robustness of the molecule

Deliverables:

Pre-clinical studies including assessment of ADMET-profiling, toxicity studies, pharmacokinetics, pharmacodynamics. Further studies in knockout mice and humanized hamster system to derive the efficacy of the molecule against COVID-19 infection

21. Quick detection of early stage oral cancer by signature metabolites using Bio-CPS modules: Small molecule intervention with anticancer activities for oral cancer

Team:

PI: Prof. Samit Chattopadhyay, Senior Professor, Department of Biological Sciences, BITS Pilani K K Birla Goa Campus, Goa

Co PIs: Dr. Partha Chakrabarty, MD, Ph D; Scientist: CSIR-IICB, Kolkata
Dr. Srivari Chandrasekhar, Secretary, DST, Former Director, CSIR-IICT, Hyderabad;
Prof. Sanket Goel, Department of EEE, BITS Pilani, Hyderabad Campus
Dr. Manas K Santra, NCCS, Pune

Proposal Duration: 18 months

Budget: INR 70.00 Lakhs

Human Resources:2 (RA)

Proposal Summary:

Earlier we have shown that tumor suppressor SMAR1/BANP get proteosomaly degraded in advanced stages of cancers. A small molecule "SCS-OCL-381" is reported from our lab that stabilizes SMAR1/BANP as shown in the research article published from our lab entitled "A novel isothiocyanate derivative inhibits HIV-1 gene expression and replication by modulating the nuclear matrix-associated protein SMAR1" published in the journal "Antiviral Research", 2019, Impact Factor: 10.1. Considering that this molecule works through SMAR1/BANP stabilization which is a tumor suppressor, we have tested its anti-cancerous activity and observed promising results. This compound will now be used against breast and oral cancer. Earlier in 2019, we have patented the molecule from CSIR-IICT, Hyderabad. In animal experiments, we observed a strong anti-cancer activity using this formulation. We now propose to use it against oral and Brest cancers. For this, animal experiments are already performed and with the funding from TIH, we shall proceed for the large scale testing both in animal and human. The bioavailability, toxicity and the biodegradability are partly tested and found to be safe to use in human.

b. As a second line of action, It has been reported that Sulforaphane extracted from Broccoli has promising anti-cancer activity by binding to a pocket of SMAR1/BANP protein and blocking its proteasomal degradation. To further prove its anti-cancer activity, we have used the fraction of Broccoli extract containing Sulforaphorane and tested that against oral cancer in mice model. We have provided enough evidence to show that this compound can prevent 4NQO-induced oral squamous cell carcinoma using immunocompetent mice model. Our formulation seems to be very promising to work against oral leucoplakias and inhibit the progress of any tumor in oral buccal cavity. Additionally, such drug will be very cheap and affordable by a large number of patients suffering from oral cancer. We think that application of an ointment containing this formulation can significantly prevent the transition of leukoplakiaancer stage II to stage III. This AYUSH-based product is going to be promising to inhibit the cancer progression in oral cancer patients upon external application. Additionally, both sulforaphane and its derivatives will also be used to find genome-wide expression of oncogenes and tumor suppressors globally. This will give us a clear idea about role of these small compounds in cancer patients. Although the animal experiments have already done with exciting results, we need to do a large-scale experiment to prove it's efficacies statistically significant. Once that is done, human trials will be executed in next year. For a detailed understanding of regulated pathways via SMAR1 upregulation mediated by our formulation, we are also planning to do a genome-wide expression analysis of oncogenes and tumor suppressor genes. This work is initiated at NCCS, Pune by two of my Ph D students.

c. After working for more than 6 years with CSIR-IICB and Narayana Hospital, Kolkata we have identified specific metabolites present in the oral cancer patient samples. Our joint observation leads towards quick detection system to predict early oral cancer using patient saliva saples. The whole study can lead to an affordable early detection kit and could prevent highly expensive and sometimes, riskier chemotherapy sessions. We have carried out a good amount of experiments to analyse the metabolites from saliva using Orbitrap (MS/MS), Themo and found some of the most important signature metabolites that are useful to detect oral cancer at a very early stage. Simply using quick fractionation and Mass-Spectrometry studies, we have come up with a novel process to quickly predict oral cancer from the saliva sample. The procedure is simple and doable at a very low (less than Rs 1000/- per sample). Intial results are really exciting. We have to increase the sample size which will require a good amount of fund from TIH. We can now use the findings for the early detection of oral and breast cancer using a gene-chip-based microarray of potential cancer biomarkers.

Objectives:

- Metabolite assay from oral cancer saliva samples
- Formulation
- Toxicity studies in GLP accredited laboratories
- Other experiments to check robustness of the molecule

Deliverables:

- Quick device and protocol to detect early cancer using Orbitrap Mass-Spectrophotometry
- Samll molecule intervention with oral anti-cancer activities

22. Development of detection system of pre-validated salivary biomarkers to determine the stages and type of cardiovascular disease

Team:

PI: Dr. Syamantak Majumder, Associate Professor, Department of Biological Sciences, BITS Pilani, Pilani campus

Co PIs: Prof. Shibasish Chowdhury, Professor Department of Biological Sciences

Prof. Inamur R Laskar, Professor, Department of Chemistry

Dr. AR Harikrishnan, Assistant Professor, Department of Mechanical Engineering, BITS Pilani,

Pilani campus

Proposal Duration: 18 months

Budget: INR 24.23 Lakhs

Human Resources: 1 (JRF)

Proposal Summary:

Cardiovascular diseases (CVD) is remain to be leading cause of mortality worldwide with a total of 17.9 million deaths alone in 2017 (in India around 49.8% mortality between 2007 to 2017 is due to CVD related complications) thus CVD has become a global epidemic. Lack of easy detection system to determine the type and stages of CVD is still remain far from true and such detection will likely help clinicians for deciding patient specific treatment regimes. Through the proposed plan, we envision to employ existing dataset to pinpoint specific biomarkers to determine the type and stages of CVD. Based on such identification, we aim to optimize the detection system (aptamer or probe based) to measure the quantity of the biomarker in samples followed by development of a portable prototype to detect the probe based measurement of biomarkers in biological samples.

Objectives:

- Identifying novel biomarker from existing dataset using *in silico* approach to perform structural analysis and further validation of biomarkers in biological samples.
- Synthesizing targeted fluorescence/luminescence based probe molecules for the detection of identified biomarkers.
- Designing and fabrication of portable prototype for probe based detection of biomarkers in biological samples.

Deliverables:

AIE probes that are designed for detection and the initial prototype

23. A Scalable Cloud and Edge-based Framework to Ease The Deployment of IoT-based Applications

Team:

PI: Prof. Vinayak Naik, Professor, Dept. of CSIS, BITS Pilani K K Birla Goa Campus, Goa

Co PI: Dr. Arnab Kumar Paul, Assistant Professor, Dept. of CSIS, BITS Pilani K K Birla Goa Campus, Goa

Proposal Duration: 18 months

Budget: INR 41.16 Lakhs

Human Resources: 3 (1 JRF & 1 RA)

Proposal Summary:

The aim of this project is to design and develop a scalable backend framework for the ease of deployment of Internet of Things (IOT-) based applications in the cloud. IOT refers to the network of sensors, and electronic devices for collecting and exchanging data with other devices and systems over the Internet. IOT devices have continuously evolved in the past decade and are used in various applications, such as healthcare, smart cities, and drones. However, IOT devices can be time-consuming to set up and the deployment becomes more complex as the number of IOT devices increases. Moreover, with a large amount of data being collected by the IOT devices and the growing prevalence of privacy-preserving machine learning (ML) models running on edge nodes located between the IOT devices and the cloud, there is a need for an optimized data storage and transfer framework that can help navigate the real-time data needs of the IOT devices and facilitate the smooth transfer of data among the IOT devices, edge nodes, and the cloud. To this end, we will develop a microservices-based framework in the cloud to compose an end-to-end IOT application that executes each service independently and hence optimally. We will provide APIs for optimized data transfer and storage in the edge and the cloud as well as develop an administrator dashboard to monitor the resource consumption of the loT-based applications deployed on the cloud. Optimal resource utilization and data storage will lead to reduced operational costs of the applications

Objectives:

- Development of a generic microservices-based framework to construct a cloud-based IOT solution that will use multiple services to collect, store, process, and communicate with a mobile application to view the data.
- Development of an optimized data storage and transfer framework which will provide APIs to the IOT devices for facilitating data movement from the IOT devices to the cloud and vice-versa.
- Designing an administrator dashboard that will enable monitoring the resource consumption of the IOT applications as well as optimize the total cost of running the application on the cloud.
- Evaluating the framework with different IOT applications as we scale up the number of users.

Deliverables:

An API to IOT applications to connect with the backend edge nodes and the cloud platform. The applications will not need to worry about the deployment, scalability and data transfer protocols needed for connecting to the backend. We will also provide an administrator dashboard that will be able to provide real-time monitoring of resource usage and show the trend of resource consumption which will help in cost effectiveness of the application.

24. Developing novel biomarker based test for Rapid diagnosis of Malaria infection as better alternate to current approaches

Team:

PI: Prof. Vishal Saxena, Professor, Department of Biological Sciences, BITS Pilani, Pilani

Co PI: Dr. Sanjay K. Kochar, Professor, Dept. of Medicine, S. P. Medical College, Bikaner

Proposal Duration: 18 months

Budget: INR 38.88 Lakhs

Human Resources: 2 (JRF and Lab technician)

Proposal Summary: Rapid diagnostic tests (RDTs) have made a significant impact on global efforts against malaria over the past two decades. Currently used dipstick based RDTs mainly target Lactate Dehydrogenase (LDH), Histidine Rich Protein (HRP) 2, Aldolase (Aldo) and Glutamate dehydrogenase (GluDH) proteins of parasite. Considering that only about two third of the reported annual malaria cases receive a confirmatory diagnostic test before treatment, there remains a critical need for new RDTs that are more sensitive (that may detect low parasitemia or even gametocytes), more accurate, robust, and more affordable. Rapid diagnosis platforms based on novel uncharacterized proteins expressing on the surface of malaria parasites/ infected RBC, or secreted out of parasite and infected RBC or cytosolic proteins having high species specificity may offer better alternative to the current RDTs.

Objectives:

- Identification of novel candidates to be used as biomarker for Malaria Rapid diagnosis
- Developing a proof of concept for an antigen or antibody based dipstick platform for field diagnosis

Deliverables:

Proof of Concept will be developed

List of Proposals shortlisted as Outsourced activity to Spokes (IIT Dharwad & SASTRA Deemed University)

S.no.	Project Title	Description	Sector	Team	TRL Level (Start-End TRL)

1	Development of resistive sensors for early detection of crop infestation	This project aims at efficient crop health monitoring by developing resistive sensors for early detection of pest attack. The validation of the sensors' performance will be done with Maize.	Agriculture	**PI:** Prof. Ruma Ghosh, Department of Electrical Engineering, IIT Dharwad **Co PI:** Prof. M Rajeswara Rao, Department of Chemistry, IIT Dharwad	TRL 1-3
2	Developing Efficient Communication Infrastructure - Connecting Ground Sensors and Satellites/Drones to Cloud and Cloud to Actuators.	Design and development of low-cost communication framework and infrastructure for data aggregation for actuator signaling. Connecting ground sensors, drone and satellite to cloud and cloud to actuators, where ground sensors will be powered from energy harvesting sources.	Agriculture	**PI:** Dr Rajshekar Bhat - Assistant Professor, Department of Electrical Engineering, IIT Dharwad	TRL 1-5
3	Smart Variable Rate Technology (VRT) application to agricultural spray drones for accurate pesticide delivery	To design and develop a dedicated agricultural spray UAVs that can deliver liquid agrochemicals at specified conditions, such as amount, spread, satisfactory coverage of intended target	Agriculture	**PI:** Dr. Surya Prakash R. Assistant Professor, Department of Mechanical, Materials and Aerospace Engineering, IIT Dharwad. **Co PI:** Dr. Keerthi M. C. Assistant Professor, Department of Mechanical, Materials and Aerospace Engineering, IIT Dharwad	TRL 1-5
4	Automatic grading of grain or fruit quality using depth information and machine learning	To design a prototype with depth vision capability along with normal RGB imaging to exclusively capture grain information in ideal imaging conditions and demonstrate proof-of-concept	Agriculture	**PI:** Dr. Samarth S. Raut, Dept. of Mechanical Materials and Aerospace Eng. IIT Dharwad **Co PI:** Dr. Mahadeva Prasanna, Dept. of Electrical Engineering	TRL 1-5

5	A solar based and CPS assisted smart dryer for a post-harvest grain storage systems	To design, develop, and prototype a solar based and CPS enabled smart dryer for a post-harvest grain storage system. Solar-based Dryer sub-modules includes solar collector, auxiliary energy system, energy-storage, dryer-tunnel.	Agriculture	**PI:** Prof. Dhiraj V. Patil, Associate Professor, Department of Mechanical Engineering, IIT Dharwad	TRL 1-5
6	Point-of-care Biosensor for the Detection of Methylglyoxal – A Diabetes Biomarker	To design and develop affordable point-of-care nano bioelectrode based electrochemical biosensor for the quantitative detection of a diabetes biomarker 'Methylglyoxal'	Healthcare	**PI:** Prof. R. John Bosco Rayappan ABCDE Innovation Centre Centre for Nanotechnology & Advanced Biomaterials School of Electrical & Electronics Engineering SASTRA Deemed University, Tamil Nadu **Co PIs**: Prof. K. S. Rajan ABCDE Innovation Centre Centre for Nanotechnology & Advanced Biomaterials School of Chemical & Biotechnology SASTRA Deemed University Dr. K. Arockia Jayalatha ABCDE Innovation Centre Centre for Nanotechnology & Advanced Biomaterials School of Electrical & Electronics Engineering	TRL 2-4

				SASTRA Deemed University Dr. N. Noel ABCDE Innovation Centre Centre for Nanotechnology & Advanced Biomaterials School of Chemical & Biotechnology SASTRA Deemed University	
7	Immunosensor for the Simultaneous Detection of Cardiac Troponin I (cTnI) and C-Reactive Protein (CRP) Biomarkers	To design and develop point-of-care immunosensor for the simultaneous detection and quantification of cardiac troponin I (cTnI) & C-Reactive Protein (CRP) biomarkers for detecting the onset of cardiovascular diseases especially Acute Myocardial Infarction (AMI)	Healthcare	**PI:** Prof. R. John Bosco Rayappan ABCDE Innovation Centre Centre for Nanotechnology & Advanced Biomaterials School of Electrical & Electronics Engineering SASTRA Deemed University **Co PIs:** Prof. K. S. Rajan ABCDE Innovation Centre Centre for Nanotechnology & Advanced Biomaterials School of Chemical & Biotechnology SASTRA Deemed University Dr. K. Arockia Jayalatha ABCDE Innovation Centre Centre for Nanotechnolog	TRL 2-4

				y & Advanced Biomaterials Sc hool of Electrical & Electronics Engineering SASTRA Deemed University Dr. N. Noel ABCDE Innovation Centre Centre for Nanotechnolog y & Advanced Biomaterials Sc hool of Chemical & Biotechnology SASTRA Deemed University	
8	Design & Developm ent of Point-of-Care Electroch emical Devices for Measure ment of Glycated Haemoglo bin and Oxidative Stress	To develop affordable point-of-care nano-interfaced electrochemical sensors based on in-house developed cerberus molecules as sensing elements for rapid measurement of glycated haemoglobin (HbA1c) and oxidative stress	Healthcare	**PI:** Uma Maheswari Krishnan Professor & Associate Dean Chemistry, Bioengineering & Pharmacy, School of Chemical & Biotechnology, SASTRA University.	TRL 2-4
9	AI Assisted eNose System for Disease Diagnosis through Exhaled Breath Analysis	The overall objective of the work is to develop an eNose with artificial intelligence approach for detection of breath markers of pulmonary and renal diseases through exhaled breath analysis and to design a real-time cyber physical disease diagnosing system and to calibrate for standard operating procedure	Healthcare	**PI:** Dr. B.G. Jeyaprakash ABCDE Innovation Centre, Centre for Nanotechnology & Advanced Biomaterials School of Electrical & Electronics Engineering, SASTRA Deemed University **Co- PIs:** Dr. R. Elakkiya ABCDE Innovation Centre	TRL 1-4

				School of Computing SASTRA Deemed University Dr. D. Balamurugan ABCDE Innovation Centre School of Electrical & Electronics Engineering SASTRA Deemed to be University, Tamil Nadu	

3. TIH Team

Team Expertise

The team comprises of both experienced and young faculty members with specific focus on Bio-CPS. The team comprises senior members with relevant experience in

- Life sciences (Bio and Pharma), Biochemistry, Biotechnology
- Engineering faculty from Electrical and Electronics Engineering, Mechanical Engineering and Computer Science
- On the innovation front and training the in charge CIIE BITS Pilani will involve cross campus team to execute the entrepreneurship development and startup activities through TBIs.
- The team has demonstrated capability to execute large consortia projects to the tune of few tens of crore at BITS Pilani
- The team members are innovators and leaders in knowledge creation, creation of IPR and prototypes. A strong aspect of the team is also is interdisciplinarity design and strong collaborations within and outside India
- BITS Pilani is positioned unique due to its cross-campus locations that we will leverage for the industry connect and sustainability

Brief Profile

Professor Souvik Bhattacharyya

Professor Souvik Bhattacharyya is the Vice Chancellor of BITS Pilani for its four campuses at Pilani, Goa, Hyderabad and Dubai. He is a Professor of Mechanical Engineering at IIT Kharagpur currently on Lien to BITS Pilani. He has been Dean and Deputy Director of IIT Kharagpur, and Vice-Chancellor of Jadavpur University; he also held a faculty position at University of Canterbury, New Zealand during 1998-2000.

He obtained his BE from Jadavpur University, MS from University of Cincinnati, and PhD from Texas A&M University, all in Mechanical Engineering.

Prof Bhattacharyya has published over 250 research articles in indexed journals and conference proceedings; he is a co-author of the Heat Transfer text with J P Holman. He has served on various national committees of DST and SERB over the last 25 years, has been on the Research Council of CSIR-CGCRI. Currently he is a member of the Court of IISc Bangalore. He also is on the Expert Advisory Committee of Advanced Manufacturing Technologies (EAC-AMT) of DST, Expert Committee for FIST Program of DST and is the Chairman of TARE, SERB.

Prof Bhattacharyya is a Fellow of the Indian National Academy of Engineering (INAE), National Academy of Science, India (NASI) and West Bengal Academy of Science & Technology. He was the first recipient of the Outstanding Teacher Award of INAE in its inaugural year in 2013.

Professor Sunil Bhand

After completing post-doctoral assignment under joint Indo-Swedish Technology transfer project funded by SIDA-DBT at University of Lund, Sweden, Dr. Bhand joined BITS Pilani in Dec 2002. Currently he is Professor of Chemistry at BITS Pilani, KK Birla Goa Campus. He has published 56 research papers and is inventor in 12 patent applications (including US, UK and Australian patent) of which 3 are granted. His research area is Biosensors and Bioanalytical Techniques for environmental and clinical analysis, biochips and Nano biosensors. 9 students have been awarded PhD and 3 students are ongoing doctoral research under his supervision/co -supervision. Secured external research grants worth USD 5 Million to BITS Pilani (World Bank, Swedish Research Council, RD Tata Trust, Tea Board, NASF-ICAR, CSIR, DAE-BRNS, UKIERI-DST, SPARC MHRD). He is an expert reviewer for Swiss National Science Foundation (SNSF, Switzerland), UKRI, Indo French CEFIRPA, DBT, BIRAC, DST-IMPRINT, Indo-Russian, SERB and PATH Innovation and DSIR schemes. Since 2014, he is Dean, Sponsored Research and Consultancy for BITS Pilani and Technical Director BITS-BIRAC-BioNEST incubator at Goa.

Prof. Samit Chattopadhyay

Dr. Samit Chattopadhyay, Senior Professor & Shri B K Birla & Shrimati Sarala Birla Chair Professor position at the Department of Biological Sciences at BITS Pilani, Goa Campus, is the former Director of CSIR-Indian Institute of Chemical Biology, Kolkata and former Director, CSIR-NEIST (North East Institute of Science and Technology, Jorhat. He had started the Translation Research Unit of Excellence (TRUE) in IICB new campus in 2016, where he established a skill development-training center and an incubation center. His major contribution was setting up of a state-of-the-art facility for genomics, proteomics, bioinformatics, cancer epigenomics, cancer cell metabolomics and microbiomes.

His pioneering work on various aspects of cancer molecular biology is of significance with potential therapeutic applications. He has published 100+ research papers in high impact journals having over 4000 citations and h-index of 32. He is a Fellow of all the three national Academies of Science. He is also the recipient of the Fellowship of The World Academy of Sciences (TWAS) and J C Bose National Fellowship.

His contribution has been in creating eco-system for research on disease and diagnostics, such as: bringing large number of mission mode and fast track projects between Biology and Chemistry for immediate translatable products for India, developing advanced knowledge in developing target-based drugs, understanding molecular basis of gene regulation and epigenetics in cancer and other diseases, molecular biology work on HIV transcription and latency, immune responses on mycobacterial infection, role of Nuclear Matrix Attachment proteins in DNA damage repair, Splicing etc., structure function relation of MAR binding proteins, role of miRNA in cancer and other diseases, plant genetics, plant molecular biology, chromosome techniques, Karyotyping and Cytogentics. Has executed projects on Cholera Bacteriophages and their physical mapping, role of RNA-protein interaction in viral transcription, immuno-biology and T helper cell

differentiation. He and his collaborators from BITS Pilani, CSIR-IICB, Bose Institute, NCCS Pune and other institutes are now trying to develop small molecule drugs against cancers and inflammatory diseases. He is also planning to initiate an advanced genetics lab to combat hereditary and rare diseases. He has trained 100+ project students and supervised 30+ PhD students. Currently, he is a part of a good number of task-force high-powered committees.

Prof. Ashis Kumar Das

Prof. Ashis Das and his team in BITS-PILANI (Pilani Campus), specialize in molecular biology of the malaria parasites and focus on work with patient derived material. Prof. Das received his PhD from the National Institute of Immunology, New Delhi in 1993. He has been a World Health Organization Fellow at the Centers for Disease Control and Prevention, Atlanta, GA, USA and a Postdoctoral Fellow in the Department of Molecular Microbiology and Immunology, School of Hygiene and Public Health, Johns Hopkins University, Baltimore, USA. Since 1998 (September) he has been part of the Department of Biological Sciences, BITS Pilani, Pilani Campus. He had earlier received funding from CSIR, UGC, DBT and industry. Prof. Das and his collaborators have been among the first to publish reports of severe P. vivax malaria validated by diagnostic PCR. The studies by the Das Group has resulted in first reports about the transcriptome of P. falciparum and P. vivax parasites isolated directly from patient material and part of the data on Whole Genome Co-Expression Network has been published. Some of the papers by Prof. Das and his collaborators are highly cited, and one has made it to the DST Elsevier Report on Indian Science under the area of microbiology. Nine PhD theses have been completed under his supervision. He has published 37 papers in peer-reviewed journals, granted two Indian patents as an inventor and has one patent application undergoing examination. He has been a reviewer for National Institutes of Health, USA for international project calls. He is currently the Principal Investigator of a multi-centric project approved by ICMR entitled “Antisense, Sense and Epigenetics in Severe Malaria” which is about to be initiated and another project under the MERA umbrella entitled “28S Ribosomal RNA Capture Assay for the Sensitive Detection of Plasmodium falciparum and Plasmodium vivax” has been approved for funding.

Prof. Vinayak Naik

Prof. Vinayak Naik heads the CSIS Department and Computer Center at BITS Pilani K Birla Goa campus. He has a PhD in Computer Science and Engineering from The Ohio State University, USA. He did Bachelor of Engineering in CSE at VJTI. His research interest includes Systems and Networks, Wireless Networks, primarily WiFi, Mobile Computing and Sensing, IoT, SDN, Data Science, Machine Learning and Artificial Intelligence.

Dr. Abhijit Pethe

Dr. Pethe received his BE (Hons.) degree in Electrical and Electronics Engineering from BITS Pilani. Subsequently he earned his MS and PhD degrees in Electrical Engineering from Stanford University,

USA. During 2007-2018, Dr. Pethe worked in various roles across semiconductor companies in the SF Bay Area, USA in the areas of logic and memory technology development. In the summer of 2018, he relocated to India and joined his alma mater as Associate Professor in the Department of Electrical and Electronics Engineering at K.K. Birla Goa Campus.

Prof. Anil B Gaikwad

Prof. Gaikwad is an Associate Professor of Pharmacy at BITS Pilani, Pilani campus. He is also working as Associate Dean of Practice School Division. He did his master's and PhD from Department of Pharmacology and Toxicology, NIPER, SAS Nagar. He was awarded Doctoral Sandwich Fellowship from DAAD (German Academic Exchange Services) during his doctoral studies. He visited reputed overseas institutes as visiting scientist in Department of Medicine/Nephrology, Albert Einstein College of Medicine, NY, USA and Nephrological Center, Medizinische Poliklinik, Ludwig-Maximilians-University, Munich, Germany, in 2010 and 2008, respectively. His research grants are from SERB, UGC, DBT, and CSIR. Till date, he has provided essential and novel evidences on histone post-translational modifications in the development of type 2 diabetic cardiomyopathy, type 1 and type 2 diabetic nephropathy. He has contributed in several book chapters published by Elsevier and has more than 30 peer-reviewed research publications. He has supervised three PhD students and at present is guiding three PhD students and one post-doctoral fellow.

Dr. Syamantak Majumder

Dr. Majumder received his PhD from Anna University (2007-2011) and his Post-Doctoral Training from University of Rochester, USA (2011-2014) and University of Toronto, Canada (2014-2017). He has been awarded with many International Fellowships and Awards such as Post- Doctoral Fellowships from Canadian Diabetes Association and Banting & Best Diabetes Centre including short term Wood-Whelan Research Fellowship from International Union of Biochemistry and Molecular Biology. He was awarded with ATVB Travel Award for Young Investigators from American Heart Association. Dr. Majumder authored 50 (21 as either first or corresponding author) published research articles, reviews, patent and book chapters including 42 research articles in peer -reviewed journals such as JCI (2018; IF 12.3), JASN (2016a, 2016b, 2017; IF 8.6), Cell Report (2016; IF 7.9), Diabetes (2016, 2018a, 2018b; IF 7.2), Diabetologia (2019; IF
7.2), Br J Pharmacol (2009; IF 6.6) and ATVB (2013, 2014; IF 6.6) with an h-index of 20. Dr. Majumder joined Department of Biological Sciences of BITS Pilani, Pilani Campus in 2017. His lab at BITS Pilani is trying to identify and target epigenetic mechanisms driving endothelial inflammation during diabetes that lead to cardiovascular and kidney diseases. Dr. Majumder's work has been funded by DST, DBT, ICMR, DRDO and BITS- Pilani Internal competitive funding schemes with a total funding exceeding a little above 5.5 Crore.

Dr. Gautam Bacher

Dr. Gautam Bacher is an Assistant Professor at the Department of Electrical, Electronics & Instrumentation Engineering at BITS Pilani, K.K.Birla Goa Campus. He obtained his B. E (Electronics and Power Engineering) from Nagpur University followed by M. Tech (Instrumentation) from NIT Kurukshetra. Further, he obtained his Ph.D. from Birla Institute of Technology & Science-Pilani, Rajasthan. His research interests include Modelling and Simulation of micro/nano biosensor devices, Electrochemical biosensors, Electrochemical impedance spectroscopy (EIS).

Dr. Sanket Goel

Prof. Goel is the former Head and Associate Professor of Department of Electrical and Electronics Engineering, BITS Pilani, Hyderabad campus. He did his BSc (H-Physics) from Delhi University, MSc (Physics) from IIT Delhi, PhD from University of Alberta, Canada in 1998, 2000 and 2005 respectively. He has worked with Institute of Plasma Research, Gandhinagar (2000 -2001), DEBEL-DRDO, Bangalore (2006), Stanford University, US (2006-2008), A*STAR, Singapore (2008- 20011) and UPES, Dehradun (2011-2015). His current research interests are Microfluidics, Nanotechnology, Materials and Devices for Energy and Biomedical Applications. As a Principal Investigator, Dr Goel has been implementing several funded projects (from DST and MNRE, GoI, UNESCO, European Commission). He has won several awards, including Fulbright-Nehru fellowship (2015). He has over 60 publications and 6 patents (1 US and 5 Indian) to his credits, delivered over 50 invited talks, guided/guiding 12 PhD and 9 Masters students. Currently he is an Associate Editor of IEEE Sensors Journal.

Dr Nitin Sharma

Dr Nitin Sharma is an Assistant Professor in the department of EEE at Birla Institute of Technology and Science Pilani, K Birla, Goa campus. He has a BE in Electronics, M.Tech in Digital Communications and PhD in Wireless Communication. His PhD thesis was on Resource Allocation in Downlink OFDMA Systems: An Evolutionary Approach. His areas of Research include Resource allocation for Multicast/Broadcast Communication Systems, Small/Femto-Cell Networks, Cognitive Radios, **D2D Communication, V2V Communication, Cloud-RAN, IoT, GNSS Signal Processing, SDR, Evolutionary Algorithms** and their use in Engineering Applications (mainly Signal and Image Processing) etc. Currently he is working in Collaboration with professors in leading universities such as *NTU Singapore, The Hong Kong Polytechnic University*, *Hongkong* and *Ryerson, University, Canada, Cranfield University, U.K, Newcastle University, U. K, Ohio University USA*.

Dr. Deepak Chitkara

Dr. Deepak Chitkara is an Assistant Professor at the Department of Pharmacy, BITS Pilani, Pilani Campus. He obtained his B. Pharmacy degree from UIPS, Panjab University in 2004 following which he did M.S. (Pharma) in Pharmaceutics and Ph.D. from NIPER, SAS Nagar. The PhD work has been

awarded "Ranbaxy Science Scholar Award-2011" in Pharmaceutical Sciences. He was an exchange research scholar at the University of Tennessee Health Science Center, Memphis for one year. After that, he did his post-doctoral training at University of Nebraska Medical Center, Omaha. During this period, he gained insights and broaden scientific background into the gene delivery aspects vis -à-vis their implications from molecular level to clinical standpoint with Prof. Ram Mahato (UNMC, Nebraska), who is an eminent scientist in gene delivery. His research interests include the nano-based delivery systems for miRNAs therapeutics and CRISPR/Cas genome editing tools as therapeutics. He has been working in the area of nanomedicines for cancer treatment for past several years, during which he has gained expertise in designing nanomedicines for delivering these therapeutics. He has published in high impact journal like Biomaterials, Cancer letters, Molecular Pharmaceutics, Bioconjugate Chemistry, Journal of Pharmacology and Experimental Therapeutics, PlosOne and Pharmaceutical Research.

Dr Siddharth Tripathi

As Part of thesis work, he developed two novel microdevices (for Blood Plasma Separation and 3D Hydrodynamic Focusing). Both these microdevices are motivated from the current worldwide effort of developing point-of-care microdevices. The purpose of the Blood Plasma Separation microdevice is to separate the plasma from other cellular components present in blood. The purpose of the 3D Hydrodynamic Focusing microdevice is to make the cells flow in a single file so that their properties can be probed unambiguously at a sensing station. Both these microdevices were invented from scratch. Latest microfabrication techniques and experimental tools were employed for testing the designs. Both these microdevices developed at IITB have been taken up for commercialization (showcased at Rashtrapati Bhawan and Geneva Health Forum). Recently, he has proposed an idea related to the above-mentioned technology and tweaking it to perform on chip detection of COVID-19 antibody testing.

Device Team: Network design, implementation of sensor networks with high frequency channels, prototyping of impurity sensors, characterization of new sensor materials, 12 years' experience in top fabrication houses around the world in producing high end logic design chips, experience working on non-Si materials. Expertise in Electrochemical impedance spectroscopy (EIS) based biosensor for quantification of biological interaction. Modelling and simulation of micro device for the development of reliable and sensitive biosensor using COMSOL Multiphysics.

Cradle-to-grave understanding of miniaturized devices for various sensing and monitoring application. This include device designing, fabrication, characterization and testing while integrating with CPS/IoT. The device fabrication approaches like photolithography, soft-lithography, 3D Printing, direct laser writing, paper-based, laser engraving etc. Detection mechanisms such as, amperometry, impedance, electrochemical, electrochemiluminescence, colorimetric, image- processing etc. Diverse applications domain from energy, environment to biomedical.

4. List of Equipment

Table 44: List of Equipment: Bio-pharma Facility (Knowledge Generation)

S.no.	Bio-pharma equipment (Knowledge Generation)	Amount in INR lakhs				
		Y1	Y2	Y3	Y4	Y5
1	NGS complete Facility		1240			
2	Refrigerated High Speed Centrifuge			25		
3	Refrigerated Microfuge			4		
4	Ultracentrifuge				30	
5	Lyophilizer				12	
6	HPLC-PDA				25	
7	Biosafety Cabinet-BSL II			12		
8	Ultra-Low temperature Freezer (-80)			8		
9	Freezer (-20)			2		
10	Refrigerator (+4)			1		
11	Water Purification System (DNAase/RNAase/Pyrogen free)			12		
12	2D Gel System with accessories and software.				25	
13	Inverted Microscope			6		
14	Co2 Incubator			6		
15	Vertical microscope			5		
16	Electronic Weighing Balance 4 digit			2		
17	Electronic Weighing balance 6 digit			4		
18	Vacuum Concentrator			6		
19	MALDI TOF Facility			475		
20	LCMSMS			325		
	Sub-total		**1240**	**893**	**92**	
	Total					**2225**

Table 45: List of equipment: Bio Facility (Knowledge Generation and GLP)

S.no.	Bio facility (Knowledge Generation and GLP)	Amount in INR lakhs				
		Y1	Y2	Y3	Y4	Y5
1	Laminar air flow (2 for animal tissue culture and 1 for microbiological culture)		10	10		
2	Incubator 37°C (for tissue culture) 4 nos.		8	8		
3	BOD incubator (Insect cell/vector culture)		5	5		
4	-80 refrigerator (2)		10	10		
5	-20 refrigerator (4 Vest frost)		8	8		
6	Cold chest		5	5		
7	Inverted light Microscope (1)		10			
8	Inverted fluorescence Microscope (1)			25		
9	Bench top centrifuge (5804R, 5417R Eppendorf) 2 Nos		10	10		
10	Real Time thermal cycler (2 Nos ABI quant studio)		12	12		
11	Tissue culture facility (2) with proper fabrication and airconditioned connection		30	30		
12	Bioruptor (Diagenode), Ice matic		5	5		
13	Water bath (temp sensitive, 4 Nos.)		2	2		
14	Western transfer apparatus (4 Nos)		2	2		
15	Lyophilizer (1 no)			2	2	
16	Fluorescence Chemidoc (1 no)		40	40		
17	Water Purification System (DNAase/RNAase/Pyrogen free) (1 No)		5	5		
18	Pipettor sets		5	5		
19	Gel systems (vertical/4 and Horizontal/4)		3	3		
20	Power Pack (4)		3	1.5		1.5
21	HPLC along with fraction collector		40	40		
22	Electronic balances (4 and 6 digits)		2	2		
23	Vortexer and gel rockers (4 Nos)		2	2		
24	Dark room for development		5	5		
25	Small furniture for laboratory supplies (store)		5	5		

S.no.	Bio facility (Knowledge Generation and GLP)	Amount in INR lakhs				
		Y1	Y2	Y3	Y4	Y5
26	Bio lab creation, Computers and printers		50	25	28	10
27	Animal Cages and small equipment		15	15		
28	Air curtain		8	8		
29	BSL2+ facility BIOSAFETY CABINET (For virus culture)		40	40		
30	GLP Facility with all accessories		159	100	100	27
31	GelDoc (1)		2			
32	Ultracentrifuge (1 No)				30	
33	UPS system				20	
34	Rapid test printer and accessories				25	25
	Sub-total		**501**	**431**	**205**	**63.5**
	Total					**1201**

Table 46: List of equipment: Biosensor Technology Platforms

S.no.	Biosensor Technology Platforms	Amount in INR lakhs				
		Y1	Y2	Y3	Y4	Y5
1	Multichannel Quartz Crystal Microbalance (01)		90			
2	Surface Plasmon Resonance SPR (two channel system) (01)			130		
3	Upright Fluorescence microscope with color CCD camera		90			
4	Multichanel liquid Handling system (automated)			35		
5	Multimode plater reader (imaging type)				80	
	Sub-total		**180**	**165**	**80**	
	Total					**425**

Table 47: List of equipment: Fabrication Facility

S.no.	Fabrication facility (incl. prototyping)	Amount in INR lakhs				
		Y1	Y2	Y3	Y4	Y5
1	Metal 3D Printer		150			
2	Printed Electronic System		40			

S.no.	Fabrication facility (incl. prototyping)	Amount in INR lakhs				
		Y1	Y2	Y3	Y4	Y5
3	High Res Screen Printer					30
4	Multijet Fusion 3D Printer			160		
5	High Res FDM 3D Printer				60	
6	Inkjet Printer				60	
	Sub-total		**190**	**160**	**120**	**30**
	Total					**500**

Table 48: List of equipment: IoT Lab and System Security Lab

S.no.	IOT Lab and System security lab	Amount in INR lakhs				
		Y1	Y2	Y3	Y4	Y5
1	Software Defined Radios		30			
2	Server with GPU (2 nos.)		80			
3	Cloud computing credits (2 nos.)		20			
4	Programable mobile phones		5			
5	Cameras		5			
6	ESP development kit		5			
7	Underwater Modems			50		
8	Systems and security lab		55	0		
	Sub-total		**200**	**50**		
	Total					**250**

Table 49: List of Equipment: Bio-CPS Incubation Facility

S.no.	Bio-CPS Incubation facility	Amount in INR lakhs				
		Y1	Y2	Y3	Y4	Y5
1	Handheld potentiostat		5			
2	Electrochemical workstation (Benchtop)			10		
3	Nanodrop spectrophotometer		6			
4	Upright optical microscope with CCD camera		5			

S.no.	Bio-CPS Incubation facility	Amount in INR lakhs				
		Y1	Y2	Y3	Y4	Y5
5	ATR-FT-IR (with Diamond attachment)		25			
6	Contact angle measurement system			25		
7	Biosafety cabinet Class II		12			
8	Weighing balance		3			
9	Deep freezer (-20 0C)		5			
10	Benchtop centrifuge		2			
11	Multichannel Pipette electronic		2.5			
12	UPS backup for the instruments		2.5			
13	Printed Electronic System			45		
14	Probe station with CV/IV meter			50		
15	ECG sensors		3.8			
16	Pulse oximeter sensors		1.8			
17	Smart wearables		6.2			
18	Matlab licenses		8			
19	Labview licenses		8			
20	Drone		10			
21	XBEE KIT		0.5			
22	Bluetooth kit		0.2			
23	DAQ chasis		0.8			
24	NI Usrp 2974		12			
25	GNSS Simulator		16			
26	PXI CONTROLLER			30		
27	Servers with CPUs		42			
28	Microspotter (lines and dots) for lateral flow strip development				65	
29	High precision paper strip cutter for lateral flow system				35	
	Sub-total		**177**	**160**	**100**	
	Total					**437**

Table 50: List of Equipment: Device team- Goa

S.no.	Device team- Goa	Amount in INR lakhs				
		Y1	Y2	Y3	Y4	Y5
1	Metal/dielectric sputter dep		350			
2	Contact litho		150			
3	Laser Mask Writer		170			
4	RIE deep			250		
5	RTP Systems			20		
6	Clean stations		20			
7	Clean Room		100			
8	Measurement			80		
9	Characterisation				45	
10	Nanoimprint Lithography				300	
11	Design suite for devices			150		
	Sub-total		**790**	**500**	**345**	
	Total					**1635**

5. Letter of Consent from Collaborators

i. Advanced Process Technology Pvt. Ltd.

Advanced Process Technology Pvt. Ltd.

ISO - 9001: 2015 Certified Company

CONSENT LETTER FROM INDUSTRY PARTNER

This is to state that **Advanced Process Technology Pvt. Ltd.** hereby consent to partner with BITS, Pilani (Host Institute name) in the proposed NM-ICPS Technology Innovation Hub (TIH)in Bio-CPS (domain area). I am aware and agree to the activities mentioned in the proposal under Industry Partnership.

I hereby consent to support the TIH in terms of:

1. Contribution in Cash: NIL.....(Rs in Lakh)
2. Contribution in Kind: NIL ..... (List activities)

Summary profile of the Industry is given below:

Name of Industry/Organisation	: Advanced Process Technology Pvt Ltd.
Nature of Business	: Manufacturing
Number of Employees	: 22
Annual Turnover	: INR 414 Lakh

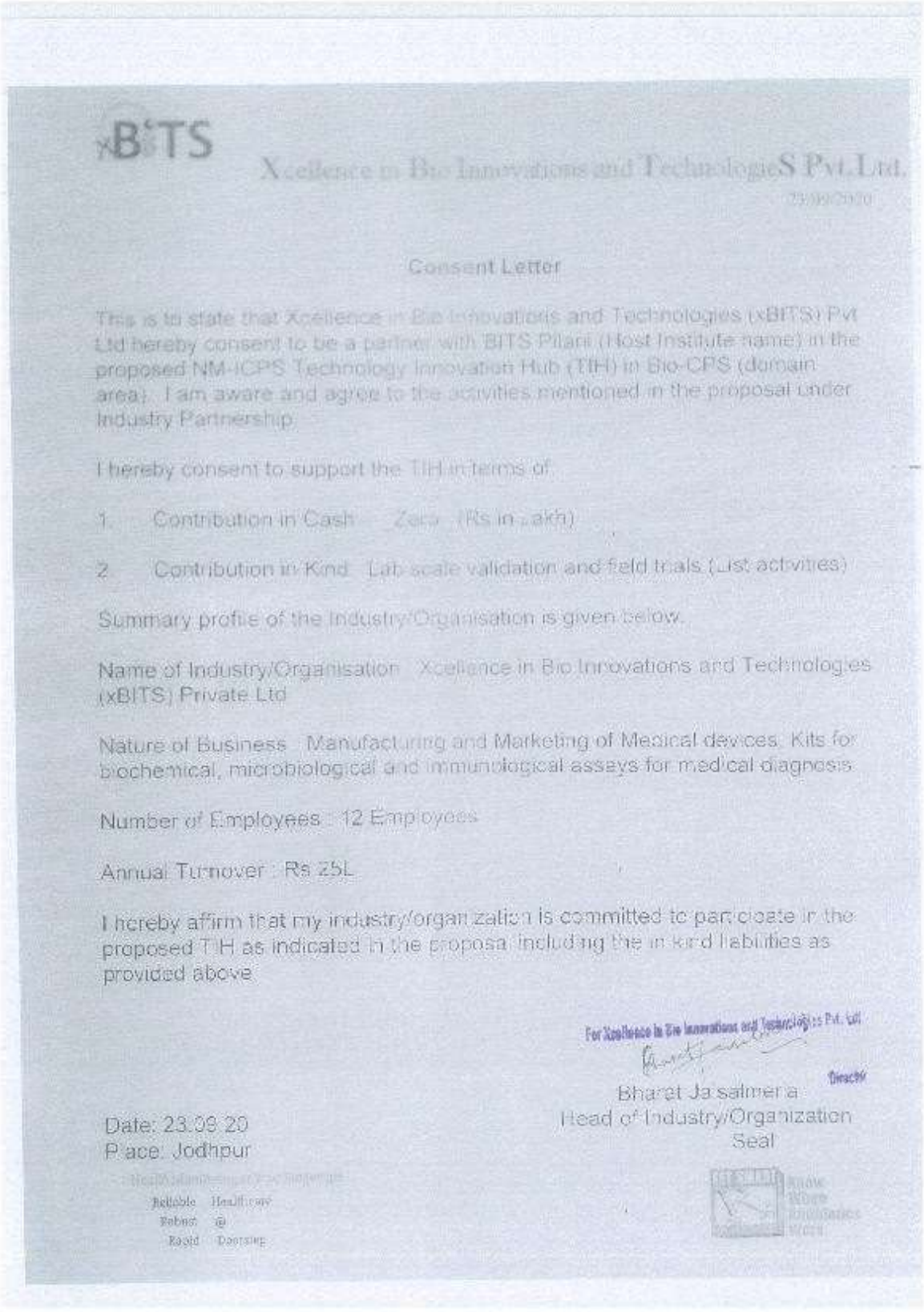
I hereby affirm that my Industry/Organisation is committed to participate in the proposed TIH as indicated in the proposal including the financial liabilities as provided above.

Date: 25/09/2020 Head of Industry/Organisation

Place: PUNE Seal

23 Electronic Co-operative Estate, Pune – Satara Road, Pune 411009 INDIA
Tel: Ph: 91-20-2422 3463, 20-2421 2740 Fax: 91- 20 -24223461 URL: www.aptglobal.com
CIN: U74993PN1999PTC013255

ii. Xcellence in Bio Innovations and Technologies Pvt. Ltd.



xBITS

Xcellence in Bio Innovations and Technologies Pvt. Ltd.

Consent Letter

This is to state that Xcellence in Bio Innovations and Technologies (xBITS) Pvt Ltd hereby consent to be a partner with BITS Pilani (Host Institute name) in the proposed NM-ICPS Technology Innovation Hub (TIH) in Bio-CPS (domain area). I am aware and agree to the activities mentioned in the proposal under Industry Partnership.

I hereby consent to support the TIH in terms of

1. Contribution in Cash : Zero (Rs in Lakh)

2. Contribution in Kind : Lab scale validation and field trials (List activities)

Summary profile of the Industry/Organisation is given below.

Name of Industry/Organisation : Xcellence in Bio Innovations and Technologies (xBITS) Private Ltd

Nature of Business : Manufacturing and Marketing of Medical devices, Kits for biochemical, microbiological and immunological assays for medical diagnosis

Number of Employees : 12 Employees

Annual Turnover : Rs 25L

I hereby affirm that my industry/organization is committed to participate in the proposed TIH as indicated in the proposal including the in kind liabilities as provided above.

For Xcellence in Bio Innovations and Technologies Pvt. Ltd.

Director

Bharat Jassalmeria
Head of Industry/Organization
Seal

Date: 23.09.20
Place: Jodhpur

iii. Electrono Solutions Pvt. Ltd.

ELECTR•NO

CONSENT LETTER FROM COLLABORATOR

I express my willingness to serve as a collaborator to the proposed NM-ICPS Technology Innovation Hub (TIH) in BIO Cyber Physical Systems (Domain area) proposed by BITS Pilani Goa Campus.

The scope of Collaboration includes Design, Development, Manufacturing of Bio Automation systems such as sensors, signal conditioners, communication devices for Internet of Things, Network solutions, Digital Twin, Analytics and Software. We also believe that we would be able to use this facility for our product design and development purposes.

I assure that I would provide scientific inputs, technical expertise and research assistance for the proposed collaborative research activities.

Date: 24/09/2020
Place: Bangalore

Signature of Collaborator

ELECTRONO SOLUTIONS PVT. LTD.
513, Vinayaka Layout,
Immadihalli Road
Whitefield BANGALORE-560 066

Seal

Signature of Head of Institution

Seal

Electrono Solutions Pvt. Ltd.
#501, Brigade IRV Center, Nallurahalli, Whitefield, Bangalore - 560 066 Karnataka, India.
PH: 080-41268358 I M: +91 9741117119 I info@electronosolutions.com
www.electronosolutions.com

iv. CoreEL Technologies

CONSENT LETTER FROM INDUSTRY PARTNER

This is to state that CoreEL Technologies India Pvt Limited hereby consent to Partner with BITS, Pilani in the proposed NM-ICPS Technology Innovation Hub (TIH) in Bio-CPS. I am aware and agree to the activities mentioned in the proposal under Industry Partnership.

I hereby consent to support the TIH in terms of:

1. Contribution in Cash: .....(Rs in Lakh)

2. Contribution in Kind.....(List activities)

- Establish Centre of Excellences under university program umbrella with academic pricings and grants for Siemens, Ansys, Mentor Graphics and Xilinx Technology.
- Conduct industry and academia training program
- Work jointly for research and patents
- Brand building
- Mobilize technology in the region

Name of Industry/Organization	: CoreEL Technologies India Pvt LTD
Nature of Business	: Electronic system level product development for Defense and aerospace
Number of Employees	: 300
Annual Turnover	: 110-120 CRORES

I hereby affirm that my Industry/Organization is committed to participate in the proposed TIH as indicated in the proposal including the financial liabilities as provided above.

Date: 23.09.2020
Place: Bangalore

CoreEL Technologies (I) Pvt. Ltd
#21, 7th Main, I Block, Koramangala, Bangalore – 560 034
Tel: 91-80-4197 0400/2522 6775, Fax: 080- 30723638 Website: www.coreel.com

v. GnomikX Pvt. Ltd.

GNOMIKX

CONSENT LETTER FROM INDUSTRY PARTNER

This is to state that GnomikX Name of Industry/Organisation) hereby consent to partner with BITS, Pilani (Host Institute name) in the proposed NM-ICPS Technology Innovation Hub (TIH)in Bio-CPS (domain area). I am aware and agree to the activities mentioned in the proposal under Industry Partnership.

I hereby consent to support the TIH in terms of:

1. Contribution in Cash: Nil (Rs in Lakh)
2. Contribution in Kind: Industry-Academia collaboration, Industry consultation and collaboration in any form within the domain knowledge of GnomikX

Summary profile of the Industry is given below:

Name of Industry/Organisation	: GnomikX
Nature of Business	: Healthcare
Number of Employees	: 5
Annual Turnover	: Didn't disclose

I hereby affirm that my Industry/Organisation is committed to participate in the proposed TIH as indicated in the proposal including the financial liabilities as provided above.

Date: 26/09/2020

Place: Pilani

Head of Industry/Organisation

Seal

GNOMIKX PRIVATE LIMITED

222/39, Ambey Shri Colony, Adarsh Nagar, Ajmer – 305001
7742512111 | www.gnomikx.com

Scanned with CamScanner

vi. Laxven Systems

LAXVEN SYSTEMS®
Third Eye Innovators

bsi.

CONSENT LETTER FROM INDUSTRY PARTNER

This is to state that **LAXVEN SYSTEMS** hereby consentto partner with BITS. Pilani (Host Institute name) in the proposed NM-ICPS Technology Innovation Hub (TIH) in Bio-CPS (domain area). I am aware and agree to the activities mentioned in the proposal under Industry Partnership.

I hereby consent to support the TIH in terms of

1. Contribution in Cash: **NIL**
2. Contribution in Kind (A). DESIGN ASSISTANCE (B). PROCURMENT ASSISTANCE (C).ASSEMBLY AND TESTING ASSISTANCE

Summary profile of the Industry is given below

Name of Industry/Organisation	: LAXVEN SYSTEMS
Nature of Business	: MANUFACTURING OF MICRO PROCESSOR BASED ELECTRONICS SYSTEMS
Number of Employees	: 75 NOS
Annual Turnover	: 25 CORES

I hereby affirm that my Industry/Organisation is committed to participate in the proposed TIH as indicated in the proposal including the financial liabilities as provided above.

Date: 28-09-2020

Head of Industry/Organisation

Place: HYDERABAD

Seal

LAXVEN SYSTEMS * HYDERABAD-51 *

Plot No. 188/A, Lane-I, Phase-II, Sector - III, IDA, Cherlapally, Hyderabad - 500 051, Telangana, INDIA.
Phone : 040-27261138 Fax : + 91-40-27261176 E-mail : laxven2000@yahoo.com
Visit us : www.laxven.com

vii. MTRC Industries

MTRC
INDUSTRIES
Plot no.211/D, IDA Phase II Cherlapally, Hyderabad-500051, Tel/Fax: 040 – 27265337
Email: mtrc.ind@gmail.com, Mobile: +91-7799417171, 9866124337

CONSENT LETTER

This is to state that MTRC Industries (An Authorized Franchisee of Novabeans Prototyping LLP), Plot no 211/D, IDA Ph II, Cherlapally, Hyderabad 500051, is a reseller of Industrial grade 3D printers like Ultimaker, Formlabs, Sinterit, 3D Systems and many more hereby consent to partner with BITS, Pilani in the proposed NM-ICPS Technology Innovation Hub (TIH) in Bio-CPS (domain area). I am aware and agree to the activities mentioned in the proposal under Industry Partnership.

I hereby consent to support the TIH in terms of:

1. Technical support required for establishment of the infrastructure.
2. Best possible pricing when compared to the market for purchase of equipment.
3. Mentor support (if required)

Summary profile of the Industry is given below:

Name of Industry/ Organisation	: MTRC Industries
Nature of Business	: Additive manufacturing services/sales
Number of Employees	: 10
Annual Turnover	: INR 1.5 Crores

I hereby affirm that my Industry/Organisation is committed to participate in the proposed TIH as indicated in the proposal including the financial liabilities as provided above.

28.09.2020

Hyderabad

Head of Industry/Organisation

MTRC INDUSTRIES HYD-51 IDA CHERLAPALLY

viii. GrypTrx Solutions Pvt. Ltd.

2-8-484, Hanamkonda, Warangal - 506001
TELANGANA, INDIA
+91 709-803-8018 | info@gryptrx.com

GrypTrx
LEGION CONNECT WITH RELIABLY

CONSENT LETTER

This is to state that Gryptrx Solutions Pvt Ltd, 2-8-484, Srinagar Colony, Hanamkonda, Warangal 506001 hereby consent to partner with BITS, Pilani in the proposed NM-ICPS Technology Innovation Hub (TIH) in Bio-CPS (domain area). I am aware and agree to the activities mentioned in the proposal under Industry Partnership.

I hereby consent to support the TIH in terms of:

1. Technical support required for establishment of the infrastructure.
2. Best possible pricing when compared to the market for purchase of equipment.
3. Mentor support (if required)

Summary profile of the Industry is given below:

Name of Industry/ Organisation	: Gryptrx Solutions Pvt Ltd
Nature of Business	: Additive manufacturing services/sales
Number of Employees	: 5
Annual Turnover	: INR 25 Lakhs

I hereby affirm that my Industry/Organisation is committed to participate in the proposed TIH as indicated in the proposal including the financial liabilities as provided above.

GRYPTRX SOLUTIONS PRIVATE LIMITED
DIRECTOR

29.09.2020
Hyderabad

Head of Industry/Organisation

ix. CAL-ON Instruments

CAL - ON INSTRUMENTS
An ISO Certified Company
Factory : Sy. No. 193, Phase-IV, IDA, Railway Station, Cherlapally, Hyderabad - 500 051.
✆ : 9603545666, 9963344333 E-mail : info@cal-on.com, www.cal-on.com
Regional Office : # 3/2, Hilton Towers, Rajagopalachari Street, Governorpet, Vijayawada- 02. ✆ : 9963344961

CONSENT LETTER FROM INDUSTRY PARTNER

This is to state that M/s CAL-ON INSTRUMENTS hereby consent to partner with BITS, Pilani(Host Institute name) in the proposed NM-ICPS Technology Innovation Hub (TIH)in Bio-CPS (domain area).

I hereby consent to support the TIH in terms of technical support only but no contribution financially. If any expenses or investment or tools/equipments/parts or components involved in this proposal/project has to be bear by the BITS, Pilani(Host Institute)

Summary profile of the Industry is given below.

Name of Industry/Organisation	: M/s CAL-ON INSTRUMENTS
NatureofBusiness	: Mfrs of Electronic Weighing Scales, Instruments, IOT Sensors & Devices
Numberof Employees	: Manufacturer

I hereby affirm that my Industry/Organisation is committed to participate in the proposed TIH as indicated above.

Date: 29-09-2020

Place: Hyderabad

Head of Industry/Organisation

A. SURESH BABU.
managing partner

x. SKY TechnoSolutions LLP

SKY TechnoSolutions LLP

H.O: 3/11, Chanduri, 2nd Cross, 1st Main, Abhayadhama Road, Whitefield, Bangalore – 560066. Ph: 9900028978, 9663909227

EMail: Sarma.mallikarjuna@gmail.com; info@skytechnosolutions.com

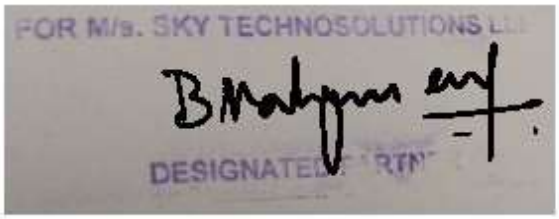
CONSENT LETTER FROM COLLABORATOR

I express my willingness to serve as a collaborator to the proposed NM-ICPS Technology Innovation Hub (TIH) in BIO Cyber Physical Systems proposed by BITS Pilani Goa Campus.

The scope of Collaboration includes SDLC for Industry 4.0 Software solutions, Data Analytics, IT Infra & IT Security, Private/ Public & Hybrid Cloud solutions.

I assure that I would provide scientific inputs, technical expertise and research assistance for the proposed collaborative research activities.

Date: 26-Sep-2020
Place: Bangalore



Seal & Signature of Head of Institution

xi. Nanobrid Innovations Pvt. Ltd.

Nanobrid Innovations

CONSENT LETTER FROM INDUSTRY PARTNER

This is to state that NANOBRID INNOVATIONS PRIVATE LIMITED hereby consent to partner with BITS, Pilani, in the proposed NM-ICPS Technology Innovation Hub (TIH) in Bio CPS. I am aware and agree to the activities mentioned in the proposal under Industry Partnership.

We hereby consent to support the TIH in terms of:

1. Contribution in Cash: NIL
2. Contribution in Kind: To provide necessary support for the development of new technologies in the Bio-CPS.

Summary profile of the Industry is given below:

Name of Industry/Organisation : Nanobrid Innovations Private Limited

Nature of Business : We specialize in next-generation nanotechnology platforms for a wide range of therapeutics.

I hereby affirm that my Industry/Organisation is committed to participate in the proposed TIH as indicated in the proposal including the financial liabilities as provided above.

NANOBRID INNOVATIONS PRIVATE LIMITED
Deepak Chitkara
DIRECTOR

Date: 25/09/2020
Place: Pilani

(Dr. Deepak Chitkara)

THANK YOU

In case of any queries, please contact:

Ms. Rashmi Nanda
Executive Assistant to Vice Chancellor,
BITS Pilani Rajasthan 333031
Desk: 01596-242090/1596-515351
M +91 9784689129
Email: rashmi.nanda@pilani.bits-pilani.ac.in