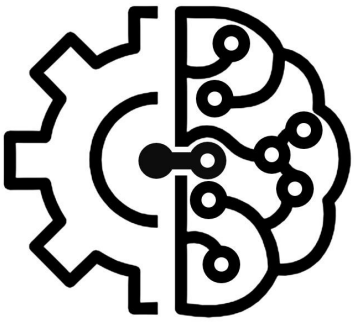

Technology
Innovation Hub on
Artificial Intelligence and
Machine Learning
for Interdisciplinary
Cyber-Physical Systems

Detailed Project Report

AI4ICPS

Submitted to the
National Mission on Interdisciplinary Cyber-Physical Systems
(NM-ICPS) by

Indian Institute of Technology Kharagpur

September 2021

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Disclaimer

This Detailed Project Report (DPR) on establishment of the AI4ICPS: Technology Innovation Hub on Artificial Intelligence and Machine Learning for Interdisciplinary Cyber-Physical Systems, is submitted to the Mission Governing Body (MGB) of the National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS), Science and Engineering Research Board (SERB), Government of India.

Contents of this DPR are confidential and may not to be shared with anybody outside of the two parties mentioned above, without written permission sought from them.

Submitted by

Virendra Kumar Tewari, Director, Indian Institute of Technology Kharagpur

Committee preparing this Report

Debdoot Sheet, Department of Electrical Engineering
Ashish Ranjan Hota, Department of Electrical Engineering
Rajendra Machavaram, Department of Agricultural and Food Engineering
Sudeshna Sarkar, Department of Computer Science and Engineering
Surjya Kanta Pal, Department of Mechanical Engineering
Surojit Mookherjee, Vinod Gupta School of Management
Uday Shankar, Rajiv Gandhi School of Intellectual Property Law

Student interns assisting the committee

Amol Grover, Vinod Gupta School of Management
Anshuman Sahoo, Rajiv Gandhi School of Intellectual Property Law
Kishore Kumar V. S., Rajiv Gandhi School of Intellectual Property Law
Lakshay Singhal, Ranbir and Chitra Gupta School of Infrastructure Design and Management
Mukesh Mallick, Vinod Gupta School of Management
Shalini Mukhopadhyay, Department of Electrical Engineering
Shuvam Bhattacharya, Rajiv Gandhi School of Intellectual Property Law
Vidisha Bhate, Rajiv Gandhi School of Intellectual Property Law

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Executive Summary

The Technology Innovation Hub (TIH) on Artificial Intelligence (AI) and Machine Learning (ML) for Interdisciplinary Cyber-Physical Systems (ICPS) (AI4ICPS) is being established by the Indian Institute of Technology Kharagpur under the aegis of the National Mission on ICPS (NM-ICPS) of the Science and Engineering Research Board (SERB), Government of India.

AI4ICPS aims to create a multidimensional ecosystem to foster innovations of AI and ML interventions to ICPS spanning across several sectors. This would address the **grand problem** of **incorporating Fairness, Accountability, Transparency and Explainability (FATE) into AI and ML** developed for translation to ICPS. **Novelty** of innovation shall include methods of black box testing, unboxing and clearboxing of complex models like deep neural networks, induction based causal reasoning leading to discovery of underlying physics of complex physical systems, space-compute-energy complexity analysis for algorithm optimization. We propose to build world class competence in FATE of (a) artificial intelligence including search, optimization, heuristics, logic, reasoning, formal methods, (b) machine learning including deep and reinforcement learning, physics integrated learning, federated learning, cloud-hybrid computing, (c) enabling technologies including machine vision, speech, natural language processing (NLP), text analytics.

This would facilitate and accelerate innovation in AI technology and services, for solving India's societal challenges while developing cloud and edge compute optimized software and hardware architectures, live testbeds and digital twins of CPS, standards for AI, safety and robustness assessment mechanisms, and open source library of tools and techniques. This would enable implementation of a public health observatory, real-time transactional energy management system, amongst others. Translation of academic research resulting in pre-/prototypes of such AI and ML interventions at Technology Readiness Level (TRL) 3 to TRL7 ready scalable products and processes for industry sectors would be the key. The **major application areas** include industry sectors of (i) healthcare, and (ii) energy infrastructure. The interventions would also be extended to (iii) precision agriculture and nutritional security, (iv) manufacturing, (v) transportation, (vi) environment and pollution, (vii) education, (viii) judiciary and legal, and (ix) communication.

AI4ICPS shall engage in activities including

1. Technology Development through development of products and prototypes from existing knowledge (TRL3), technology or product delivery in specific sectors (TRL2-3), expert driven research (TRL3).
2. Human Resources Development (HRD) and Skill Development (SD) through fellowships, project grants and program laboratory upgradation for undergraduate (UG), post graduate (PG), doctoral and post-doctoral candidates, early-career Research Assistant Professors and Chair Professors on ICPS, programs for up-/re-skilling of industry workforce across the height of the organizational pyramid.

3. Entrepreneurship, Innovation and Startup Ecosystem through grand challenges and competitions, promote and accelerate young technology entrepreneurs, entrepreneur in residence, seed and ignition funding support, technology business incubator, dedicated innovation accelerator.
4. International Collaborative Research Programs through support for Indian component of expenses for project staff, workshops and meetings, travel support, etc.

The AI4ICPS shall create an ecosystem of services on offer, including but not limited to

1. Research and New Knowledge Generation through research in FATE of AI and ML extended to thematic areas for translational to ICPS which shall contribute to TRL3 ready technology development
2. Innovation, Technology Commercialization and Startups through its Industry - TIH - Academia co-working Product Engineering Group (PEG) which co-work at the Hub and shall contribute to TRL 4-6 translation.
3. Cloud for ICPS which is reactive and responsive in realtime to train and develop AI and ML algorithms for ICPS intervention and enable AI compute as a cloud based service.
4. National Knowledge Portal (NKP) on AI4ICPS for providing study materials as curated coursework and certification material through online content delivery network (CDN) channels, datasets, APIs and standard code release, benchmarks and case studies, access to digital twin simulators of CPS for virtual environment experiments.
5. Live Testbeds on AI4ICPS which shall consist of cloud connected and IoT/ IoE enabled physical systems across the sectors of interest for live tryouts of cloud based AI and ML for plant control and plant operations.
6. Technology Certification and Audit services for AI and ML intervention to ICPS, and their safety and verification.
7. Incubation, Acceleration and Launchpad services for hand holding of new ventures, startups and spinoffs, as well as scout for innovation potential early on through student projects, challenges and competitions, etc. This shall also facilitate marketplace connection for new ventures and identify academic IPs with commercial potential.
8. Consultancy Services for technology scaling up and upgradation, and technology product auditing within the scope of the Hub.
9. Reskilling and Upskilling services through workshops, seminars, schools with sector specific focus on AI and ML intervention, as well as enabling direct to home delivery of contents through the KNP.

The organization of AI4ICPS shall be functioning under the leadership of a Chief Executive Officer (CEO) enabling the several activities through offices of the Chief Innovation Officer (CIO), Chief Technology Officer (CTO) and the Chief Operating Officer (COO). The Hub Governing Body (HGB), Scientific Advisory Body (SAB), and the Board of Directors (BOD) of AI4ICPS registered as a Section 8 Company will set its overall direction and roadmap while monitoring the activities in meeting the objectives.

Chapter 1: Context and Background

Genesis

Cyber-physical system (CPS) can generally be defined as a system in which a mechanism is controlled and monitored by a computer based algorithm. The interdisciplinary area of CPS (ICPS) is identified as one such emerging field in which progress is expected to have a significant impact on health care, urban transportation, water distribution, energy, urban air quality, manufacturing and governance. Cyber refers to the conglomerate of sensors, transducers, actuators, communication and telemetry systems, computing including mathematics and algorithms, software and hardware. Physical involves manufacturing and processing plants, healthcare equipment and instrumented hospitals, to complex socio-technical systems such as smart farms, smart energy grids, smart urban water networks, smart homes, smart factories, or smart cities.

Technology innovation in ICPS are transdisciplinary interventions which enable traditional industry, enterprise and services sectors to transition to the new age adapting to the changes in political, economic, social, technological, environmental and legal (PESTEL) on account of age-dynamics of society, civilization and earth. Such interventions span across technology vertical viz. Artificial Intelligence (AI) and Machine Learning (ML), Internet of Things (IoT) and Internet of Everything (IoE), Data banks, services and analysis, Robotics and autonomous systems, Cybersecurity for physical infrastructure, Sensors and actuators, Autonomous navigation, Computer vision (CV), Augmented reality (AR), Speech analytics, Natural language processing (NLP), New materials and device technology, Human computer interaction (HCI), etc.

Technology Readiness Level (TRL)[1] is an objective indicator of the current state of such an intervention which is being proposed for a CPS industry sector. It spans across the spectrum starting with observation of a basic principle to its economic survivability in a competitive Industry as detailed in Table 1.1, with an example of the incandescent electric bulb as technology intervention, innovating the electric energy sector and transforming the energy Industry[2]. Academic institutes traditionally contribute to fundamental research and knowledge creation activities which contribute to TRL 1-3. Industry deals with TRL 7-9. A technology innovation bridges the TRL 4-6 to transition to create transformative changes with an Industry.

[1] https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

[2] https://www.delmarfans.com/educate/basics/who-invented-light-bulbs/

Table 1.1: Technology Readiness Level (TRL) definition with reference to a technological intervention of the electric bulb leading to transformational growth of electrical energy industry.

TRL1	Observation of basic principles *e.g. Sir Humphrey Davy, an English Physician in 1802 demonstrated electric light by passing current through a platinum strip. It was a short lasting glow for one time use.*
TRL2	Formulation of technology concept *e.g. Sir Humphrey Davy in 1809 demonstrated the first carbon arc lamp. It could be switched on-/off as needed, but consumed a large amount of current, quickly draining the battery.*
TRL3	Experimental proof of concept *e.g. Pavel Nikolayevich Yablochkov, a Russian Electrical Engineer in 1875 demonstrated use of parallel carbon rods to extend battery life.*
TRL4	Technology validation in lab *e.g. Frederick de Moleyns, an English Inventor in 1841 patented an incandescent lamp made using a glass bulb with partial vacuum, and powdered charcoal between two platinum filaments to emit light. Sir Joseph Swan, an English Chemist in 1878 patented a working incandescent lamp with platinum lead wires and light-emitting carbon element enclosed in an air removed bulb.* *Thomas A. Edison and his team of American Inventors in 1879 used a thin filament with high electrical resistance.*
TRL5	Technology validation in relevant environment *e.g. Thomas A. Edison demonstrated the thin filament bulb at New Year's Eve in 1879 in Menlo Park, NJ, USA.*
TRL6	Technology demonstration in relevant environment *e.g. Edison and Swan United Electric Light Company Ltd. launched in 1883 the electric lighting business. General Electric (GE) founded as its successor.*
TRL7	System prototype demonstration in operational environment e.g. *Willian D. Coolidge, an American Physicist at GE in 1911 developed tungsten filament for incandescent lamps which lasted longer and burned brighter than the carbon filament.*
TRL8	System complete and qualified *e.g. Irving Langmuir, an American Chemist and Physicist in 1911, discovered that filling a light bulb with an inert gas such as nitrogen and twisting the filament lengthened the life of the tungsten filament.*
TRL9	Actual system proven in operational environment *e.g. The US oil crisis of 1970 demanded energy efficient residential lighting. Twisted tungsten filament and gas filled incandescent and fluorescent lamps demonstrated the new business for electrical energy transforming the energy Industry.*

AI4ICPS is the Technology Innovation Hub (TIH) on Artificial Intelligence (AI) and Machine Learning (ML) for Interdisciplinary Cyber-Physical Systems (ICPS) being established by the Indian Institute of Technology Kharagpur under the aegis of the National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) of the Department of Science and Technology, Government of India.

AI4ICPS aims to enable translation of academic research resulting in pre-/prototypes of AI and ML interventions to ICPS at TRL3 to TRL7 ready scalable products and processes for the Industry. This shall be enabled through the Industry - TIH - Academia co-working Product Engineering Group (PEG). We shall address technology innovation challenges primarily in the areas of AI and ML interventions to ICPS required for meeting the requirements of current age and future ready Industry for India and the world.

Alignment with National Strategy and Policy

Our mission is to align with NM-ICPS[3] and the national network of Hubs to research and develop new knowledge, technology solutions, skilled human resource and salubrious eco-system for entrepreneurship to enable the nation become an industrial power center of ICPS[4].

The AI and ML interventions that are proposed here are motivated by and align with the NITI Aayog National Strategy on Artificial Intelligence[5]. In cognizance with this strategy recommendation we propose creating an ecosystem, which shall serve not only the purpose of new technology development on AI and ML interventions to ICPS, but shall also cater to HRD and skills development, promote innovation and entrepreneurship, accelerate startups in the space and build long lasting International cooperation to fulfill India's approach to leadership in AI. Accordingly ICPS thrust sectors of healthcare, agriculture, education, smart cities and infrastructure, smart mobility and transportation, and manufacturing gain strong focus in our mandate. Environment and earth sciences, law and judiciary, and communication being the other strong pillars which enable technology innovations to salubriously reach out are also considered.

One aspect of our ecosystem is to develop and operationalize the National Knowledge Portal (NKP) of AI4ICPS to up-/re-skill professionals at large to augment the gap in availability of broad based expertise. The digital twins of ICPS and cloud connected live labs shall promote access to otherwise privy resources at reduced cost. We shall build and operationalize a cloud for ICPS in line with recommendations of AIRAWAT[6] to enable access to specialized AI compute resources as a service. The NKP shall also feature codebase, APIs, benchmarks serving an AI Marketplace.

[3] https://pib.gov.in/newsite/PrintRelease.aspx?relid=186157
[4] https://serbonline.in/ICPS/HomePage
[5] https://niti.gov.in/national-strategy-artificial-intelligence
[6] https://niti.gov.in/sites/default/files/2020-01/AIRAWAT_Approach_Paper.pdf

The AI and ML technology innovations to ICPS align with Digital India[7] and initiatives on Fairness, Accountability, Transparency and Explainability (FATE), Standards and Regulatory of AI, interventions to the sectors of Education, Law and Judiciary, Environment and Pollution, Innovation and Entrepreneurship programs, and the NKP are some of the activities of AI4ICPS that are closely aligned with the program on Responsible AI for Social Empowerment (RAISE)[8].

Table 1.2 lists the alignment of AI4ICPS with National strategy and policy which stress on AI and ML core competence building and their interventions across Industry sectors.

Table 1.2: Alignment of AI4ICPS activities and programs with National strategy and policy

Core competence in Artificial Intelligence and Machine Learning	National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) (http://www.serb.gov.in/nm-icps.php), National Strategy on Artificial Intelligence, NITI Aayog (https://niti.gov.in/national-strategy-artificial-intelligence), New Education Policy (https://mhrd.gov.in/nep-new)
National Knowledge Portal on AI4ICPS	New Education Policy (https://mhrd.gov.in/nep-new), Digital India (https://www.digitalindia.gov.in/)
AI Cloud for CPS	AIRAWAT - Establishing AI Specific Cloud Computing Infrastructure for India, NITI Aayog (https://niti.gov.in/sites/default/files/2020-01/AIRAWAT_Approach_Paper.pdf)
HRD and Skill Development	New Education Policy (https://mhrd.gov.in/nep-new), Pradhan Mantri Kaushal Vikas Yojana (https://pmkvyofficial.org/), Skill India (https://skillindia.nsdcindia.org/)
Innovation, Entrepreneurship and Startups	Startup India (https://www.startupindia.gov.in/), National Science & Technology Entrepreneurship Development Board (NSTEDB) (http://www.nstedb.com/)
International Collaboration	DST International S&T Cooperation (https://dst.gov.in/international-st-cooperation), ASEAN-India Science, Technology and Innovation Cooperation (https://aistic.gov.in/ASEAN/)
AI and ML intervention to Healthcare	National Health Mission (https://nhm.gov.in/), National Health Stack, NITI Aayog (https://niti.gov.in/writereaddata/files/document_publication/NHS-Strategy-and-Approach-Document-for-consultation.pdf), National Digital Health Blueprint

[7] https://www.digitalindia.gov.in/
[8] https://ai.gov.in/

	(https://www.nhp.gov.in/NHPfiles/National_Digital_Health_Blueprint_Report_comments_invited.pdf)
AI and ML intervention to Precision Agriculture and Nutritional Security	Unnat Bharat Abhiyan (http://unnatbharatabhiyan.gov.in/)
AI and ML intervention to Manufacturing	Smart Advanced Manufacturing and Rapid Transformation Hub (SAMARTH) Udyog Bharat 4.0 (https://www.samarthudyog-i40.in/)
AI and ML intervention to Transportation	Smart Cities Mission (http://smartcities.gov.in/), Atal Mission for Rejuvination and Urban Transformation (http://amrut.gov.in/), Zero Emission Vehicles (ZEVs) Policy Framework, NITI Aayog (https://niti.gov.in/writereaddata/files/document_publication/EV_report.pdf)
AI and ML intervention to Environment and Pollution	National Center of Geoinformatics (https://ncog.gov.in/), National Clean Air Programme (NCAP) (http://moef.gov.in/wp-content/uploads/2019/05/NCAP_Report.pdf), National Mission for Clean Ganga (https://nmcg.nic.in/)
AI and ML intervention to Energy Infrastructure	National Mission for Enhanced Energy Efficiency (https://beeindia.gov.in/content/nmeee-1), Smart Cities Mission (http://smartcities.gov.in/)
AI and ML intervention to Education	New Education Policy (https://mhrd.gov.in/nep-new)
AI and ML intervention to Judiciary, Legal and Law Enforcement	National Mission of Justice Delivery and Legal Reforms (https://doj.gov.in/national-mission-justice-delivery-and-legal-reforms)
AI and ML intervention to Communication	National Strategy for 5G Deployment (https://www.sitara.org.in/national-strategy-for-5g-deployment)

Sectors and Sub-sectors

AI4ICPS activities shall focus on core areas of AI, ML and enabling technologies, including and not limited to

- Artificial Intelligence (AI)
  - Search
  - Optimization
  - Planning
  - Heuristics
  - Logic
  - Reasoning
  - Formal methods
  - Control
  - AI for Verification
  - Computer aided design (CAD) for AI
- Machine Learning (ML)
  - Deep learning
  - Reinforcement learning
  - Bayesian learning
  - Physics + Machine learning
  - Federated learning
  - Edge computing for ML and Inference
  - Cloud hybrid compute for ML
  - Complexity analysis of ML
  - CAD for ML
- Enabling Technologies
  - Fairness, Accountability, Transparency and Explainability (FATE) of AI and ML
  - Verification of AI and ML
  - Certification and Safety analytics of AI and ML
  - Computer vision
  - Speech processing
  - Natural language processing (NLP)
  - Text analysis
  - Augmented, virtual and mixed reality systems (AR / VR)
  - Internet of things (IoT), Industrial IoT, Internet of everything (IoE)
  - Security of AI and ML for ICPS
  - Cloud computing and storage
  - Distributed computing
  - Hardware as a service
  - Software as a service
  - Platform as a service
  - Power audit of computation

The following application sectors of ICPS shall be focussed for AI and ML intervention, including and not limited to

- Healthcare
  - Point of care (POC) diagnostics
  - Hospital care, institutional diagnosis and healthcare delivery
  - Home care
  - Remote care and wellbeing
  - Health observatory and conservatory
  - Medical imaging
  - Genomics and Bioinformatics
  - Radiomics
  - Clinical and surgical workflow
  - Robotic surgery
- Precision Agriculture and Nutritional Security
  - Smart agri-machines
  - AI and ML for agriculture
  - IoT for agriculture
  - Water conservation
  - Water management
  - Nutrition
  - Food security
- Manufacturing
  - Design automation
  - Additive manufacturing
  - Micro-manufacturing processes
  - Simulated and virtual manufacturing
  - Digital intervention
  - Robotics and automation
  - Safety analytics
  - Quality analytics
  - Reliability analytics
- Transportation
  - Electric vehicles
  - Road transportation
  - Rail transportation
  - Water transportation
  - Transportation infrastructure
  - Vehicle sub-system development
  - Vehicle sub-system benchmarking
  - AI enabled maintenance
  - AI enabled operations
  - Maintenance of bridges and structures
  - Maintenance of rolling stock, OHE, track, signalling and telecommunications
  - Maneuvering and pilotage assistance
  - Transportation big data analytics
  - Failure prediction and prognosis

- Environment and Pollution
    - Wide area geospatial monitoring and policy planning
    - Pervasive sensing
    - Pollution monitoring
    - Weather anomaly forecasting
    - Intelligent and safe mining
- Energy Infrastructure
    - Wide area energy monitoring and management
    - Infrastructure energy monitoring and management
    - Energy storage and management
    - Smart grid
- Education
    - Personalized learning
    - Digital learning
    - Assistive learning
    - Gamed learning
    - Biomarkers for learning assessment
    - Lesson personalization
    - Direct to home delivery
    - Re- / Up-skilling
    - Instrumented classrooms
- Judiciary, Legal and Law Enforcement
    - Judiciary and legal processes
    - Legal analytics
    - Legal education
    - Democracy
    - Ethics and regulation
- Communication
    - Modulation, signal design, detection
    - Precoding, equalization, synchronization
    - Source and channel coding
    - Information theory
    - MIMO systems
    - Millimeter wave communication
    - Cognitive radio
    - Smart grid communication
    - Fiber-based and wireless optical communication
    - Power line communication
    - Cross-layer design and networking
    - Green and energy harvesting communication
    - 4G, LTE, 5G, WiFi, WiMax, etc.
    - THz communication
    - Wireless power transfer

Description of the Technology Innovation Hub

AI4ICPS shall be operational as a Section 8 Company registered in India according to the Companies Act, 2013 and owned by the Indian Institute of Technology Kharagpur. It shall follow standard practices of Corporate Governance. The Hub Governing Body (HGB) serves as the apex administrative unit advising the Board of Directors (BOD) of the Company and set its overall direction in consultation with the Scientific Advisory Board (SAB). An Executive Council (EC) shall oversee operation of AI4ICPS. The Company shall be executively led by a Chief Executive Officer (CEO), implementing the activities through the Chief Innovation Officer (CIO), Chief Technology Officer (CTO) and the Chief Operating Officer (COO). The Office of CIO shall implement activities related to HRD and Entrepreneurship, Innovation and Startup Ecosystem activities. CTO shall implement activities of Technology Development following a project based mode. COO shall implement and administer financial, legal, contracting, HR, secretarial activities for enabling Offices of CEO, CIO and CTO be functional. Organization structure, roles and responsibilities are detailed in Chapter 9: Management

AI4ICPS shall engage in the following activities including and not limited to

1. Technology Development through
    - 1.1. Development of Products and Prototypes from Existing Knowledge (Annexure T.1)
    - 1.2. Development of Technology or Product Delivery in Specific Sectors (Annexure T.2)
    - 1.3. Expert Driven Research (Annexure T.3)
2. Human Resources Development (HRD) and Skill Development (SD)
    - 2.1. High End Skill Development (Annexure H.1)
    - 2.2. Comprehensive and Holistic Advancement of National Knowledge Yield and Analytics (CHANAKYA) Fellowships
        - 2.2.1. Under-Graduate Fellowship (CHANAKYA-GI) (Annexure H.2)
        - 2.2.2. Post-Graduate Fellowship (CHANAKYA-PG) (Annexure H.3)
        - 2.2.3. PhD Fellowship (CHANAKYA-DF) (Annexure H.4)
        - 2.2.4. Post Doctoral Fellowship (CHANAKYA-PD) (Annexure H.5)
        - 2.2.5. Research Assistant Professor (CHANAKYA Faculty) (Annexure H.6)
        - 2.2.6. Chair Professor (CHANAKYA Chair Professor) (Annexure H.7)
    - 2.3. Laboratory for New PG Programme (Annexure H.8)
3. Entrepreneurship, Innovation and Startup Ecosystem (Annexure E)
    - 3.1. Grand Challenges and Competitions (CPS-GCC) (Annexure E.1)
    - 3.2. Promotion and Acceleration of Young and Aspiring Technology Entrepreneurs (CPS-PRAYAS) (Annexure E.2)
    - 3.3. Entrepreneur in Residence (CPS-EIR) (Annexure E.3)
    - 3.4. CPS Startup Ignition Grant (Annexure E.4)

3.5. Technology Business Incubator (CPS-TBI) (Annexure E.5)
3.6. Dedicated Innovation Accelerator (CPS-DIAL) (Annexure E.6)
3.7. Seed Support System (CPS-SSS) (Annexure E.7)

4. International Collaborative Research Programs (Annexure C)

The AI4ICPS shall create an ecosystem of services on offer including but not limited to

1. Research and New Knowledge Generation through research in core and thematic areas, and translational research in AI and ML for ICPS which shall contribute to TRL3 ready technology development. (Annexures T.1, T.2, T.3)
2. Innovation, Technology Commercialization and Startups through its Industry - TIH - Academia co-working Product Engineering Group (PEG) which co-work at the Hub and shall contribute to TRL 4-6 translation. (Chapter 9: Management)
3. National Knowledge Portal (NKP) on AI4ICPS for providing study materials as curated coursework and certification material through online content delivery network (CDN) channels, datasets, APIs and standard code release, benchmarks and case studies, access to digital twin simulators of CPS for virtual environment experiments. (Chapter 8: Technology: National Knowledge Portal)
4. Live Testbeds on AI4ICPS which shall consist of cloud connected and IoT/ IoE enabled physical systems across the sectors of interest for live tryouts of cloud based AI and ML for plant control and plant operations. (Chapter 8: Technology: Live Testbeds on ICPS)
5. Cloud for ICPS which is reactive and responsive in realtime to train and develop AI and ML algorithms for ICPS intervention and enable AI compute as a cloud based service. (Chapter 8: Technology: Cloud for ICPS)
6. Technology Certification and Audit services for AI and ML intervention to ICPS, and their safety and verification. (Chapter 9: Management)
7. Incubation, Acceleration and Launchpad services for hand holding of new ventures, startups and spinoffs, as well as scout for innovation potential early on through student projects, challenges and competitions, etc. This shall also facilitate marketplace connection for new ventures and identify academic IPs with commercial potential. (Annexures E.1, E.2, E.3, E.4, E.5, E.6, E.7)
8. Consultancy Services for technology scaling up and upgradation, and technology product auditing within the scope of the Hub. (Chapter 9: Management)
9. Reskilling and Upskilling services through workshops, seminars, schools with sector specific focus on AI and ML intervention, as well as enabling direct to home delivery of contents through the KNP. (Annexure H.1)

Chapter 2: Problems to be Addressed

Gap Analysis

A thorough exercise for analysing the gaps in the current state of AI and ML for CPS across various sectors yielded the following.

- **Core Technology Gaps**, which shall guide activities of Technology Development.
    - Lack of an integrated systems level understanding of plant control mechanisms in real world CPS by integrating data driven methods with Physics based methods of control. Such approaches would empower Fairness, Accountability, Trust and Explainability (FATE) of AI and ML interventions to ICPS.
    - Availability of AI and ML algorithms which can be implemented in a low resource setting environment. Limitations with edge compute devices deployed on real world CPS include
        - Computational capacity of GFlops or MFlops, instead of TFlops available on server scale infrastructure which are traditionally used within laboratory environments.
        - Memory capacity in MB of random access memory (RAM) and GB of secondary storage, instead of GB or TB of RAM and TB or PB of secondary storage available on server scale infrastructure within a laboratory environment.
        - Power availability ranging from sporadic or intermittent power supply, or dependency on current rating limited battery units. Edge devices are placed in numerous numbers, often close to the sensors and actuators to minimize noise due to long cabling, but also creates challenges since miniaturization also limits power availability and power retention/storage capacity.
        - Algorithms as such are expected to have computing resources schedulers aware of the resource availability on the edge compute devices, which is a requirement not enforced on algorithms implemented on server scale infrastructure.
    - Anomaly detection capabilities on the CPS in real time which includes ability to detect sensor, transducer, actuator, communication and telemetry, power source and edge compute failure on CPS involving its locally available edge compute capacity which can be networked to create a redundant compute services edge

cloud. Strategies to mitigate such failures and a reference design for such a technology need to be developed.

- Federated learning and inference methods, which can operate at scale, are resilient to failure of the nodes, and demonstrate at least a linear scalability in performance with respect to scaling of nodes, are currently not available beyond some small scale deployments. We need to develop methods which
  - do not rely on centralized synchronization server for information exchange,
  - shall be able to operate under asynchronous inter-node communication,
  - across nodes with heterogeneous refresh rates and computation speeds, and is
  - resilient to sudden drop-off of nodes, without causing failure to the whole system of federated learning and inferencing.
  - Able to compute and solve
  - Since they are expected to work on edge compute devices connected as an edge compute cloud on the CPS, these shall have to be developed with intelligent resource aware scheduling features as mentioned above.
  - Federated learning has surged to mitigate the challenge of data privacy with inability to share data from multiple collection nodes to a centralized learning server, in the CPS space, the need arises for ability of on-site data consumption to minimize demands on sensor and actuator telemetry bandwidth and power requirements.
- Data and knowledge fusion methods which promote learning with limited data require to be developed for sector specific CPS. While generic reusable methods are proposed in literature, the knowledge fusion is largely contributed by the mathematical models from understanding Physics of plants for a specific CPS. These specific models also need to be tested in relevant environment for its functioning, and also methods have to worked on discovery or automatically deriving the knowledge given engineering designs, floor plans, etc. of the plants, in order to augment the capacity of models when they learn with limited or unreliably annotated data.
- Adaptability of AI and ML algorithms to target CPS sectors with inherent limitations in its resources needs to be worked out. Some examples include the ability to use speech to text models trained one one language, to work on a new language when provided with only a word corpus or dictionary in the new language, but without any training data of matched text-speech pairs. Similar scales of challenges exist across sensors as well, viz. ability to recognize faces using a low resolution webcam when the model is trained with high resolution professional camera quality images.

- **Technology Enablement Gaps**, which shall guide innovation and technology translation for commercialization
    - Standardized tests are not available to assess AI and ML for its Fairness, Accountability, Trust and Explainability (FATE). While there are microcosmic efforts towards these, in research groups, to propose generalizable theory and tests towards these, they are predominantly limited to low level consumer grade problems with language vision and do not scale up to CPS plants. The DARPA program on Explainable AI (XAI)[9] is one such endeavour. We require to establish consorted and focussed efforts towards developing such standards and tests for evaluating reliability of AI and ML before these interventions are deployed on CPS.
    - Enabling of AI and ML interventions through codes as APIs which can be interoperable across 3rd party CPS. This shall be made possible when such vendors and CPS manufacturers follow common standard guidelines of data and control exchange. However the challenge being that no such open standard currently exists and as a result makes interoperability a major challenge.
    - Lack of availability of computer aided design (CAD) tools for AI and ML, which can enable accelerated adoption of these interventions across CPS. Some methods like AutoML[10, 11] are available within academic and research environments, however these do not take into account the constraints of CPS architecture and edge compute. CAD tools for AI and ML for CPS which take into account such operational constraints need to be developed.
    - Lack of Industry scale ready CPS testbeds for AI and ML is a major adoption barrier, which challenges creation of new ventures and Startups which cannot afford to have in house testbeds for testing and demonstrating their interventions. Such live testbeds of industry scale plants shall have to be created and made CPS compliant for creating a rich ecosystem. Not only creation, such testbeds shall have to be provisioned as cloud connected services, so as to rule out the requirement of physical mobility of personnel and AI and ML computers that shall have to be connected with the plant to try out the interventions. Plants available within academic research and teaching institutions which are of Industry scale and used to academic purposes for knowledge enhancement can be used provisioned to serve as live testbeds, generating more use case data for the academic owner and generating revenue through rental of facilities during unutilized times, thereby empowering building of a rich ecosystem for democratic access to live testbeds.

[9] https://www.darpa.mil/program/explainable-artificial-intelligence
[10] https://cloud.google.com/automl
[11] https://www.ml4aad.org/automl/

- In not all cases AI and ML interventions are mature enough to be directly connected to the physical CPS plants, which may pose risks of uncontrollable hazards. Such situations can be mitigated by creating Physics based models integrated with real time operating data driven Digital Twin models of the live testbeds. Such Digital Twins can enable testing of AI and ML interventions for identification of any possible threats to its deployment in the live testbed. Also, cloud connected live testbeds shall always not be available to multiple users for concurrent use, and such Digital Twins of CPS shall serve for on demand service provisioning. These can also serve as Virtual Labs for educational and training programs, generating greater acceptable outreach to the community.
- Accessibility to well curated datasets is a challenge to building reliable AI and ML models. This requires access to a clean and standardized form of data viz. Sensor, transducer, actuator reading, along with expert driven curation. Also in order to be able to tackle any sort of dataset bias which may percolate into an AI and ML model increasing its risk for physical deployment on CPS, shall require that data is collected from multiple sources. Despite there being some efforts towards this on individual research group level, to the general space of AI and ML research, no such source exists for data from CPS and plants at Industrial scale. This challenges, early stage adoption and bold initiatives by AI and ML researchers in developing solutions targeted at CPS.
- Legal and associated socio-economic frameworks for disputes on liability and ownership during any adverse impact due to AI and ML intervention in CPS also need to be very closely studied. Currently there is no instituted mechanism of mitigating challenges associated with liability and ownership.
- Lack of frameworks and standards for securing AI and ML interventions to CPS to attacks which can have adversarial impact on its operations need to be established.

- **Ecosystem Preparedness**, which challenges adoption of new ideas as worthy interventions for CPS
  - Academic research and development including AI and ML interventions typically are restricted to TRL1-2 and in some cases extend to TRL3. Industry scale manufacturable technology requires it to be in TRL7 for its adoption. There needs to be a mechanism to bridge this Gap in technology readiness of AI and ML interventions to ICPS. This can be done through constituting Academia - TIH - Industry coworking groups, in order to scale up the TRL of interventions enabling their effective commercial translation, as is the working proposition of AI4ICPS.
  - Similarly, a barrier in CPS industry sectors is the adoption barrier in terms of Knowledge Readiness level (KRL) which is ripe in Academia at KRL9 for AI and ML,

and at KRL7 for most interventions to ICPS. The common sources for up-/reskilling of the Industrial workforce, available through MOOCS are KRL1-3 and hence pose a challenge with uptake of new interventions in CPS Industry sectors. Mechanisms shall have to be developed to create CPS sector specific courses for up-/re-skilling for understanding AI and ML interventions which can be taken up.

- Unavailability of standards for AI and ML interventions to ICPS, challenges the integration of such interventions to legacy CPS infrastructure. Strong focus has to be on developing interoperability standards for the purpose of use. Without the existence of such standards, it shall not be possible to allow seamless integration of AI and ML interventions across a range of 3rd party CPS systems. Also in absence of standards, it is challenging to define policies around safety during use.
- Another challenge within the ecosystem is lack of knowledge sharing with the Startup ecosystem. Large players in the Industry often have inhouse competence to work on TRL4-6 translation for taking the interventions to a production stage at TRL7. However, Startups generally lack such specialized services inhouse, and unless Academic at KRL9 takes initiatives to hold hands of Startups to translate their TRL3 to TRL6 along with Startups, exponential transformation in Industry for inclusion of interventions in CPS shall not be realistically possible.

- **Preparedness of CPS Architectures for AI and ML**, in terms of being able to adapt and support these new interventions without transformative changes to existing infrastructure
  - Conventional plants which denote CPS across sectors, are not traditionally endowed to support high computational demands of AI and ML. While some interventions have been made possible through telemetry and communication of sensors and actuators, offloading computation to server scale systems; such arrangements cannot be scaled at large. There is a requirement for building low resource footprint compute systems which supports AI and ML interventions, their training as well as inferencing, in a federated manner, and also can be scaled up without limitation of a centralization server and its bottlenecks. This shall enable such a federated edge cloud infrastructure to function under redundancy, and within data privacy requirements.
    - Edge compute devices shall feature low memory and power footprint.
    - They shall abide by Green Computing recommendations[12].
  - Another requirement is to develop Edge computing platforms for CPS which can be modular and can support across a range of computing system architecture viz. CPU, GPU, FPGA, ASIC. It is also expected that the developed AI and ML interventions are also modularly scalable in a device agnostic manner. Also these

[12] https://rebootingcomputing.ieee.org/

are expected to feature the currently unavailable standard of in-cloud learning and on-edge inferencing with real-time model update based on federated learning.

Local and Regional

Kharagpur is uniquely located at the confluence of the heartlands of agriculture rich, mineral rich and human resource rich states of East India including West Bengal, Odisha, Bihar, Jharkhand. This richness had added to the a vibrant economy with industry spanning across food production and packaging, supply chain, steel, cement and heavy machinery manufacturing and assembling, waste disposal and waste to wealth industry. This has seen transitioning of the livelihood and local economy of the region, with an adoption of modern practices. Eventually, while we have been able to demonstrate small scale benefits of such interventions, the progress requires us to bring in more interventions to rid humans of menial and mundane jobs to maintain the society. While incorporation of machines across all sectors had brought in this revolution, enabling humans to earn dignified living by being machine operators, the next revolution also requires ability to incorporate human like precision intelligence in artificial forms, to enable humans to graduate to the next better job of building better artificially intelligent life form, rather than toil the mundane job of a machine operator. The Indian Institute of Technology Kharagpur has been a harbinger of many such interventions on pilot scale, but there is a limitation to the ability of a Research and Education focussed Institution to enable daily use of such products and processes, which need Industrial grade scalability capabilities. While graduates of the Host Institute and local Universities are a viable workforce who also aspire to build and produce cutting edge technology, for the well needed market which exists for local and national consumption, yet the challenge is that a Innovation Catapult ecosystem is currently lacking. Scaling an Invention to be an Innovation and then to form an Enterprise to launch in Industry requires not just access to technology, but a well bred ecosystem to support the Business around it. With lack of such a cogent ecosystem for Business inception of innovations, the youth is forced to migrate to Hubs of Bengaluru, Mumbai, Delhi NCR to chase their dreams. There often they are limited to the access to incoming new source of technology innovations which are born at mature Institutions like IIT Kharagpur, spanning not just an areas of AI and ML, but also spanning across the several academic units which encompasses ICPS and serves to have live demonstrations testbeds, to validate pre-launch technology at TRL5-6.

Inception of the TIH on AI and ML for ICPS at Kharagpur, shall not only serve the desires of the local population and surrounding regional industry directly, but shall also start creating a richer human resource breeding through local jobs, which shall improve the overall quality of life, and infuse deep pockets of spending propensity to the local economy boosting it down the pyramid. This shall open up the opportunity of executive and white collared jobs in the local city limits,

providing opportunities to those who wish not to migrate, inline with recommendations of the NITI Aayog "Strategy for New India at 75"[13].

National

The Hub shall strive to solve few of the following National challenges, striving to reap out a dividend of the perceived threats associated with

- Addressing the challenge with acute lack of skilled professionals and graduates to the requirement of CPS industry which are willing to adopt AI and ML interventions to keep up with the demand of time.
- Skilling professionals shall be through standardization of the 'contents', 'duration', 'mode of delivery' and 'certification' of the skilling and up-/re-skilling programs offered by the Hub for the ecosystem leading to a translatory benefit of Society and Economy.
- Create an ecosystem fostering start-up, spinoffs and entrepreneurs, linking them with Industry and providing them with a launchpad for marketplace entry.
- Creating standards to guide technological policies associated with innovation adoption in sectors are often heavily connected to the legacy technologies/processes, and challenge adoption of new technologies.
- Address ethical and privacy issues that emerge with the possibility of adoption of new technologies.
- Risks of over-regulation and protectionism in the country and market as compared to elsewhere in the developed world, which shall be mitigated by conducting benchmarking studies, publishing results of experiments and trials conducted of such AI and ML interventions on live testbeds of CPS.
- To capture value from CPS the Hub shall deploy new technologies e.g. cloud computing, storage, computing and analytical software, etc.
- The Hub shall be experimental and shall operate as an independent business entity outside of the traditional administrative norms of academia, with its own leadership to appreciate the value in AI and ML interventions to CPS as well as how to unlock the economics of this value.
- There are a wide range of skills relevant for CPS, including knowledge of cloud, distributed computing, robotics, the ability to programme and use software, market-specific knowledge and communication, which may not be available in required quantity and quality, and hence the Hub shall facilitate and implement HRD programs.
- One way to provide the multi-disciplinary skills required for CPS is for students to work closely with a company during their studies. Collaboration between a university/institution with expertise and business with real-world problems can be beneficial for both parties.

[13] https://niti.gov.in/writereaddata/files/Strategy_for_New_India.pdf

Chapter 3: Aim and Objectives

Development Objectives

Objective 1: Technology Development

Challenge: These activities shall address the current unavailability of innovation in TRL1-4 to service the following core technology gaps, including but not limited to (1) data driven and physics integrated CPS control methods, (2) algorithms which are designed to work under limited resource settings, (3) algorithms which are resilient to anomaly in CPS and can reconfigure themselves around to be able to work under failure of some of the nodes in an edge computing CPS environment, (4) allow for federated learning and inferencing at scale, (5) allow and enable fusion of data with traditional knowledge about CPS to allow AI and ML models to update themselves about plant ageing and operational dynamics, (6) algorithms which can function in a low resource settings of edge computing systems on CPS.

Approach:

T.1: Development of Products and Prototypes from Existing Knowledge - This set of activities shall be undertaken under the leadership of the Chief Technology Officer (CTO) along with Engineering Managers, Project Engineers and others. The primary task to be undertaken under this component is to develop TRL6 for the (1) National Knowledge Portal (NKP), (2) AI Cloud for ICPS, (3) Release and maintain a codebase, APIs, and datasets for CPS on the NKP, (4) Oversee creation of a platform to host and enable service to Digital Twins of CPS, (5) Enable cloud connected access to Live testbeds of CPS.

T.2: Development of Technology or Product Delivery in Specific Sectors - This set of activities shall be undertaken by the CTO along with Product Managers and others to service and create TRL4-6 level technology for the 9 CPS industry sectors which are identified as of interest for AI4ICPS in application sectors. This set of activities shall contribute to creating 13 cloud connected Live testbeds made available through the NKP. These activities shall be supported by expert driven research.

T.3: Expert Driven Research - This set of activities will be project linked activities to look at translating TRL3 to TRL4 for creating a bouquet of offerable IPs and products. This shall be centered around primarily creating Digital twins of the 14 Live Testbeds to be hosted on the NKP. The Project Engineers involved in this component shall also support creating the different components of the primary product and service enablers for AI4ICPS which are indicated in T.1

Impact: This objective is anticipated to contribute the following tangible measures of deliverables in addressing the challenges as indicated above. Number of new technologies to be developed (TRL1-6) = 32, Number of new technology products to be developed (TRL4-6) = 30, Publications of the innovation in technology in Journals, Conferences, Patents, Copyrights, etc. = 90, Increase in CPS research base = 120.

Objective 2: HRD and Skill Development

Challenge: These set of activities shall serve to address the challenges of ecosystem preparedness, viz. (1) Knowledge Readiness Level (KRL) of industry workforce and new workforce getting ready for Industry jobs, (2) lack of productization standards knowledge availability and understanding of TRL6 readiness in academia. This shall also contribute to assist the tasks of Expert Driven Research.

Approach:

H.1: High End Skill Development - This activity shall consist of: (a) Professional Skill Development Workshop (CPS-PSDW) for up-/re-skilling of existing Industry workforce. This shall be through 2 weeks, 25 hours/week workshop in a batch of at least 90 students. Set of 5 workshops shall be organized over the period of 5 years at least. Additional workshops will be funded through external funding and participant subscription. The workshop shall be conducted by Research Assistant Professor, Chair Professor, PhD and PostDocs, and Engineering teams of AI4ICPS. (b) Advanced Skill Training Institute (CPS-ASTI) shall be for training graduates from Diploma / Vocational training institutes, in order to prepare them for Industry developing and deploying AI and ML interventions to conventional plants across CPS sectors. This shall be through selecting an Institute through a competitive call, and developing curriculum and labs for them to equip the institute build a comprehensive component of their programs for this new age transition. The target is to train 180 candidates in a span of 2 years.

H.2: Under-Graduate Fellowship (CHANAKYA-GI) - This activity shall consist of awarding 340 UG project fellowships in total, for a period of 10 months for each award, program spanning for 5 years. The fellowship program shall support monthly fellowship and special funds for executing student projects, preferably final year projects which are aligned on AI and ML interventions to ICPS. Projects shall be peer reviewed for selection based on their merit and innovation potential. These projects are in groups of 2 students each. This is to promote innovations on rapidly translatable interventions, which may also be a sub-component of a bigger product, and can be executed in 10 months. This is to promote students to take up careers in innovation while learning about TRL4-6 translation through projects.

H.3: Post-Graduate Fellowship (CHANAKYA-PG) - This activity shall consist of awarding a total of 62 PG program fellowship in total, for a period of 2 years for each award, program spanning for 5 years. The fellowship shall be paid monthly following standard MHRD rates. Additional grant for executing the final year thesis project on AI and ML for ICPS. This activity is anticipated to result in a new PG program leading to the award of a M. Tech degree along the lines of AI and ML for ICPS, consisting of components of relevance to making products and processes along the theme of AI4ICPS.

H.4: PhD Fellowship (CHANAKYA-DF) - This activity shall consist of awarding a total of 25 Doctoral fellowship, for a period of 4 years for each award, program spanning for 5 years. The fellowship shall be paid monthly following standard SERB JRF/SRF rates. This activity is anticipated to result in training more Doctoral graduates with strong focus along the lines of AI and ML for ICPS, consisting of components of relevance to making products and processes along the theme of AI4ICPS, and well skilled to accelerate innovation translation TRL1-6. Fellows shall be working aligned to the technology development projects, working towards TRL1-3 and assisting in translation of their developed technology to TRL4-6 driven by the Project Engineers. Graduates of this program are expected to create similar technology innovation programs as the AI4ICPS and look at deeper inclusion of AI and ML for ICPS.

H.5: Post Doctoral Fellowship (CHANAKYA-PD) - This activity shall consist of awarding a total of 25 Post-Doctoral fellowship, for a period of 3 years for each award, program spanning for 5 years. The fellowship shall be paid monthly following standard SERB RA rates. This activity is anticipated to result in training more Post-Doctoral Fellows with strong focus along the lines of AI and ML for ICPS, consisting of components of relevance to making products and processes along the theme of AI4ICPS, and well skilled to accelerate innovation translation TRL1-6. Fellows shall be working aligned to the technology development projects, working towards TRL1-6 along with Project Engineers, also mentor PhD, PG and UG projects on specific topics. Graduates of this program are expected to create similar technology innovation programs as the AI4ICPS and look at deeper inclusion of AI and ML for ICPS.

H.6: Research Assistant Professor (CHANAKYA Faculty) - This activity shall consist of awarding a total of 6 Faculty fellowship, for a period of 3 years for each award, program spanning for 5 years. The fellowship shall be paid monthly following standard INSPIRE Faculty award rates. Faculty fellows shall have a strong focus along the lines of AI and ML for ICPS, consisting of components of relevance to making products and processes along the theme of AI4ICPS, and well skilled to accelerate innovation translation TRL1-6. Faculty Fellows shall be aligned to the technology development projects, working towards TRL1-6 along with Project Engineers, also mentor PostDocs, PhD, PG and UG projects on specific topics. They shall also be driving the Advanced Training schools and programs.

H.7: Chair Professor (CHANAKYA Chair Professor) - This activity shall consist of awarding a total of 6 Chair Professor positions, for a period of 3 years for each award, program spanning for 5 years. The honorarium shall be paid monthly following standard Chair Professor recommendation rates of SERB and managed by the Host Institute of the concerned Faculty. This position also shall support a fixed amount for Travel and Contingency towards such costs in promoting activities of AI4ICPS. Chair Professors shall have a strong focus along the lines of AI and ML for ICPS and work towards identifying and scouting new innovations for their TRL1-6 translation, and promote the spirit of AI4ICPS along with overseeing the overall functioning of the center. Amongst others, they shall also mentor Faculty Fellows, PostDocs, PhD, PG and UG projects on specific topics. They shall also be driving the Advanced Training schools and programs.

H.8: Laboratory for New PG Programme - This activity shall set up a specialized lab for the new PG program in AI and ML for ICPS. This shall be primarily for teaching purpose and during the spare time the equipment shall be used for students projects. This shall be operations from within AI4ICPS to have strong connections to the innovation ecosystem, and nurture technology innovation in a practical environment.

Impact: This objective is anticipated to contribute the following tangible measures of deliverables. Number of people trained through high end skill development = 630, Number of UG project fellowships = 340, Number of PG program fellowships = 62, Number of PhD fellowships = 25, Number of Post-Doctoral Fellowships = 25, Number of Research Assistant Professors = 6, Number of Chair Professors = 6, Number of New PG program laboratory created = 1.

Objective 3: Entrepreneurship, Innovation and Startup Ecosystem

Challenge: This set of activities shall be addressing the challenges in availability of an ecosystem for innovation marketplace and entrepreneurship, as well as the gaps in technology enablement, viz. (1) Knowledge sharing of TRL4-6 with Startups, (2) innovation to enable deploying AI and ML interventions to 3rd party CPS plants, (3) lack of CAD tools for AI and ML intervention design, (4) develop and integrate with testbeds, virtual twins of CPS, (5) salubrious ecosystem for promoting and encouraging innovation and entrepreneurship around the theme of AI and ML interventions to CPS, (6) create new ventures to build computations and enabling hardware and support architectures for AI and ML interventions to CPS viz. hybrid computing architecture, server-cloud-edge hybrid architectures for computation, cloud for CPS, federated learning, etc.

Approach:

E.1: Grand Challenges and Competitions (CPS-GCC) - These challenges shall be for encouraging early stage and pre-incubated inventions along lines of AI4ICPS, providing them quarterly residential support, training in respect of creating the minimum viable product (MVP) at

TRL3, and creating a business model around the product. The Top-5 ideas per quarter shall be financially supported with a product creation grant for scaling their MVP to TRL3. A final competition between each of the Top-5 per quarter shall select the finalist to be funded to support their MVP scaling of TRL3 to TRL4. This shall be able to support every year 20 such ideas TRL3 ready MVP and 4 ideas at TRL4. Over the period of 5 years, this shall be able to support 20 ideas to TRL4. The participants shall be able to apply for other support programs as well, but not participate in any more than one program at a given time. It is anticipated that winners subsequently onboard CPS-PRAYAS.

E.2: Promotion and Acceleration of Young and Aspiring Technology Entrepreneurs (CPS-PRAYAS) - These activities shall be for on-site incubation for a period of 1 year each, 2 innovations at TRL4 shall be supported for TRL5 scaleup and validation in relevant CPS environment. The live testbeds shall be extended to support such work. Additional support for technology buildup shall be promoted by the different Engineering staff of the TIH. The TIH shall also be supporting some fabrication, consumables, etc. to these Entrepreneurs through best available resources, and preparing them with Business and Marketspace training support to look at exploring options of raising Ignition Grants and Venture Capital investments. In a period of 5 years, this shall be able to support 10 such Entrepreneurs. The participants shall be able to apply for other support programs as well, but not participate in any more than one program at a given time. Successful graduates may apply subsequently for CPS Startup Ignition Grant.

E.3: Entrepreneur in Residence (CPS-EIR) - This activity shall support 20 entrepreneurs per year through a 1 year long fellowship program with on-site residency requirements at the AI4ICPS, who shall walk in with ideas at TRL1-3, explore and create MVP at TRL3-4. Candidates are expected to be Graduates in Engineering with a passion for innovation, but shall require hand-holding for understanding technology space in AI and ML intervention to CPS. During this period they shall learn about the nuances of technology development and participate in the various innovation workshops at AI4ICPS. Within this period they are anticipated to have built up a MVP at TRL3 and onboard on the CPS-GCC for further scaling. This shall support a total of 100 beneficiaries in the program duration of 5 years. The participants shall be able to apply for other support programs as well, but not participate in any more than one program at a given time.

E.4: CPS Startup Ignition - This activity shall support 10 Early stage start-ups per year which have demonstrated a MVP at TRL5 through a funding ignition program without residency requirement, to enable scaling it to TRL6, and virtual incubation support. The support shall be The participants shall be able to apply for other support programs as well, but not participate in any more than one program at a given time. This shall be for a fixed tenure of 1-3 year in phased support, and performance is monitored. The ignition support shall be met as a venture valued equity investment by AI4ICPS with investor's exit priority on subsequent investment. This shall support

a total of 30 beneficiaries in the program duration of 5 years. The participants shall be able to apply for other support programs as well, but not participate in any more than one program at a given time.

E.5: Technology Business Incubator (CPS-TBI) - This shall be for creating the ecosystem for coordinating and organizing the various Incubator programs, supporting the Business ecosystem understanding for new ventures, and for hand holding participants in the CPS-GCC, CPS-PRAYAS, CPS-EIR, CPS Startup Ignition. This shall be a dedicated unit overseeing the programs including organizing special workshops for marketing, networking, launchpads, and also build and operationalize a common laboratory space, makerspace for supporting these programs.

E.6: Dedicated Innovation Accelerator (CPS-DIAL) - This shall be an office manned by the Chief Executive Officer (CEO) along with the Chief Innovation Officer (CIO), Chief Operating Officer (COO), General Managers, etc. and is responsible for administrative operationalization of the AI4ICPS. This program shall create and organize about 5 special programs per year spanning across design innovation thinking, business building, venture profiling, exponential thinking, launchpad and roadshow programs for the AI4ICPS. Also this office shall oversee the sustainability of the activities and strategize on how to create new scope and opportunities for scaling up operations.

E.7: Seed Support System (CPS-SSS) - This program shall be a mode of debt financing, in the lines of a pre Series A seed investment. This shall be extended to 2 enterprises per year, with virtual incubation requirement, and a total of 10 shall be supported in the program span of 5 years. This may be subsequent to the CPS Startup Ignition. The ignition support shall be met as a venture valued equity investment by AI4ICPS, based on a phased investment manner, with investor's exit priority on subsequent investment. The participants shall be able to apply for other support programs as well, but not participate in any more than one program at a given time.

Impact: This objective is anticipated to contribute the following tangible measures of deliverables. Through CPS-EIR the number of early stage ideas supported to build upto TRL3 = 100, through CPS-GCC the number of new ideas supported to scale MVP to TRL3 = 100, through CPS-PRAYAS the number of mature ideas supported to scale MVP to TRL4 = 20, Number of CPS Startup Ignition = 50, Number of enterprises supported through CPS-SSS = 10, Number of CPS-TBI formed = 1, Number of CPS-DIAL formed = 1, Number of Startups and Spinoffs = 60.

Objective 4: International Collaborative Research Programme

Challenge: This activity shall serve to build domestic competence in AI and ML interventions to CPS which is not well available within the realms of the Host institute and within the country. They shall be means of forging long term collaboration with other AI and ML innovation ecosystems across the world for strengthening our understanding.

Approach: This shall be through funding of 4 international collaborative research programs for Academic researchers over a period of five years, with each of the project awards spanning a period of 3 years. The project shall support the Indian counterpart for costs for manpower salary at SERB rates, support for International travel, organizing International workshops and conferences, for which the cost component of the Indian counterpart shall be met. Applicable overhead shall also be extended to the Host Institution for meeting the administrative charges. The projects shall be carried in coordination with the AI4ICPS, interacting and utilizing resources including HR and infrastructure to the best extent possible, and also the projects should be strongly focussed towards building TRL1-3 or if with existing knowledge then on creating TRL4, such that new ventures are formed out of these explorations, or they lead to a direct commercialization of the technology. The projects shall have their Foreign counterparts funded by a National/Funding agency in their own country. Foreign counterparts are preferred to be academic. The program shall be in lines of the DST International Cooperation in S&T programs.

Impact: This program shall be able to support 5 international collaborations.

Deliverables

These activities shall cumulatively contribute to creating the following line of innovations.

Optimized Architectures for Edge Computation

- Computer throughput aware algorithms
- Low memory footprint
- Low power density
- Capable of In-Cloud learning and On-Edge inferencing
- Capable of working in Ad-hoc configuration & supports Federated Learning
- Real-time, Responsive, Reactive AI+ML Cloud for CPS
- Green computing & networking

Standards for AI4ICPS

- Common standard Operating System (OS), Libraries and APIs
- Formal Verification of AI+ML for ICPS
- Legal Standards
- Standardized tests to certify for
    - Fairness
    - Accountability
    - Transparency
    - Explainability

National Knowledge Portal (NKP) on AI4ICPS

- Datasets, Codes, APIs
- Cloud connected Digital Twins of ICPS
- Cloud connected ICPS Live Testbeds
- Open Benchmarks and Case studies
- Direct-to-User delivery of contents and services for Re-/Upskilling

Digital Twins of CPS and Live Testbeds

- Live Testbeds of CPS systems
- Data generation in real time
- Computer Aided Design (CAD) tools
- AI+Mobile Healthcare Unit
- Digital Farm and Machinery
- Manufacturing processes
- Transportation (Vehicle + System + Infrastructure)
- Digital Earth Model for Environment
- Power Distribution System
- Instrumented and Digital Classrooms
- Simulated Legal Arguments and Augmentation of Legal Processes

Safe and Robust AI4ICPS

- Adversarial attack resistant
- Side channel attack robustness
- Encrypted AI+ML design
- Privacy preserving AI+ML
- Safety analytics of AI+ML for ICPS

Standard offerings on Enabling Technologies and Services

- CAD Tools on AI-4-ICPS
- Multilingual and cross-lingual Natural Language Processing (NLP)
- Vision and Language for Human-CPS interaction
- IoT and IoE for AI+ML and ICPS connectivity
- AR/VR for human immersive tryouts on Digital Twins of CPS

Chapter 4: Strategy

Alternative Strategy

Currently there are only few focussed programs on dedicated technology innovation accelerators within the Country across few sectors of ICPS, primarily through Research Parks at IITs and DRDO Young Scientist Labs. While the Research Parks are a broader umbrella of activities also including innovation acceleration, and also include CPS out of the several areas in which they support activities, companies and Startups. None within the country are known to be focussed on AI and ML space of ICPS. While academic research in India, quality of researchers in India as at par with that of AI leadership nations including Canada, USA, Switzerland, Germany, Singapore, we have not been able to reap significant benefits out of it due to absence of special purpose instruments to mobilize captive innovations in academic and rapidly translate them to products creating ventures and Enterprises to sustain their availability in market. While AI product hotspots in traditional IT Hotspots of Bengaluru, Hyderabad, Delhi NCR are capable of developing software components to it, the underlying fundamentals and mathematics are still sourced from Academic Institutions, with IIT Kharagpur being a large sized contributor. Further to it, unless such AI and ML software tools are developed and produced to be compliant with Physical Plants and Systems of CPS, they fail to reap the monetizing benefits and fail to have a deep rooted impact on society. Technology Innovation Accelerators unless located close to academic research units which offer a playground of CPS, shall not be able to offer exponential growth in AI and ML offerings. Such challenges are discussed in detail in Gap Analysis.

Reasoning of Proposed Strategy

Such transformative changes with the introduction of innovation accelerators within academic institutions have been observed in AI economies of Canada, USA, Switzerland, Germany, Singapore and is worthy of being tried out in India. A parallel of such innovation translation aspects have been observed in the sectors of Semiconductors and Electronic System Design and Manufacturing in economies of Japan, South Korea, Taiwan. In the sector of Machinery and Automobiles, it has been observed in the USA, Germany, Japan, South Korea, Russia. In the sector of Defense Manufacturing such has been observed in Israel, France. In the sector of Medicine and Vaccines such exponential transformation and creation of market opportunity has been observed in India.

Priority of Location

The Hub shall be located at Kharagpur campus of IIT Kharagpur. The campus spans across 2100 acres or 8.5 Sq. km and currently hosts 46 academic units including departments, centers, schools, academies. These departments include the Centre of Excellence in Artificial Intelligence, Departments of Computer Science and Engineering, Electrical Engineering, Electronics and Electrical Communication Engineering harbour 750+ faculty members, 5000+ researchers, PhD, PG, and UG candidates who specialize in various core and implementation aspects of AI and ML. They are crucial in providing the TLR 1-3 ready inputs on these areas of interest to the Hub. The other aspect of crucial importance is the presence of topical expertise and facilities on the different sectors of CPS which span across the Centre of Excellence in Advanced Manufacturing Technology, Departments of Agricultural and Food Engineering, mechanical Engineering, Civil Engineering, School of Medical Science and Technology, Dr. B. C. Roy Institute of Medical Science and Research, G. S. Sanyal School of Centre for Railway Research, Centre for Ocean, River, Atmosphere and Land Sciences (CORAL), Aditya Choubey Centre for Re-Water Research, School of Energy Sciences, Center for Educational Technology, Department of Ocean Engineering and Naval Architecture, Center for Computational and Data Sciences, Ranbir and Chitra Gupta School of Infrastructure Design and Management. These units have several specialized and industry scale laboratories which shall be upgraded to serve as cloud connected live testbeds. Several projects of national Importance including the National Supercomputing Mission, National Digital Library of India which are being executed at Kharagpur are also closely aligned as the foundational strength of this Hub. The Hub is focussed on not just Technology Development, HRD and Skills Development, but also on Entrepreneurship and launching of innovations as Startups and enterprises, which require nurturing on Business Ecosystem and Legal frameworks, which are some of the unique offerings to be facilitated with specialized academic and pedagogical training through the Vinod Gupta School of Management, Rajendra Misra School of Engineering Entrepreneurship, Rajiv Gandhi School of Intellectual Property Law. Incubation, corporate connection support, startup facilitation shall be provided also through the Science and Technology Entrepreneurship Park (STEP) and the IIT Kharagpur Kolkata Research Park.

Opportunity of Leveraging Government Funds

The Hub shall strategize on exploring to leverage the following opportunities, for long term continuity of its capacity augmentation. These shall be a phased transition with welcoming a matched quantum of Industry participation to the cost of the innovation translation with focus on TRL4-6 and as need be to also include TRL1-3 and TRL 7-9.

Table 4.1: List of identified Government funds which shall be explored for opportunity of being leveraged by the Hub to augment its existing capacity of programs.

Component	Activity	Government Fund
Technology Development	Dev. of Products and Prototypes from Existing Knowledge	SERB-FICCI Industry Relevant R&D Scheme
	Dev. of Technology or Product Delivery in Specific Sectors	DST Device Development Programme (DDP), Instr. Dev. Programme (IDP)
	Expert Driven Research	MHRD IMPRINT and UAY, BIRAC BIPP
HRD and Skill Development	High End Skill Development	SERB Assistance to Professional Bodies for Seminars and Symposia
	Under-Graduate Fellowship (CHANAKYA-GI)	DST-INSPIRE Scholarship for Higher Education
	Post-Graduate Fellowship (CHANAKYA-PG)	DST-INSPIRE Scholarship for Higher Education
	PhD Fellowship (CHANAKYA-DF)	SERB-FICCI Prime Minister's Fellowship for Doctoral Research, DST-INSPIRE Fellowship
	Post Doctoral Fellowship (CHANAKYA-PD)	SERB National Post Doctoral Fellowship (NPDF)
	Research Assistant Professor (CHANAKYA Faculty)	DST-INSPIRE Faculty Scheme
	Chair Professor (CHANAKYA Chair Professor)	DST Swarnajayanti Fellowship
Entrepreneurship, Innovation and Startup Ecosystem	Promotion and Acceleration of Young and Aspiring Technology Entrepreneurs (CPS-PRAYAS)	DSIR PRISM, BIRAC SITARE, BIRAC E-YUVA, BIRAC PACE
	Entrepreneur in Residence (CPS-EIR)	Startup India Women Entrepreneurship
	CPS Startup Ignition Grant	BIRAC BIG
	Seed Support System (CPS-SSS)	NSTEDB TBI Seed Support, BIRAC SBIRI
International Collaboration	Collaborative Research Programme	DST International S&T Cooperation, DST VAJRA

Ongoing Activities

The following ongoing and recently completed activities shall be abjuncting the Hub to extend CPS facilities towards creation of the live testbeds and other infrastructure of relevance to the execution of programs of the Hub (Described in Chapter 8: Technology)

Table 4.2: Relevance of ongoing projects and activities in adjuncting strengths of the Hub.

Component	Ongoing Activity to Strengthen Component
National Knowledge Portal (NKP)	MHRD National Digital Library of India (NME-ICT), AWS National AI Resource Portal, Virtual Labs (NME-ICT)
AI Cloud for CPS	National Supercomputing Mission (NSM)
ADAS for Tractor and Applicator	Centre of Excellence for Digital Farming Solutions for Enhancing Productivity by Robots, Drones and AGVs (NAHEP)
Instrumented Road for Traffic & Str. Health	Thin Whitetopping: A Pilot Study for Design, Construction and Performance Evaluation (PWD, Govt. of WB)
Cloud Controlled 3D Printing	DHI Centre of Excellence in Advanced Manufacturing Technology, Centre of Excellence in Robotics
AI enabled Smart Hospital	Dr. B. C. Roy Institute of Medical Science and Research
Smart Drive System for Smart Cities	Indo-German Collaborative Research Centre on Intelligent Transportation Systems, Opened & Intelligent Plug-in Hybrid Electric Vehicle (PHEV) Technologies for Smart Indian Cities (UAY Min. of HI&PE)
Wastewater Engineering Plant	Design, Installation and Operation of Treatment Plant for UASB Effluent to Produce Portable Quality Treated Water (Wheels India Niswarth Foundation)
Energy Smart Build. Microgrid	UK India Clean Energy Research Institute (UKICERI) (DST)
AI enabled Mobile Unit for Remote Care	DSIR Common Research And Technology Development Hub (CRTDH) - Healthcare Technology
Instrumented Classroom	Setting up of Teaching Learning Centre for Pedagogy Design & Research (MHRD)
Smart Beamforming for Next Gen Wireless	Design and Development of Wide-Band Millimeter-Wave Phased Array Antenna With Beam Forming Module (IMPRINT & Rosenberger Tech.), Channel Modelling and Signal Processing for Terahertz Systems for 6G (Samsung R&D India)

Chapter 5: Target Beneficiaries

Beneficiary Identification

Table 5.1: Beneficiary of the different activities undertaken by the Hub

Component	Activity	Target Beneficiary
Technology Development	Development of Products and Prototypes from Existing Knowledge	Industry, PSU, Line Ministry and Govt. Departments (See details in Table 5.2)
	Development of Technology or Product Delivery in Specific Sectors	Industry, PSU, Line Ministry and Govt. Departments (See details in Table 5.2)
	Expert Driven Research	Industry, PSU, Line Ministry and Govt. Departments (See details in Table 5.2)
	Technology Products	Students, Professionals seeking Up-/re-skilling, Universities, Research Institutions, Industry, PSU, Line Ministry and Govt. Departments
	Publications, IPR, other Intellectual Activities	Researchers, Technology and Product Manufacturing
HRD and Skill Development	High End Skill Development	Diploma pursuant students, Professional seeking Up-/Re-skilling
	Under-Graduate Fellowship (CHANAKYA-GI)	Undergraduate students at Host Institute
	Post-Graduate Fellowship (CHANAKYA-PG)	Postgraduate students at Host Institute
	PhD Fellowship (CHANAKYA-DF)	Doctoral candidates at Host Institute
	Post Doctoral Fellowship (CHANAKYA-PD)	Post doctoral candidates at Host Institute
	Research Assistant Professor (CHANAKYA Faculty)	Early career assistant professor career pursuant

	Chair Professor (CHANAKYA Chair Professor)	Professionally distinguished professor at Host Institute
	Laboratory for New PG Programme	Postgraduate students under CHANAKYA-PG
Entrepreneurship, Innovation and Startup Ecosystem	Grand Challenges and Competitions (CPS-GCC)	Students and Young Innovators
	Promotion and Acceleration of Young and Aspiring Technology Entrepreneurs (CPS-PRAYAS)	Young Technology Entrepreneurs below the age of 45
	Entrepreneur in Residence (CPS-EIR)	Full time Entrepreneurs, preferably under the age of 45,exploring new venture creation opportunities
	CPS Startup Ignition Grant	Early stage Startups with a MVP at TRL5
	Technology Business Incubator (CPS-TBI)	Innovators, Entrepreneurs, Startups
	Dedicated Innovation Accelerator (CPS-DIAL)	Startups, Entrepreneurs, Intrapreneurs from Industry, PSU, Line Ministry and Govt. Departments
	Seed Support System (CPS-SSS)	Startups
International Collaboration	Collaborative Research Programme	Academic Researchers, Industry, PSU, Line Ministry and Govt. Departments

Table 5.2: Some of the Industry beneficiaries of various technologies proposed to be developed by the Hub. These include some of the parties who were consulted during preparation of the Report, and is not an exclusive list. In due course of the project, other entities shall also be consulted for furtherance.

Developed Technology	Beneficiary
National Knowledge Portal (NKP)	Students and Professionals
AI Cloud for CPS	CDAC, Nvidia, Intel, Synopsys, Techwave
ADAS for Tractor and Applicator	TAFE, John Deere, Mahindra
Instrumented Road for Traffic & Str. Health	Ministry of Road Transport and Highways, Smart Cities Mission
Cloud Controlled 3D Printing	Siemens, GE
AI enabled Smart Hospital	JSV Innovations, GE, Philips. Predible, Siemens
Smart Drive System for Smart Cities	Tata Motors, Eaton, Exide, Shell, POSOCO
Wastewater Engineering Plant	Public Works Department, Public Health Engineering Division
Energy Smart Build. Microgrid	CESC, Exide,
AI enabled Mobile Unit for Remote Care	Achira, JSV Innovations, Microfluidic Chipshop, Radical Health
Instrumented Classroom	TCS
Smart Beamforming for Next Gen Wireless	Ericsson

Stakeholder Analysis

This Report was prepared in consultation with the following stakeholders:

Government agencies, Departments and Industry Members

1. Achira
2. Advance Tech
3. Affine Analytics
4. AgNext
5. Ansaldo
6. Blackbuck
7. CDAC
8. CESC
9. Coal India

10. DVC
11. Eaton
12. Emami
13. Ericsson
14. Exide
15. Frauscher
16. GE
17. HAL
18. Heavy Engineering Corporation
19. Hella
20. Ingenium Naturae
21. Intel
22. John Deere
23. JSV Innovations
24. KPIT
25. LegalKart
26. Lignin Biosciences
27. Mahindra
28. Microfluidic Chipshop
29. Microsoft
30. Miranda Automation
31. Neurosynaptic
32. Nvidia
33. Philips
34. POSOCO
35. Prasan Solutions
36. Predible
37. Radical Health
38. Shell
39. Siemens
40. Sigtuple
41. Spotdraft
42. Synopsys
43. TAFE
44. Tata Motors
45. Tata Power
46. Tata Steel
47. TCS
48. Techwave

Academic and Research Institutions

1. AIIMS Bhubaneswar
2. AIIMS Jodhpur
3. AIIMS Rishikesh
4. CMC Ludhiana
5. CSIR Central Mechanical Engineering Research Institute
6. CSIR Institute of Genomics and Integrative Biology
7. IIIT Hyderabad
8. IISc Bangalore
9. IIT Bombay
10. IIT Guwahati
11. IIT Jodhpur
12. IIT Kanpur
13. IIT Madras
14. IIT Patna
15. MIT
16. Northeastern University
17. PGIMER Chandigarh
18. Purdue University
19. Rush University Medical Centre
20. Tecnologico de Monterrey, Mexico
21. Tata Medical Center Kolkata
22. University of Edinburgh
23. University of Manchester
24. University of Southampton
25. University of California Irvine
26. University of Glasgow
27. University of Mons, Belgium

Faculty Members at the Host Institute

1. Abhijit Mukherjee, Department of Geology and Geophysics
2. Adway Mitra, Centre of Excellence in Artificial Intelligence
3. Akhilesh Kumar, Department of Industrial and Systems Engineering
4. Alok Kanti Deb, Department of Electrical Engineering
5. Amit Upadhyay, Vinod Gupta School of Management

6. Anirban Mukherjee, Department of Electrical Engineering
7. Anupam Basu, Department of Computer Science and Engineering
8. Arghya Deb, Department of Civil Engineering
9. Arijit Mondal, Centre of Excellence in Artificial Intelligence
10. Aritra Hazra, Department of Computer Science and Engineering
11. Arkopal Kishore Goswami, Ranbir and Chitra Gupta School of Infra. Design and Management
12. Arnab Sarkar, Advanced Technology Development Center
13. Ashis Bhattacherjee, Department of Mining Engineering
14. Ashis K. Datta, Department of Agricultural and Food Engineering
15. Ashish Kumar Nath, Department of Mechanical Engineering
16. Ashish Ranjan Hota , Department of Electrical Engineering
17. Ashok Kumar Pradhan , Department of Electrical Engineering
18. Aurobinda Routray, Department of Electrical Engineering
19. Ayantika Chatterjee, Advanced Technology Development Center
20. Bharath H. Aithal, Ranbir and Chitra Gupta School of Infrastructure Design and Management
21. Bhargab Maitra, Department of Civil Engineering
22. Brajesh Kumar Dubey, Department of Civil Engineering
23. Cheruvu Siva Kumar, Department of Mechanical Engineering
24. Damodhara Rao Mailapalli, Department of Agricultural and Food Engineering
25. Debarati Sen, G. S. Sanyal School of Telecommunication
26. Debashish Chakravarty, Department of Mining Engineering
27. Debdeep Mukhopadhyay, Department of Computer Science and Engineering
28. Debdoot Sheet, Department of Electrical Engineering
29. Dillip Kumar Swain, Department of Agricultural and Food Engineering
30. Goutam Sen, Department of Industrial Systems and Engineering
31. Hari Niwas Mishra, Department of Agricultural and Food Engineering
32. Jayanarayanan Kuttippurath, Center for Ocean, River, Atmosphere and Land Sciences
33. Jayanta Bhattacharyya, Department of Mining Engineering
34. Jhareswar Maiti, Department of Industrial and Systems Engineering
35. Jiaul Hoque Paik, Center for Educational Technology
36. Makarand Madhao Ghangrekar, Department of Civil Engineering
37. Manjira Sinha, Center for Educational Technology
38. Nilanjan Das Chakladar, Department of Mechanical Engineering
39. Nirmalya Ghosh, Department of Electrical Engineering
40. Om Prakash Sha, Department of Ocean Engineering and Naval Architecture
41. Pabitra Mitra, Department of Computer Science and Engineering
42. Padmavati Manchikanti, Rajiv Gandhi School of Intellectual Property Law
43. Pallab Dasgupta, Department of Computer Science and Engineering

44. Partha Pratim Chakrabarti, Department of Computer Science and Engineering
45. Partha Pratim Das, Department of Computer Science and Engineering
46. Partha Saha, Department of Mechanical Engineering
47. Parthasarathi Chakraborty, Center for Ocean, River, Atmosphere and Land Sciences
48. Parthasarathi Ghosh, Cryogenic Engineering Center
49. Pavitra Sandilya, Cryogenic Engineering Center
50. Plaban Kumar Bhowmick, Center for Educational Technology
51. Poulomi Ganguli, Department of Agricultural and Food Engineering
52. Prabodh Bajpai, Department of Electrical Engineering
53. Prabuddha Ganguli, Rajiv Gandhi School of Intellectual Property Law
54. Prasad Kumar Bhaskaran, Department of Ocean Engineering and Naval Architecture
55. Prashanth Reddy Hanmaiahgari, Department of Civil Engineering
56. Rajendra Machavaram, Department of Agricultural and Food Engineering
57. Rajlakshmi Guha, Center for Educational Technology
58. Rintu Banerjee, Department of Agricultural and Food Engineering
59. Sankha Deb, Department of Mechanical Engineering
60. Sanjay K. Chaturvedi, Subir Chowdhury School of Quality and Reliability
61. Saptarshi Ghosh, Department of Computer Science and Engineering
62. Satadal Saha, School of Medical Science and Technology
63. Siddhartha Mukhopadhyay, Department of Electrical Engineering
64. Somsubhra Chakraborty, Department of Agricultural and Food Engineering
65. Soumen Das, School of Medical Science and Technology
66. Soumyajit Dey, Department of Computer Science and Engineering
67. Sriman Kumar Bhattacharyya, Department of Civil Engineering
68. Sudeshna Sarkar, Department of Computer Science and Engineering
69. Sudip Misra, Department of Computer Science and Engineering
70. Sudipta Mukhopadhyay, Department of Electronics and Electrical Comm. Engineering
71. Suman Chakraborty, Department of Mechanical Engineering
72. Surjya Kanta Pal, Department of Mechanical Engineering
73. Surojit Mookerjee, Vinod Gupta School of Management
74. Uday Shankar, Rajiv Gandhi School of Intellectual Property Law
75. Vikranth Racherla, Department of Mechanical Engineering
76. Virendra Kumar Tewari, Department of Agricultural and Food Engineering

Cost Sharing and Beneficiary Participation

Table 5.3: Mechanisms to be explored for beneficiary participation in activities and cost sharing.

Component	Activity	Target Beneficiary	Cost Sharing Mechanism
Technology Development	Development of Products and Prototypes from Existing Knowledge (See details in Table 5.2)	Industry, PSU, Line Ministry and Govt. Departments	Project expenses sharing, Equipment sponsorship, IP licensing and buyout agreements.
	Development of Technology or Product Delivery in Specific Sectors (See details in Table 5.2)	Industry, PSU, Line Ministry and Govt. Departments	Project expenses sharing, Equipment sponsorship, IP licensing and buyout agreements.
	Expert Driven Research (See details in Table 5.2)	Industry, PSU, Line Ministry and Govt. Departments	Project expenses sharing, Equipment sponsorship, IP licensing and buyout agreements.
HRD and Skill Development	High End Skill Development	Diploma pursuant students, Professional seeking Up-/Re-skilling	Workshop and course fee subscriptions.
	Under-Graduate Fellowship (CHANAKYA-GI)	Undergraduate students at Host Institute	Additional fellowships by Industry and CSR.
	Post-Graduate Fellowship (CHANAKYA-PG)	Postgraduate students at Host Institute	Additional fellowships by Industry and CSR.
	PhD Fellowship (CHANAKYA-DF)	Doctoral candidates at Host Institute	Additional fellowships by Ministry, Industry and CSR.
	Post Doctoral Fellowship (CHANAKYA-PD)	Post doctoral candidates at Host Institute	Additional fellowships by Ministry, Industry and CSR.
	Research Assistant Professor (CHANAKYA Faculty)	Early career assistant professor career pursuant	Additional positions supported by the Ministry, Industry and CSR.
	Chair Professor (CHANAKYA Chair Professor)	Professionally distinguished professor at Host Institute	Additional positions supported by the Ministry, Industry and CSR.

	Laboratory for New PG Programme	Postgraduate students under CHANAKYA-PG	Additional equipment from Industry and CSR.
Entrepreneurship, innovation and Startup Ecosystem	Grand Challenges and Competitions (CPS-GCC)	Students and Young Innovators	DSIR PRISM, BIRAC SITARE, BIRAC E-YUVA, BIRAC PACE
	Promotion and Acceleration of Young and Aspiring Technology Entrepreneurs (CPS-PRAYAS)	Young Technology Entrepreneurs below the age of 45	Startup India Women Entrepreneurship
	Entrepreneur in Residence (CPS-EIR)	Full time Entrepreneurs, preferably under the age of 45, exploring new venture creation opportunities	Additional positions supported by the Ministry, Industry and CSR.
	CPS Startup Ignition Grant	Early stage Startups with a MVP at TRL5	BIRAC BIG
	Technology Business Incubator (CPS-TBI)	Innovators, Entrepreneurs, Startups	Additional support by the Ministry, Industry and CSR.
	Dedicated Innovation Accelerator (CPS-DIAL)	Startups, Entrepreneurs, Intrapreneurs from Industry, PSU, Line Ministry and Govt. Departments	Additional support by the Ministry, Industry and CSR.
	Seed Support System (CPS-SSS)	Startups	NSTEDB TBI Seed Support, BIRAC SBIRI
International Collaboration	Collaborative Research Programme	Academic Researchers, Industry, PSU, Line Ministry and Govt. Departments	DST International S&T Cooperation, DST VAJRA

Impact on Weaker Sections of Society

This project does not have any negative impact on the weaker sections of society. It shall implement activities and programs to re-/up-skill Industry Technicians in adopting new technologies on AI and ML interventions to CPS. The specific activities under High End Skill Development shall be of benefit to the several Polytechnic and Diploma Colleges locally that shall provide skilling for a better quality of livelihood to the weaker sections including Tribals.

Chapter 6: Legal Framework

Project Specific Framework

The following aspects shall have to be carefully considered within the gambit of executing the projects leading to development of products and processes of AI and ML interventions to ICPS.

Data Protection and Privacy

There is no single comprehensive law for data protection in India. Instead, much like the US, the laws are scattered across various legislations, unlike in the EU which comes consolidated under the General Data Protection Regulation (GDPR) 2016/679. The National guidelines shall have to abide by the policies laid out in

- Information Technology Act, 2000
- Personal Data Protection Bill, 2019
- National Cyber Security Policy, 2013
- National Data Sharing and Accessibility Policy (NDSAP)

Intellectual Property Rights

- The Design Act, 2000
- The Patents Act, 1970
- The Copyright Act, 1957

Standards

- Bureau of Indian Standards (BIS) Act, 2016
- Bureau of Indian Standards Rules, 2018
- Bureau of Indian Standards (Conformity Assessment) Regulations, 2018

Sector Specific Legal Frameworks which shall have to be adhered to include

1. Healthcare
    a. Digital Information Security in Healthcare Act, 2017
    b. National Digital Health Blueprint (NDHB)
    c. National Health Stack (NHS)
2. Precision Agriculture and Nutritional Security
    a. Plant Variety and Farmers Rights Act, 2001
    b. Seeds Act, 1966

c. Food Safety & Standards (Prohibition & Restriction on Sales) Regulation, 2011
d. Insecticides Act, 1968
e. Dangerous Machines (Regulation) Rules, 2007
f. Director General of Civil Aviation Remotely-piloted aircraft system (RPAS) Guidelines, 2020

3. Manufacturing
    a. New Industrial Policy, 1991
    b. National Manufacturing Policy
    c. Micro, Small and Medium Enterprises Development (MSMED) Act, 2006
    d. Environment Protection Act, 1986
    e. Water (Prevention and Control of Pollution) Act, 1974
    f. Air (Prevention and Control of Air Pollution) Act, 1981
    g. Environmental Impact Assessment (EIA) Notification, 2020
    h. Dangerous Machines (Regulation) Rules, 2007
4. Transportation
    a. Indian Motor Vehicles (Amendment) Act, 2019
    b. Dangerous Machines (Regulation) Rules, 2007
    c. National Highways Authority of India Act, 1988
5. Environment and Pollution
    a. Environment Protection Act, 1986
    b. Water (Prevention and Control of Pollution) Act, 1974
    c. Air (Prevention and Control of Air Pollution) Act, 1981
    d. Environmental Impact Assessment (EIA) Notification, 2020
6. Energy Infrastructure
    a. National Renewable Energy Act, 2015
    b. Dangerous Machines (Regulation) Rules, 2007
    c. Energy Conservation Act, 2001
7. Education
    a. National Education Policy 2019
8. Judiciary, Legal and Law Enforcement
    a. National Mission of Justice Delivery and Legal Reforms
9. Communication
    a. Telecom Regulatory Authority of India (Amendment) Act, 2014
    b. Cable Television Network Act, 1995
    c. National Telecom Policy, 1994
    d. New Telecom Policy, 1999
    e. Broadband Policy, 2004
    f. National Telecom Policy, 2012

Strengths and Weaknesses of the Framework

Currently India does not have a comprehensive law on AI and ML or on ICPS. The set of laws and regulations are spread across various sectors which have been indicated above, and shall be updated in the due course of the project to include any new legislation. The National Strategy for Artificial Intelligence. NITI Aayog is the only comprehensive roadmap document towards this. However, with the specific laws around data privacy, protection, cyber-security, data ownership which are indicated earlier are a set of very strong laws which strengthens us in ensuring that such accidental breaches are not committed.

Impact on Achievements

Each project shall outline at the start of the project and in due course of its intermediate progress reviews all compliances with applicable laws including the overarching set of laws associated with Data Privacy and Protection, Intellectual Property and Standards.

In addition to adherence with the Laws and Regulations in India, based on the scope of introduction of such developed products and processes, they shall also be checked for compliances with laws of

- North America (US and Canada),
- Europe - Middle East - and - Africa (EMEA), and
- East Asia (South Korea, Taiwan, Singapore, Hong Kong, Japan).

Standards shall also be looked into for compliance with the following international bodies

- International Electrotechnical Commission (IEC)
- International Organization for Standardization (ISO)
- Deutsches Institut für Normung (DIN)
- IEEE Standards Association (IEEE-SA)
- The World Wide Web Consortium (W3C)

Chapter 7: Environmental Impact

Measures Identified to Mitigate Adverse Impact

The Hub deals with innovations in AI and ML for ICPS which shall primarily be of software nature and in some cases may involve computational hardware units required for execution of the software. This shall not have any direct impact on the Environment or Human lives. However, some interventions being directly related to and deployed on Physical Systems across various sectors shall require sector and project specific identification of any impacts that shall have to be mitigated. All projects on completion shall be submitted for review in regards to their Environmental Impact if any to the National regulators. Generally all projects to follow guidelines identified in the Environment Protection Act, 1986.

Table 7.1: Agencies have been identified for any EIA audits for the respective sectors.

Sector	Agency Concerned
Healthcare	Central Drugs Standard Control Organisation (CDSCO), Ministry of Health and family Welfare (MoHFW)
Precision Agriculture and Nutritional Security	Ministry of Agriculture and Farmers' Welfare (MoAFW), Food Safety and Standards Authority of India (FSSAI), Ministry of Health and family Welfare (MoHFW)
Manufacturing	Ministry of Heavy Industries and Public Enterprises (MoHI&PE)
Transportation	Ministry of Road Transport and Highway, Ministry of Housing and Urban Affairs
Environment and Pollution	Ministry of Environment and Forests (MoEF)
Energy Infrastructure	Ministry of Power, Ministry of New and Renewable Energy
Education	Ministry of Human Resource Development (MHRD)
Judiciary, legal and Law Enforcement	Ministry of Law and Justice
Communication	Ministry of Communications, Ministry of Electronics and Information Technology

Issues Related to Land, Forest, Wildlife, Rehabilitation and Resettlement

1. Land acquisitions are not involved.
2. Environmental clearances are not involved as it is based on green technologies.
3. Forestry clearances are not required as there is no clearance of forest land or acquisitions are involved.
4. Wildlife clearances are not required as the project is being implemented at an existing academic institution and there is no direct or indirect impact on wildlife.
5. No mitigation plan for rehabilitation and resettlement required since no new land acquisitions shall be made as the project is being implemented at an existing academic institution.

Chapter 8: Technology

Research on Fairness, Accountability, Transparency and Explainability (FATE) of AI and ML for ICPS

Research in AI shall be in the areas of optimization, search, reasoning and planning which are very important for CPS systems. ML research shall include working on fundamental ML algorithms including deep learning (DL), convex optimization (CO), reinforcement learning (RL), representation learning (RepL), learning on unstructured data viz. using graphs within DL (GDL), for specific requirements of CPS. Some of the relevant thematic domains such as computer vision, signal processing, signal and data compression, natural language and speech processing, social media analytics, are also of immense importance in building CPS involving both humans and machines. Human-centric machine learning models are useful in modeling CPS and the Hub shall work on models and algorithms for evaluating, supporting and enhancing decision making processes where algorithmic and human decisions feed and influence each other. The Hub shall also focus on moral machines which involves enabling machines to make moral decisions, enveloped by the major challenge of quantifying societal expectations about the ethical principles that should guide machine behaviour. A practical aspect of ML is the reliance on an immense amount of data and computation power for training. The hub shall also focus on computing hardware platform specific optimization of AI+ML algorithms. Also in view of challenges associated with the sharing of massive amounts of data and privacy concerns around personal information, the Hub shall also concentrate on privacy preserving learning and Federated Learning (FedL). AI+ML methods also play an important role in security of sensor data, their encryption and in detecting attacks. Privacy preserving AI algorithms are also important in this context. Another special focus will be on deep learning algorithms for data with complex structures, such as spatio-temporal data. Another focus will be the generation/simulation of artificial data which will be able to reproduce statistical properties of the genuine data, especially for complex structures. Causality will be another focus area of the hub, where we will use statistical concepts to identify causal relations between different processes in complex systems.

These shall be based on prior work experience on the areas including:

AI algorithms: Search, planning, optimization: IIT Kharagpur has deep expertise in fundamental AI methods. Pioneering work has been done in the domain of resource constrained and multi-objective search algorithms. A composition of memory-bounded search techniques which work within the given memory and any-time algorithms which produce an initial solution quickly have been studied and applied in solving problems related to robustness of embedded control

systems which is a generalization of multi-dimensional search. Besides, the quality time trade-off has been studied over AND/OR heuristic search techniques while generating a set of ordered solutions. In addition to these, automated planning techniques are adapted in formal verification of distributed control. These methods play an important role in a CPS in intelligent planning and to make optimum decisions.

Publications:

1. Satya Gautam Vadlamudi, Sandip Aine, Partha Pratim Chakrabarti: Anytime pack search. Natural Computing 15(3): 395-414 (2016)
2. Kamalesh Ghosh, Pallab Dasgupta, S. Ramesh: Automated Planning as an Early Verification Tool for Distributed Control. Journal of Automated Reasoning 54(1): 31-68 (2015)
3. Satya Gautam Vadlamudi, Sandip Aine, P. P. Chakrabarti: Incremental Beam search. Information Processing Letters 113(22-24): 888-893 (2013)
4. Satya Gautam Vadlamudi, Sandip Aine, P. P. Chakrabarti: Incremental Beam search. Information Processing Letters 113(22-24): 888-893 (2013)
5. Sunandita Patra, Satya Gautam Vadlamudi, Partha Pratim Chakrabarti: Anytime Contract Search. SGAI Conference 2013: 139-155
6. Kamalesh Ghosh, Pallab Dasgupta, S. Ramesh: Planning with Action Prioritization and New Benchmarks for Classical Planning. Australasian Conference on Artificial Intelligence 2012: 779-790
7. Priyankar Ghosh, Amit Sharma, P. P. Chakrabarti, Pallab Dasgupta: Algorithms for Generating Ordered Solutions for Explicit AND/OR Structures. Journal of Artificial Intelligence Research 44: 275-333 (2012)
8. Satya Gautam Vadlamudi, Piyush Gaurav, Sandip Aine, Partha Pratim Chakrabarti: Anytime Column Search. Australasian Conference on Artificial Intelligence 2012: 254-265
9. Satya Gautam Vadlamudi, Partha Pratim Chakrabarti, Sudeshna Sarkar: Anytime Algorithms for Mining Groups with Maximum Coverage. AusDM 2012: 209-220
10. Satya Gautam Vadlamudi, Sandip Aine, Partha Pratim Chakrabarti: MAWA* - A Memory-Bounded Anytime Heuristic-Search Algorithm. IEEE Trans. Systems, Man, and Cybernetics, Part B 41(3): 725-735 (2011)

ML algorithms: IIT Kharagpur researchers have worked on fundamental algorithms of Machine Learning including Deep Learning and their applications to various domains. CPS systems generate a large amount of data from the different sensors and the various process parameters. Data driven models have a great potential to complement physics based or simulation models for greater accuracy in modelling of complex systems and data driven models can be developed faster. ML algorithms have been developed to work with different types of input data such as

images, video and text, multimodal data, temporal and spatio-temporal data, and graphs. They have been used for algorithms for prediction and forecasting and modelling in diverse domains such as medical imaging, NLP tasks, climate modelling and transportation. Reinforcement Learning algorithms have been used for optimum control.

Publications:

1. P. Porwal, D. Sheet, et al. "IDRiD: Diabetic Retinopathy–Segmentation and Grading Challenge", Medical Image Analysis, 59, 101561, 2020
2. D. China, D. Sheet, et al., "Anatomical Structure Segmentation in Ultrasound Volumes using Cross Frame Belief Propagating Iterative Random Walks", IEEE Journal of Biomedical and Health Informatics, 23, 1110-1118, 2018
3. P. Poudel, A. Illanes, D. Sheet, M. Friebe, "Evaluation of commonly used algorithms for thyroid ultrasound images segmentation and improvement using machine learning approaches", Journal of Healthcare Engineering, 2018, 8087624, 2018
4. A. Guha Roy, D. Sheet, et al., "ReLayNet: retinal layer and fluid segmentation of macular optical coherence tomography using fully convolutional networks", Biomedical Optics Express, 8, 3627-3642, 2017
5. S. Conjeti, D. Sheet, et al., "Supervised domain adaptation of decision forests: Transfer of models trained in vitro for in vivo intravascular ultrasound tissue characterization", Medical Image Analysis, 32, 1-17, 2016

Anomaly Detection, Prognostics and Diagnostics: Data driven methods have been used to identify anomalies in system behaviour. Among different applications, we have worked on identifying extended anomalies in spatio-temporal data, such as climatic data.

Publications:

1. Adway Mitra, Ashwin K. Seshadri: Detection of spatiotemporally coherent rainfall anomalies using Markov Random Fields. Computers & Geosciences 122: 45-53 (2019)
2. Sharma, M. K., D. Sheet, and P. K. Biswas. "Spatiotemporal deep networks for detecting abnormality in videos." Multimedia Tools and Applications (2020): 1-32.
3. Sharma, M. K., D. Sheet, and Prabir Kumar Biswas. "Image Embedding for Detecting Irregularity." Proceedings of 3rd International Conference on Computer Vision and Image Processing. Springer, Singapore, 2020.

Explainable ML: Neural network based ML algorithms have been traditionally considered opaque. But many applications involving CPS demand that the system actions are explainable. This has led to a lot of research in interpretable ML models and in generating explanations for decisions suggested by ML models.

Systems Explainers of Deep Neural Networks: Deep CNNs today need explanation of their functional logic for verification and certification purposes. One option being use of input-output reasoning explainers using class activation maps (CAM), gradient CAM (Grad-CAM), random input sampling ensemble (RISE), which generate explainers on input data. The other way is to exploit understanding of linear systems theory, viz. Convolutions, correlation, system response analysis in Fourier domain. These methods provide input data agnostic system level analysis of trained CNNs.

Publications:

1. Rachana Sathish, Debdoot Sheet, "Unit Impulse Response as an Explainer of Redundancy in a Deep Convolutional Neural Network", CVPR W. Explainable AI, 2019.

Electrical Power Budgeting of AI Computation: Deep learning and similar iterative solver for optimization which make use of iterations over data to reach a desired performance level. By virtue of the fully/-partial convex nature of the optimizers, it is observed that the time taken to reach 95% from 90% accuracy is double of the time taken to reach 90% accuracy. This amounts to exponential increase in energy required for computation. Also, inferencing at the edge device is power budgeted, and hence there is a demand for the development of hardware resource/power aware algorithms, where the nature of tensor compute needs to be varied across target platforms being CPU (Intel/ARM), GPUs, FPGAs, etc. Some related works include MobileNets, Efficient Nets. This is inline with the IEEE Rebooting Computing initiative and the Low Power Image Recognition (LPIR) Challenge.

Probabilistic Modeling of Complex Systems: Complex systems involving multiple spatio-temporal processes that mutually interact are often difficult to model, especially because of the involved uncertainties. Probabilistic modelling provides a principled way to represent causal or conditional relationships between processes along with a measure of the involved uncertainties, and probabilistic inference techniques allow us to make estimates about process variables which cannot be directly observed.

Publications:

1. Adway Mitra, Soma Biswas, Chiranjib Bhattacharyya: Bayesian Modeling of Temporal Coherence in Videos for Entity Discovery and Summarization. IEEE Trans. Pattern Anal. Mach. Intell. 39(3): 430-443 (2017)
2. Adway Mitra, Soma Biswas, Chiranjib Bhattacharyya: Temporally Coherent CRP: A Bayesian Non-Parametric Approach for Clustering Tracklets with applications to Person Discovery in Videos. SDM 2015: 801-809

3. Unsupervised feature selection using feature similarity, P Mitra, CA Murthy, SK Pal, IEEE transactions on pattern analysis and machine intelligence 24 (3), 301-312, 2002
4. Density-based multiscale data condensation, P Mitra, CA Murthy, SK Pal, IEEE Transactions on pattern analysis and machine intelligence 24 (6), 734-747, 2002
5. A probabilistic active support vector learning algorithm, P Mitra, CA Murthy, SK Pal, IEEE Transactions on Pattern Analysis and Machine Intelligence 26 (3), 413-418, 2004
6. BASS net: Band-adaptive spectral-spatial feature learning neural network for hyperspectral image classification, A Santara, K Mani, P Hatwar, A Singh, A Garg, K Padia, P Mitra, IEEE Transactions on Geoscience and Remote Sensing 55 (9), 5293-5301, 2017

Verification, Security, Certification, Safety Analytics: The Formal Verification Research Group at IIT Kharagpur is one of the most industrially relevant groups of its kind in the world. It has more than 20 years of collaboration history with leading national and international companies, including HAL, Indian Railways, Intel, Synopsys, SRC, Texas Instruments, National Semiconductors, IBM, Google, General Motors, Tata Motors, Bosch, and leading academic institutions in this domain, including the Technical University of Munich in Germany, Warwick Manufacturing Group in UK, Verimag in France.

The Security for Embedded Systems Lab (SEAL) at IIT Kharagpur is the country's leading centre for the security of embedded systems. It has unique equipment and test beds for mounting power and electromagnetic attacks deep inside integrated circuits and systems, and world leading capabilities on finding attacks and developing counter-measures. It has more than 10 years of collaboration with international and national reputed organizations, like Intel Labs USA, NTT Labs Japan, BOSCH, Synopsys, Qualcomm, DRDO, ISRO, and universities like K U Leuven Belgium, Telecom ParisTech, NYU USA, Radboud University, Netherlands, NTU Singapore, IIT Madras, ISI Kolkata, etc.

Both these groups are very well known in their fields and work very closely with the industry. Some of the notable achievements of these groups are as follows:

1. HAL has recently developed India's first avionic indigenous real time operating system. This RTOS was designed and formally proven in collaboration with IIT Kharagpur. The RTOS has already been deployed in the aircrafts manufactured by HAL.
2. Indian Railways has migrated its signalling systems to electronic interlocking equipment. Each EI equipment has to be programmed with yard specific logic which ensures that the signalling does not allow unsafe movements of trains in the stations. The logic developed for a yard may have errors that are sensitized only under very specific movement of trains, and may escape detection during testing. IIT Kharagpur has developed a software that can prove the safety of the EI logic for a yard, thereby eliminating the possibility of signalling errors.

3. In collaboration with Intel and Synopsys, IIT Kharagpur has developed technology for validating intelligent power management strategies for integrated circuits.
4. SEAL Lab has also been working in the design of countermeasures against the side channels, providing suitable defences against power attacks, incorporating fault tolerance, and defending against cache attacks. However, the central goal in all these countermeasures has been to develop defences by design, so as to reduce the overhead of countermeasures and also to provide better guarantees for security: a combination which is extremely challenging to attain.

Data-Driven Stochastic Optimization and Predictive Control:

A fundamental technological challenge is to ensure that networked cyber-physical systems operate in a safe, reliable and efficient manner in the presence of uncertainty. In addition to conventional sources of uncertainty such as faults, process noise, and disturbances, modern engineered systems encounter a variety of new sources of uncertainty. For instance, efficient and reliable operation of the future electricity grid requires making real-time decisions in the presence of a high penetration of electric vehicles and intermittent renewable energy generation. Similarly, in the transportation sector, autonomous and (hybrid) electric vehicles need to operate under highly variable traffic conditions.

In order to address the above challenges, researchers at IIT Kharagpur have been developing data-driven stochastic optimization and control algorithms that leverage increased data collection and processing capabilities (enabled by IoT and edge compute devices) and provide rigorous mathematical guarantees on their performance. Recent focus has been on the class of distributionally robust optimization problems where the distribution of uncertain parameters is not perfectly known, but is assumed to belong to a family of distributions that is constructed directly from observed data. IIT Kharagpur researchers have developed distributionally robust optimization and control algorithms that (i) are computationally tractable, (ii) can incorporate (safety-critical) constraints on state and control inputs, and (iii) have rigorous guarantees on performance and constraint satisfaction in the finite-sample as well as asymptotic regimes [1], and have examined the performance of these techniques in the context of economic dispatch problems in power grid [2] and regret-optimal routing decisions in traffic networks [3]. Ongoing work is focused on applying similar algorithms for energy management in smart buildings [4] and securing interdependent assets on large-scale networks [5].

Research along this thematic area is being carried out in collaboration with research groups at ETH Zurich (Switzerland), University of California, Berkeley (USA), University of Groningen (Netherlands), DESY (Germany) and Purdue University (USA).

Publications:

1. Hota, Ashish R., Ashish Cherukuri, and John Lygeros. "Data-driven chance constrained optimization under Wasserstein ambiguity sets." In 2019 American Control Conference (ACC), pp. 1501-1506. IEEE, 2019.
2. Poolla, Bala Kameshwar, Ashish R. Hota, Saverio Bolognani, Duncan S. Callaway, and Ashish Cherukuri. "Wasserstein Distributionally Robust Look-Ahead Economic Dispatch." arXiv preprint arXiv:2003.04874 (2020).
3. Dietrich, Jonathan, Ashish R. Hota, and Ashish Cherukuri. "Data-driven regret minimization in routing games under uncertainty." In 2019 18th European Control Conference (ECC), pp. 1702-1707. IEEE, 2019.
4. Schütte, Maximilian, Ashish R. Hota, Annika Eichler, and John Lygeros. "Dynamic Mechanism Design for Human-in-the-Loop Control of Building Energy Consumption." In 2019 American Control Conference (ACC), pp. 247-252. IEEE, 2019.
5. Hota, Ashish R., Abraham A. Clements, Saurabh Bagchi, and Shreyas Sundaram. "A game-theoretic framework for securing interdependent assets in networks." In Game Theory for Security and Risk Management, pp. 157-184. Birkhäuser, 2018.

NLP and Text Mining: IIT Kharagpur has deep expertise in Natural Language Processing (NLP) in general and in Indian languages in particular. We have built basic linguistic blocks for Indian languages and developed resources for the same. We have worked on different application tasks such as Information Retrieval, Information Extraction and Summarization. We have worked on cross-lingual and multi-lingual systems for developing parsers, Information Retrieval and Information Extraction systems. We have worked in the biomedical domain to build knowledge graphs and to extract relations and pathways in this domain. We have worked on using information from product reviews for recommendation and summarization.

There has been a focus on multilinguality and to make use of representations of textual units by collating information from multiple sources and transfer learning to work on low resource scenarios to bootstrap NLP systems.

Recommendation Systems: Our team has deep expertise in developing recommendation systems. We have worked on developing recommendation algorithms that leverage transaction data as well as content data and known ontologies. We have worked on representations of items, sessions and users based on transactions as well as content data and algorithms that deliver high quality recommendations. We have worked on review recommendation systems.

Publications:

1. Das, Ayan; Sarkar, Sudeshna; Transform, Combine, and Transfer: Delexicalized Transfer Parser for Low-resource Languages ACM Transactions on Asian and Low-Resource Language Information Processing (TALLIP) 19 (1) 2019; ACM

2. Bhattacharya, Paheli; Goyal, Pawan; Sarkar, Sudeshna; Using Communities of Words Derived from Multilingual Word Vectors for Cross-Language Information Retrieval in Indian Languages; ACM Transactions on Asian and Low-Resource Language Information Processing (TALLIP) 18(1) pp 1:1 – 1:27 2019 ACM
3. Gupta, Ashim; Goyal, Pawan; Sarkar, Sudeshna; Fully Contextualized Biomedical NER European Conference on Information Retrieval, ECIR 2019 , pp 117-124; 2019
4. Mondal, Ishani; Purkayastha, Sukannya; Sarkar, Sudeshna; Goyal, Pawan; Pillai, Jitesh; Bhattacharyya, Amitava; Gattu, Mahanandeeshwar; Medical Entity Linking using Triplet Network Proceedings of the 2nd Clinical Natural Language Processing Workshop; pp 95-100; 2019
5. Sinchani Chakraborty, Sudeshna Sarkar, Pawan Goyal, Mahanandeeshwar Gattu; Biomedical Relation Classification by single and multiple source domain adaptation.; Louhi@EMNLP; pp 75-80; 2019
6. Sukannya Purkayastha, Ishani Mondal, Sudeshna Sarkar, Pawan Goyal, Jitesh K. Pillai; Drug-Drug Interactions Prediction Based on Drug Embedding and Graph Auto-Encoder in {19th {IEEE} International Conference on Bioinformatics and Bioengineering, {BIBE} 2019, Athens, Greece, October 28-30, 2019}, pp 547-552; 2019
7. Muthusamy Chelliah, Yong Zheng, Sudeshna Sarkar; Recommendation for Multi-stakeholders and through Neural Review Mining; CIKM pp 2979-2981 2019
8. Paul, Debanjan; Sarkar, Sudeshna; Chelliah, Muthusamy; Kalyan, Chetan; Sinai Nadkarni, Prajit Prashant; Recommendation of high quality representative reviews in e-commerce; Proceedings of the Eleventh ACM Conference on Recommender Systems; pp 311-315 2017 ACM
9. Das, Ayan; Zaffar, Affan; Sarkar, Sudeshna; Delexicalized transfer parsing for low-resource languages using transformed and combined treebanks; Proceedings of the CoNLL 2017 Shared Task: Multilingual Parsing from Raw Text to Universal Dependencies ; pp 182-190; 2017
10. Chowdhury, Gourab; Srilakshmi, Madiraju; Chain, Mainak; Sarkar, Sudeshna; Neural Factorization for Offer Recommendation using Knowledge Graph Embedding; Proceedings of the {SIGIR} 2019 Workshop on eCommerce, co-located with the 42st International {ACM} {SIGIR} Conference on Research and Development in Information Retrieval, eCom@SIGIR 2019, Paris, France, 2019
11. Sonie, Omprakash; Sarkar, Sudeshna; Kumar:, Surender; Concept to code: learning distributed representation of heterogeneous sources for recommendation; Proceedings of the 12th {ACM} Conference on Recommender Systems, RecSys 2018, Vancouver, BC, Canada, pp 531-532; 2018
12. Muthusamy Chelliah, Sudeshna Sarkar: Product Recommendations Enhanced with Reviews. RecSys 2017: 398-399

13. Maunendra Sankar Desarkar, Sudeshna Sarkar, Pabitra Mitra: Preference relations based unsupervised rank aggregation for metasearch. Expert Syst. Appl. 49: 86-98 (2016)
14. Agnivo Saha, Sudeshna Sarkar: Enhancing Neural Network Based Dependency Parsing Using Morphological Information for Hindi. CICLing (1) 2016: 366-377
15. Ayan Das, Agnivo Saha, Sudeshna Sarkar: Cross-lingual transfer parser from Hindi to Bengali using delexicalization and chunking. ICON 2016: 99-108
16. Ayan Das, Agnivo Saha, Sudeshna Sarkar: Development of a Bengali parser by cross-lingual transfer from Hindi. WSSANLP@COLING 2016: 33-43
17. Paheli Bhattacharya, Pawan Goyal, Sudeshna Sarkar: Query Translation for Cross-Language Information Retrieval using Multilingual Word Clusters. WSSANLP@COLING 2016: 152-162
18. Ayan Das, Pranay Yerra, Ken Kumar, Sudeshna Sarkar: A study of attention-based neural machine translation model on Indian languages. WSSANLP@COLING 2016: 163-172

Medical Imaging: Development of deep CNN and DNN based models for CT/MRI reconstruction, denoising, restoration, super-resolution. Also to include radiology, microscopy and ultrasound image simulation, super-resolution, image compression. Data privacy preserved learning of reconstruction algorithms in a federated/distributed setting. These are being undertaken with Nvidia, Sigtuple Technologies Pvt. Ltd.

Medical Image Analysis: Image segmentation, detection and identification of cellular pleo-/polymorphism, tissue atypia, heterogeneous diseases in macro-imaging viz. X-rays, CT, MRI, PET/SPECT; meso-imaging viz. Ultrasonography and optical coherence tomography of coronary/carotid arteries, retina; micro-imaging viz. Digital pathology and exploratory microscopy. Also includes multi-modal dataset integration for learning, and learning from weak/noisy labels and non i.i.d. Data across distributed datasets. Data privacy preserved learning of reconstruction algorithms in a federated/distributed setting. These are being undertaken along with Intel in the development of a large scale Healthcare AI algorithms benchmarking.

Healthcare, Cognitive and Bioinformatics: Continual and online learning for personalized mental / physical health monitoring using body sensors viz. ECG, PCG, phonocardiography, EOG; clinical / pathological biomarkers, behavioural patterns.

Digital Media Compression Technologies: Development of data driven feature learning methods for high density and high fidelity compression of images, videos, and medical images. High compression efficiency beyond that achieved using the classical methods like JPEG, J2K, H.263/264, HEVC, AVC.

Medical cyber-physical system (MCPS): An extension of a generic cyber-physical system, can provide a unified healthcare network for better health resources (data, networked medical

devices, experts etc.) management, medical decision making, and efficient patient care. Here, an MCPS based medical imaging system is proposed. The proposed development integrates three major components, i.e. networked optical microscopic imaging device, automated decision making and secure network model. The proposed imaging system is a low-cost, portable digital microscope that can capture high-resolution microscopic images of pathological samples. It will be controlled through a software-empowered microcontroller board. It also enables network communication for remote access and data transmission. Next, the decision-making process is a critical integration of Machine learning and Image processing. It allows automated medical screening that assists experts in crucial issues. Lastly, the network model (wireless and/or) will offer a highly reliable and secure communication network between human and healthcare services. The proposed MCPS will be designed for uninterrupted, effortless and high-quality healthcare services where disease diagnosis will be executed promptly with minimum human intervention, non-screened medical samples will be redirected to the nearest processing hub, and remote diagnosis will be performed without physical presence.

Autonomous Surgery, Surgical Assistance and Surgical Informatics: Development of video/stereo and multi-sensor fusion based methods for full-/partial autonomous surgery, autonomy of monotonic surgical phases using robotic surgery systems like daVinci from Intuitive Surgicals. Also development of surgical video analysis based surgical phase monitoring and surgery end-state prediction.

AI Cloud for CPS

AI4ICPS at IIT Kharagpur aims to develop a **reactive and responsive in real-time (R3)** elastic cloud computing service with federated learning and inferencing capability in order to provide computing support for AI and ML interventions in CPS applications in our country.

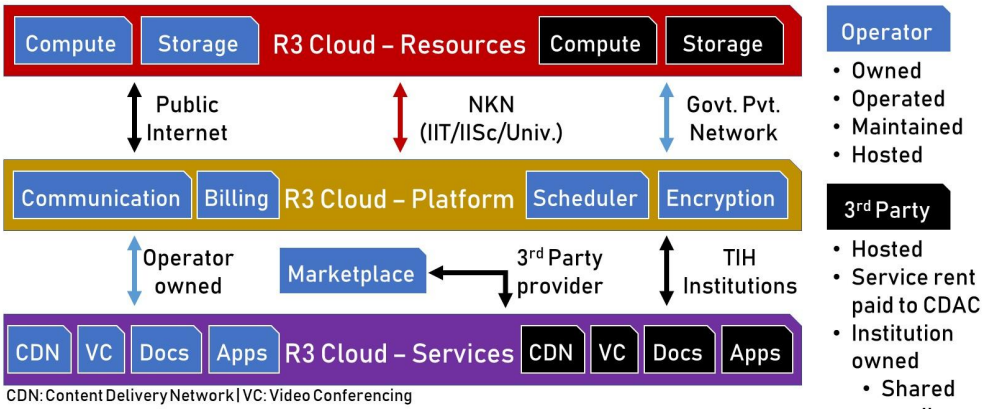
The broader ambition is to facilitate and accelerate innovation in AI cloud technology and services, for large scale solution development and thereby its deployment, for solving India's societal challenges using high performance and high throughput AI-specific supercomputing technologies. Furthermore, it is desired to develop this service not as a centralized unit, but as a distributed system of data centers located across the geographical spread of our Nation. Furthermore, ensuring energy efficient operation of the data centers, secure communication backbone, and developing a competitive pricing scheme are critical for the success of this

venture in the highly competitive cloud service provisioning market dominated by a few multinational corporations such as AWS[14], Microsoft[15] and Google Cloud Platform[16], Alibaba[17], etc.

Challenge: Compared to conventional approaches, such as rule-based expert systems or PID controllers, state-of-the-art AI and ML algorithms typically have several orders of magnitude higher computational requirements. This poses a fundamental challenge for CPS applications which require computations to be carried out in a time-critical manner. It is often impractical to deploy heavy compute nodes on physical systems and processes. For example, an automated driver assistance system (ADAS) of a passenger commuter vehicle relies on estimation of real-time road and traffic conditions using data gathered by IoT sensors and vehicle-to-vehicle communication, and prediction of future traffic conditions along its route. Such computationally heavy algorithms are often impractical to be solved onboard the vehicle.

Alternative approaches include off-loading heavy computations to dedicated compute nodes, i.e., rely on cloud or edge computing to compute control actions. While cloud (and edge) computing is a mature discipline, CPS applications come with further challenges including the scale of deployment, stringent latency requirements, and heterogeneity of applications. The conventional cloud services are often not designed to meet the above requirements. Therefore, there is a critical need to provide cloud compute support to enable large-scale deployment including both training and inferencing of AI and ML algorithms in CPS applications.

Approach: An overview of the technology to be developed in order to address the challenges discussed above and a detailed exposition of proposed R3 cloud architecture is given below.



[14] https://aws.amazon.com/automotive/autonomous-driving/

[15] https://www.volkswagenag.com/en/news/2018/09/volkswagen-and-microsoft-announce-strategic-partnership.html

[16] https://cloud.google.com/solutions/designing-connected-vehicle-platform

[17] https://in.alibabacloud.com/

Figure 8.1: Architecture of the conceived R3 Cloud for AI and ML services for ICPS.

1. **R3 Cloud - Resources:** These consist of hardware resources for (a) computing, (b) storage, and (c) networking, that serve as the physical backbone of the R3 cloud service. These shall reside in physical data centers and rented rack space across the Nation, to enable creation of a service redundant to catastrophic total disruption. Options of partnering with supercomputing service providers of the Nation like CDAC shall be explored for their resourcing. These shall include a heterogeneous spectrum of Graphics Processing Units (GPU) and Central Processing Units (CPU) computing resources, Field programmable Gate Array (FPGA) and System on Chip (SOC) for AI and ML applications, Network Attached Storage (NAS) and Just a Bunch of Disks (JBOD) configured storage system employing traditional low cost Hard Disk Drives (HDD) and current age Solid State Drives (SSD), Flash, and new advances in Ferrite Core Memory. Networking between nodes of a cluster and between clusters shall include current age technologies on high speed copper fabric interconnects beyond Gigabit Ethernet, as well as fiber optic connectivity. Technologies like NVLink for multi-GPU platform linking for dynamic scalability shall also be employed. Provisions to have inline encryption for networked cyber security shall also be included. These shall usher new directions to solving the Federated Learning problem under expected levels of data privacy constraints.

2. **R3 Cloud - Platform:** The architecture of the cloud platform, including communication, energy-aware scheduling across multiple data centers, virtualization, auto-scaling, cyber security, access for multiple institutions, among others will be planned and deployed in the pilot project. While this shall start initially with available tools commonly used for managing these requirements of communication, billing, scheduling and encryption, the platform shall also enable on ground testing of development of new technology innovations.

3. **R3 Cloud - Services:** While the larger goal is to serve a gamut of AI and ML workloads, two suitable ML workloads will be enabled in the pilot project, and the performance of the platform in meeting the requirements of the applications and its energy efficient operation will be investigated. These shall include simple services like content delivery of video lectures, video conferencing and virtual class room delivery facility, simple document services, ERP services, and also Coding Cloud[18], App based services, etc. Such services, including customized commercial offerings for nische CPS sectors viz. EHR and Imaging AI for Healthcare can also be provided by third party providers, enabling commercialization and revenue earning routes for the cloud.

[18] Similar to https://colab.research.google.com/

4. **R3 Cloud - Marketplace:** In order to facilitate research labs, industry and start-ups to develop AI and ML algorithms in their technological solutions, the cloud service should be made available beyond academic institutions and government organizations. Accordingly, an energy-sensitive dynamic auction and pricing framework will be developed to fair and competitive provisioning of the cloud infrastructure for users. This shall also be a common place[19] offering the innovations in the sector as pay per use services.

Impact: This shall serve to enable import substitution and foreign exchange costs due to reliance on the traditional cloud service provider which are foreign companies including AWS, Microsoft Azure, Google Cloud, Alibaba Cloud, and also pose serious restriction to the current requirements of data privacy requirements of the Nation. Nonetheless, none of them are suited for CPS applications and hence is the need to build one from foundations up. Having worked out a solution to this space, this shall also be a critical foreign exchange earning mechanism for the Nation, and establish India as a critical player in the serious scientific compute business.

Partners: This shall be developed in collaboration with CDAC (Kolkata and Chennai Centers) and Nvidia. Edge compute cloud hardware units[20] to service the R3 requirements of CPS shall be developed along with Techwave[21].

Proposing Faculty of Host Institute: Debdoot Sheet and Ashish Ranjan Hota

National Knowledge Portal (NKP)

The NKP shall be a comprehensive cloud based solution for providing study materials as curated coursework and certification material through online content delivery network (CDN) channels, datasets, APIs and standard code release, benchmarks and case studies, access to digital twin simulators of CPS for virtual environment experiments. This shall serve as the digitally connected interface of the Hub providing access to the innovative services.

Challenge: Currently there are numerous platforms which serve only a part of the required services to be provided for knowledge delivery, and this is the most crucial aspect of bridging the KRL preparedness of CPS Industry for AI and ML adoption. Platforms for MOOCS like NPTEL[22], Udemy[23], Coursera[24], Unacademy[25], etc. offer certifications and courses through traditional forms of lecturing, but do not let students interactively connect on to a virtual platform to try them out

[19] Similar to https://aws.amazon.com/marketplace
[20] Analogous to AWS Snowball https://aws.amazon.com/snowball/ with specifics for R3 cloud
[21] https://techwave.net/
[22] https://nptel.ac.in/
[23] https://www.udemy.com/
[24] https://www.coursera.org/
[25] https://unacademy.com/

on CPS. Similarly, there are cloud based computational service providers for AI and ML algorithm use, which are generic and do not provide options for on-the-go running of simulators for CPS plants viz. Solar power plant, water treatment plant, etc. Leave along the challenge that public cloud service providers like Amazon AWS[26], Microsoft Azure[27], Google Cloud[28], Alibaba Cloud[29], IBM Cloud[30] generally do not have a one click solution for accessing computers, but requires the user to set in a bunch of complex instructions often privy to only one with a foundational degree in computer sciences, and not other disciplines of engineering. While an innovative approach of creating Virtual Labs[31] through NME-ICT of MHRD had provided a similar blended learning experience for undergraduate engineering education, but do have a computational and resource scaling limitation for hosting realisting CPS plants and are not available for commercial purposes.

Moreover, these courses are generally blanket guided and generic in nature, and not tuned to specific industry sectors. On account of these, the challenge with AI and ML adoption barrier in Industry is still persistent.

Approach: The NKP shall consist of the following product components to be developed based on available technologies and existing knowhow.

1. **NKP - Content Delivery Network (CDN):** The current services for MOOC delivery either use video sharing platforms like Youtube, Vimeo or whitelabelled CDN services for sharing videos, and lecture notes, worksheets, quizzes, and programming or numerical assignments are shared through other platforms. This asynchronous nature of multiple platforms, creates a cognitive clutter for the one opting for such a subject, and often than not is demotivated from engaging in an interactive mode for learning a subject. This product shall not only be a CDN service to integrate all such interactive mechanisms of course delivery in a single platform service, but shall also make it simple to operate for the instructor to create a course with such heterogeneous offerings. In the recent surge of online class delivery in the wake of COVID-19, eyes have turned on towards some such engaging classroom hosting platforms like BigBlueButton[32] which integrate a learning management system (LMS) with a CDN. However, there is a limit to scalability of such platforms when implemented from single provisioning servers. Challenges exist in terms on how many concurrent subscribers can be supported on a platform, how many concurrent courses can be supported, asynchronous vs. synchronous course subscription, support for low-bandwidth and high-latency communication networks, as

[26] https://aws.amazon.com/
[27] https://azure.microsoft.com/en-in/
[28] https://cloud.google.com/
[29] https://in.alibabacloud.com/
[30] https://www.ibm.com/in-en/cloud/
[31] http://www.vlab.co.in/
[32] https://bigbluebutton.org/

well as possibility of scaling up by hot plugging in of servers to an adhoc network configuration, including provisioning of such services for closed institutional groups as well. This platform shall include current understanding of distributed data load distribution, using AI assisted network load distribution, and AI assisted CDN configuration, DL/ML based high density media content compression, in order to enable such services.

2. **NKP - Datasets:** This shall be an ever updating archive for release of CPS plant specific datasets, to enable creating of new AI and ML based models for control and monitoring of such practical CPS. While there is no dearth of datasets on speech, language, vision, and also niche areas like environment and pollution, etc. There is a challenge with availability of datasets for practical plants like that of a complete steel plant, or a national electrical energy grid, etc. There is also a challenge in availability of curated datasets which significantly hampers the quality of any algorithm being developed. Another significant deterring factor has been that in the current format datasets are available as static release, and they do not keep on growing over the day. This platform shall address all of these challenges. On the top of it, this shall be integrated with the CDN such that in-course experiments can be carried out easily. Provision for distributed hosting of the datasets, using the R3 Cloud, enabling federated compute, etc. shall be enabled.
3. **NKP - API Library and Code base:** This shall feature a standard version controlled and searchable database of APIs and standard code release. This shall on one hand be similar to features available through GitHub[33] or BitBucket[34], but shall be curated and shall have core released by certified projects of the Hub only. This shall enable a quality assurance and reliability certification of the API Library and code base.
4. **NKP - Benchmarks and Case studies:** This shall include release of performance benchmarks on AI and ML algorithms, across a set of CPS systems, and on heterogeneous compute platforms, with studies on their deployment in real life units. Such benchmarks and case studies shall enable adopting industries to choose from a spectrum of already performed experiments, before narrowing down on a set of candidate technologies. This shall also be a showcase for innovations on offer for commercialization. This shall include the proof of TRL5-6 readiness of the technologies, primarily including API and Codebases of AI and ML for ICPS.
5. **NKP - Connector for Digital Twins:** This shall enable the platform for access to digital twin simulators of CPS for experiments in a virtual environment. The connector shall enable calling of such simulators as on demand within a course, execution of it with compute powered through the AI cloud for CPS, and the twins shall be built with datasets available within NKP. While some of the Twins in their initial phase shall be based on

[33] https://github.com/
[34] https://bitbucket.org/product

Physics models, they shall eventually be organized to be data driven and ML based. The list of such digital twins that shall be enabled in a phased release after being developed by the Hub are detailed subsequently.

6. **NKP - Plugin to AI Cloud for CPS:** This shall enable users of the NKP to connect with the AI cloud from within session environment for executing their AI and ML models, worksheets, experiments with Digital Twins, etc. which shall require high density on-demand compute power that can be provisioned through the AI Cloud for CPS.
7. **NKP - Plugin to Cloud Connected CPS Testbeds:** This shall enable users of the NKP to connect with the physical CPS testbeds for performing experiments. This shall be a seamless service similar to the experience of performing experiments on the Digital Twins of CPS. This shall also enable seamless connection with the AI Cloud for CPS in order to enable users execute their AI based control and analytics algorithms directly on it. The Testbeds are detailed subsequently.

Impact: This shall solve a major impediment in knowledge delivery for bridging KRL on AI4ICPS. This shall be a major revenue stream for financial sustenance of the Hub.

Proposing Faculty of Host Institute: Debdoot Sheet, Sudeshna Sarkar, Surjya Kanta Pal, Rajendra Machavaram

Digital Twins of CPS Hosted Through NKP

Table 8.1: Digital Twin of CPS plants to be developed for the physical plants operational at IIT Kharagpur that shall be provisioned for activities of the Hub through cloud connected services.

Prod. No.	Name	CPS Application Sector	Proposing Faculty	Industry and Govt. Dept. Partner
1.	Simulator of Tractor & Applicator ADAS	Precision Agri. & Nutri. Sec.	Rajendra Machavaram and Virendra Kumar Tewari	TAFE
2.	Road Traffic & Structural Health Simulator	Transportation	Swati Maitra and Bharath Aithal	Ultratech Cements Ltd. and PWD
3.	Digital Twin of 3D Printing Process	Manufacturing	Cheruvu Siva Kumar and Surjya Kanta Pal	EOS GmBH, Systemantics, Siemens
4.	Simulator of a Smart Hospital Processes	Healthcare	Satadal Saha, Suman Chakraborty, Anirban Mukherjee, Debdoot Sheet	Tata Medical Center Kolkata

5.	Simulator for Automotive Drive System	Transportation	Siddhartha Mukhopadhyay, Pallab Dasgupta, Soumyajit Dey, Sudeshna Sarkar	Tata Motors Ltd.
6.	Digital Twin of Wastewater Engg. Plant	Environment & Pollution	Makarand Madhao Ghangrekar, Brajesh Kumar Dubey, Sudip Misra	
7.	Digital Twin of Smart Building Energy Microgrid	Infrastructure & Energy	Siddhartha Mukhopadhyay, Prabodh Bajpai	Shell
8.	Simulator of Human Physiology & Pathology	Healthcare	Suman Chakraborty, Nirmalya Ghosh, Satadal Saha, Debdoot Sheet	AIIMS Bhubaneswar
9.	Chatbots for Legal Aid	Judiciary, Legal & Law Enf.	Saptarshi Ghosh, Uday Shankar, Sudeshna Sarkar, Partha Pratim Chakrabarti	LegalKart
10.	Digital Twin of Next Gen Wireless	Communication	Debarati Sen, Pallab Dasgupta, Debdoot Sheet	Ericsson

These Digital Twins shall feature the following attributes on being implemented.

1. **Simulator of Tractor & Applicator ADAS:** Precision Agriculture intelligent operating system can help the farmer to understand the real time situation of the farm and to make the proper decisions in controlling the tilth condition during tillage operations, seed depth and seed rate during sowing and planting operation, rate of fertilizer, pesticide and herbicide during inter-cultural operations and yield of the crop before harvesting. Improving on tractor-implement systems has been a subject of considerable research, operational efficiency of the tractor-implement system can be improved by either maximizing the work output or minimizing the fuel consumption. Again, it could be achieved by proper matching of implement to tractor and optimizing the tractor-implement operating parameters.

   Approach: Tractor tractive efficiency is the percentage of tractor axle power that is transformed into tractor drawbar power. This performance parameter can affect productivity and fuel consumption of a tractor. The design of the tractors is pivotal on the maximization of the traction efficiency and simultaneous minimization of fuel consumption. Traction ability of a tractor during field operations depends on tractor mass, implement type, soil texture, forward speed, ploughing depth of implement, and traction force generated by driving wheels. Physics and learning from data driven models shall be implemented to create these simulators.

Impact: AI can predict and forecast on the base of parallel reasoning. Therefore there is a need to predict the tractive performance parameters and fuel consumption of a tractor for various soil conditions, tractor operating parameters and implement type.

2. **Road Traffic & Structural Health Simulator:** In recent years, the development of road infrastructure has become a priority area in India. Thousands of kilometres of roads are being constructed in several states of our country under various road development projects like NHDP, Bharatmala, etc. Development of road infrastructure however is not limited to the construction of new roads only. Maintenance of the existing roads is extremely important as roads are considered to be one of the most capital intensive built infrastructure. Advanced countries are facing a huge challenge of sustainability and maintenance of their rapidly expanding built infrastructure and spend several million dollars per year to monitor their condition and performance. In India, roads are found to undergo faster deterioration mainly due to poor construction practices, inadequate understanding of the pavement materials, soil characteristics, increased traffic loading including overloading and climatic variations. As a result, the performance of roads in terms of their riding quality and structural strength are greatly compromised with reduction in their overall service life.

   Approach: Currently deployed structural health monitoring approaches involve one time evaluation techniques with specialized equipment at selected points only. These are basically reactive in nature instead of proactive, which detect damages only after they appear on the pavement. The real-time structural condition of the pavement, the initiation of damage, the rate of deterioration, the effect of various axle loads, overloading and weathering effects, etc. cannot be assessed from these distress surveys. A more systematic proactive approach to address these issues is the real time health or condition monitoring of pavement. Artificial intelligent based data analysis approach is a promising avenue that can be effectively utilized for developing a comprehensive and integrated real time performance monitoring and management system for smart concrete pavement. These shall include (a) Development of load-to-response model with two major components namely, pavement structural model and traffic simulation model, (b) Validation of the load-to-response model using selected field data, (c) Generation of load-to-response database from the validated load-to-response model, (d) Development of AI based response-to-load model using the generated database.

   Impact: Adoption of appropriate strategies for performance management in order to implement suitable maintenance and rehabilitation measures of existing road infrastructure is the need of the day.

3. **Digital Twin of 3D Printing Process:** Additive Manufacturing is a layer by layer in which digital data from CAD models is used to generate real physical parts. IIT Kharagpur a machine (EOS M290 with Exposure Optical Tomography and Melt Pool Monitoring which

does so for Metals, which is the only unique test bed in academic institution in the country where in considerable amount of digital data is logged for variety of materials in a region by region and layer by layer mode. We would use this test bed to develop and deploy algorithms based on AI for prediction and control of material properties and microstructure that would be suitable for various real life applications. The framework is in place and there is potential to develop our own data set based service model to deploy it for end users giving higher success rates than expensive experimental trials. A digital twin of the process with monitoring data will also be developed that can be used.

4. **Simulator of Smart Hospital Processes:** India has a deficit of 600,000 doctors, 2.0 million nurses and over 5.0 million other health workers. Over 80% of 'medical' practitioners in rural India are 'quacks'. There is a staggering mismatch in distribution of doctors and other health workers between rural and urban areas. The only way to reach healthcare to the over 70% Indian rural population is to adopt "E-health" solutions as being an equally (if not more) effective alternative to traditional across-the-table methods. The Government of India has lent credence to this hypothesis by formulating the National Digital Health Blueprint 2017. An EHR (Electronic Health Record) constitutes the backbone of any digital health model. This will be in the form of an integrated decision-support system. 'Medicine' is an imperfect science; even in the best of hands and facilities, there will be variation in outcome. Imagine what happens in the myriads of prescriptions being given to millions of patients everyday by medical practitioners with training in widely divergent conditions. Through reliance on this system we will never be able to improve 'quality' of care; and thus achieve better outcome and cost-reduction in the current environment. It is a well-documented fact that improvement of quality leads to rationalisation and in most cases, reduction of cost of care. We will apply AI & ML to provide a solution where through deep learning from available and emerging data, certain standards of governance and clinical practice will be set which will guide practitioners for generations.

   Impact: Such simulators which provide ability to (a) further Development & Deployment of AI & ML-enabled comprehensive clinical algorithm- based Software Ecosystem (EHR) that mimics the doctor's mind and bridges the CHWs to the back-end doctors at other locations; (b) End-stage development (TRL 4 onwards) of multiple diagnostic (body fluids, body signal, imaging) technologies and integration with the AI & ML decision support system for comprehensive clinical care on the same portable and mobile platform.

5. **Simulator for Smart Drive System:** AI and ML interventions for smart urban mobility shall be undertaken with three distinct foci.

   (a) Improving Life Cycle ownership Experience of Individual Vehicles and Fleets: This would address issues of optimal energy cost (fuel economy), maintenance and warranty

costs, enhanced experiences in respect of safety as well as drivability, and mass customisation of vehicles based on geography and drive history.

(b) Improving Urban Transportation Infrastructure: This would address issues of optimal mobility, drivability and safety management utilising traffic signalling, smart poles, as well as V-to-I wireless networks. It would also address optimal management of the charging infrastructures to be installed across Indian cities integrating needs of vehicle users, service providers as well distribution grid managers.

(c) Improving Automotive Designs and Manufacturing: This would address issues of improvement of vehicle designs, manufacturing and quality for the automotive sector, particularly addressing low cost 2/3/4 wheeler vehicle markets of India. It would include enhancing automotive designs as well as automotive manufacturing processes, across successive models of vehicles, with ML technologies which leverage big-data sources from connected dealerships, connected and driven vehicles.

The first two foci require real-time communication between and seamless integration of both onboard and cloud-based computing units. The third focus area requires encompassing enhancing QA technologies for automotive manufacturing with live production data available over Industry 4.0 platforms. Therefore, in order to facilitate AI and ML interventions in this sector, automotive engineers and researchers shall be equipped with a digital simulator and test-bed to rapidly test the performance of their control and estimation algorithms and benchmark AI/ML software to meet automotive safety, reliability and performance standards. Furthermore, the digital twin shall be interfaced with the digital twin on wireless networks and smart building microgrid.

6. **Digital Twin of Wastewater Engineering Plant:** Treatment and reuse of wastewater for different applications is a lucrative proposition in this context. However, managing wastewater treatment facilities for effective treatment of wastewater is a challenge due to the different operational failures, which include human errors, equipment malfunction, faulty implementation strategies etc. Hence reliability of the wastewater treatment scheme is connected to: (1) the variability of treatment effectiveness under normal and emergency operation, (2) the probability of mechanical failures, and (3) the impacts of failures upon effluent quality. In order to enhance reliability of a treatment process, sensor based control strategies are important. Control strategies which implement models, which takes into account the variability of the process by measuring the different parameters in real time and predicting the future course of corrective action is the need of the hour. Coupling the models with automated operation of the treatment plant using various pneumatic and hydraulic mechanical systems closes the loop towards a completely automated plant.

Approach: Design of models which simulate the treatment process that contain important parameters of the combined reactor system. We shall identify all different range of possible loading conditions and how the overall system can be modelled as a set of switched subsystems with significantly different dynamics or a time varying nonlinear differential algebraic systems. Then adaptive (switched) robust control rules can be derived for the overall system. The control strategy should be able to estimate what operational scenarios the system is in and optimally switch between multiple optimal feedback rules, each of which can be simple (eg. Explicit MPC, observer-based feedback rules, or PID controllers) or fully nonlinear model predictive controllers with state estimation. To this aim we will explore various techniques that offer a balanced trade-off between performance and computational complexity, including: (a) model approximation using low-order hybrid models (in particular piecewise affine models, as they result in mixed-integer linear optimization problems, for which recently some relatively efficient solvers have become available, (b) parameterized MPC approaches, where a low number of control law parameters, thresholds, etc. are optimized instead of all the control inputs of the system, (c) construction of a limited family of suitable starting points that can still yield sufficient performance, (d) Consideration of multiple nonlinear MPC controllers instead of a full-fledged nonlinear and hybrid one, in combination with reduced-complexity nonlinear optimization algorithms.

Impact: The implementation of automation strategies for these proposed/ installed pilot setups can render valuable feedback to the futuristic IoT applications for smart water and wastewater management.

7. **Digital Twin of Smart Building Microgrid:** The electricity grid is witnessing fundamental transformations in recent years, and is expected to operate in a fairly decentralized manner with a significant penetration of small-scale renewable and distributed energy resources, responsive loads, storage systems, and electric vehicles. Many of these energy resources reside in residential and commercial buildings, which are also one of the largest consumers of energy; by some estimates they account for 30% of the global consumption. As a result, smart residential and commercial buildings are expected to play a central role to improve energy efficiency in the future electricity grid. While architectural and technological solutions for efficient energy management of buildings and co-located distributed energy resources have been developed, efficiency can be further improved by integrating weather and occupancy prediction, learning the preferences of building occupants, incentivizing occupants for energy efficient behavior, monitoring long-term health of assets (such as storage systems), and incorporating grid scenarios and dynamics prices in energy management decisions. In order to achieve the above objectives, a digital twin of a smart building microgrid system shall be developed which will enable development and integration of AI and ML in cyber-physical energy systems. This will

consist of realistic dynamical systems model of buildings, renewable energy resources and CAD tools, and will enable researchers and engineers to quickly build and evaluate realistic test scenarios and benchmark the performance of their algorithms.

8. **Simulator of Human Physiology & Pathology:** Proof of concept and experimental validation of ischemic stroke and its core-penumbra have been published and patented in animal studies and small cohort human data (at TRL-4 stage). Similar subtle regional gradation or topology of ischemic and other diseases are often intuitively expected due to collateral oxygen and blood supplies throughout the body.

   Approach: From *medical imaging data* estimate injury topology. Few medical image modalities (CT, MRI, Ultrasonography, etc.) or specific (weighted) sequences of these modalities are well-established to visualize particular disease or injury for clinical estimates. If these preferred imaging data are not available (services not available, or not safe or not affordable), supervised AI-ML models will be learned/developed (from pairwise available imaging volumes) to estimate those preferred imaging data and/or directly estimate the injury topology from available (non-preferred) imaging data.

   Applying anatomical atlas of that particular organ, estimate gradational footprint of the disease in different anatomical regions of the organ. Though anatomical atlases of different organs are sometimes available, often they are not age-specific, or demography-specific, or modality-specific. AI-ML based image warping and co-alignment tools would be helpful to develop (modality, demography, age) specific anatomical atlases of different physiological organs. These AI-ML models would be extended to align the available imaging data to estimate injury gradational footprint on different anatomical regions.

   From *clinical physiology*, make robust estimates of functional impairment due to the disease. Causal relations between anatomical regions and functional impairment would be mapped using Bayesian AI-ML models learned from clinical knowledgebase and imaging database (developed above or available from collaborating medical centers or online repositories). AI-ML based model pruning could be done for Feature sensitivity and selectivity analysis to reduce complexity and redundancy, increase robustness, and handle missing features or data.

   Developing *digital twins of different organs by signal-fusion*. Complex digital twin models of the organ would be learned using different physiological signals, their multi-spectral features, and clinical parameters (age, gender, demography, history, heredity, etc.). Feature sensitivity and importance in such modeling in a robust AI-ML background would provide knowledge of the minimum set of signals for monitoring the organ.

   Monitoring operation of the organs to predict any abnormality. Over the longitudinal dataset, dynamics of these digital twins of the organs would be learned incorporating clinical history, heredity information, physician scores and annotations using causal

relationship among different (potentially few missing) factors in a Bayesian reasoning AI-ML framework. Therapeutic efficacy in particular disease and organ models could be analyzed.

9. **Chatbots for Legal Information Aid:** The judicial system in common law countries, viz., USA, UK, and India, follows the law of precedent (called "stare decisis") to adjudicate the disputes along with the statutory laws. The law of precedent mandates that the legal issues decided by the highest court bind the subordinate courts for all future issues involving same legal questions. Hence, in such systems, law practitioners arguing an ongoing case have to find and cite prior cases which are relevant to the current case, and which are favorable to their argument. The identification of such cases has always been a herculean task for lawyers as it involves a process to select the similar cases amidst voluminous judicial pronouncements.

   The recent years have seen a rapid increase of the number of legal documents that are digitally available, and it is now intractable for legal practitioners to manually find relevant prior cases that would assist an ongoing case. Additionally, legal documents (e.g., prior case descriptions) are often lengthy and written in a complicated language, thus requiring a lot of time to be read fully. Hence legal practitioners often prefer to go through summaries of the legal documents (e.g., legal catchphrases, headnotes), in order to quickly identify potentially relevant ones. Thus, the legal industry and legal research today heavily depend on Artificial Intelligence algorithms (specifically, Information Retrieval / Machine Learning / Natural Language Processing) for automated processing of legal documents and data.

   A related problem in India and many other countries is the lack of awareness of law, in general, among the common masses. For even day-to-day issues like warranty of malfunctioning products, tenant-landlord issues, the common man in India is not aware of the relevant laws. Additionally, the high cost of consulting a legal professional even for preliminary advice often prohibits the common man from taking legal course in getting his / her dues. The language of legal instruments including enacted law is not very lucid and understandable to common people. The decided cases turn on the meaning that judges ascribe to words, and lawyers must use the right words to effectuate the wishes of their clients. The vocabulary of law conveys contextual meaning such as certain words are used only in legal context, some commonly used words acquire a different or new meaning, words carrying meaning in a given context and words signify a legal doctrine. The apt learning of the meaning of the legal language would make the usage very precise. Thus, it would be desirable to employ necessary technology to make the common people understand the meaning of the language so that individuals get the benefit of the law without the assistance of lawyers. Motivated by this scenario, we also aspire that the system developed as part of this project would also be able to guide a

common person in law-related matters.

Approach: There are several existing legal information systems e.g., LexisNexis, WestLaw, Manupatra (a legal search system that is popular in India). From our discussions with legal professionals (from the Rajiv Gandhi School of Intellectual Property and Law, IIT Kharagpur as well as with law practitioners from outside India), we understand that all these systems charge very high subscription cost, and very few legal professionals (other than large law firms/institutes) can afford to regularly access these systems. Importantly, all the legal search systems mentioned above are for use by legal professionals, and cannot be used by a common layman (who cannot search using legal keywords) even if he were to afford the subscription fees. In contrast, the system we envision will be usable both by law practitioners and by a common man who will be able to state his problem in natural English language. Some of the approaches to be employed include: (a) Understanding the structure of legal case documents, (b) Legal document summarization, (c) Legal Document Similarity for Legal Search / Recommendation, (d) Legal Question Answering, (e) Developing interpretable algorithms for legal tasks, (f) Extending the methodologies to legal documents of other countries.

Impact: A legal assistance system that caters to legal experts as well as to the common man, and an automated and interpretable algorithms for several legal tasks such as summarization, outcome prediction, legal question answer, legal search and recommendation.

10. **Digital Twin of Next Generation Wireless Communication System:** Smartphones, smart IoT devices are connected with radio-frequency signals. WiFi and Long Term Evolution (LTE) are available almost everywhere. In fact wireless is no longer referred to in the narrow sense of communication. It is now concerned with beyond only relay and sending of messages. This has raised a lot of questions around the physics of signal transmission and its processing to harness the maximum capacity of information in it. This digital twin shall create computational models of realistic communication systems which shall model the following in enhancing the scope of performing innovative experiments.

    Approach: Waveforming and multipaths are no more considered noise or an unwanted nuisance anymore. With advent of fast computing technologies at the speed comparable to carrier signals, multipaths mitigation through wave forming is used for improving quality of communication, and getting rid of the line of sight requirement. The digital twin shall comprise the ability to model (a) multipaths and virtual antennas, (b) time reversal principle, (c) MIMO, MISO, SIMO, SISO communication systems, (d) effective bandwidth including options for diversity exploitation.

    Impact: This kind of a digital twin capable of supporting envisaged 6G standards shall enable performing AI and ML interventions for experiments and full digital verification in applications associated with (a) centimeter accurate indoor positioning, (b)

accurate indoor motion tracking, (c) wireless events detection, (d) radio biometrics for human recognition, (e) device-free speed estimation, (f) wireless power transfer and energy efficiency (g) power wave forming, (h) joint waveforming and beamforming, (i) spatial focussing effects, (j) tunneling effect for cloud based radio access network, (k) heterogeneous communication in IoT.

Live Testbeds of CPS with R3 Cloud Connectivity

Table 8.2: IoT and Cloud connectivity to be established at currently operational CPS plants at IIT Kharagpur for turning them into Live Testbeds with R3 Cloud Connectivity.

Prod. No.	Name	CPS Application Sector	Proposing Faculty	Industry and Govt. Dept. Partner
1.	ADAS for Tractor and Applicator	Precision Agri. & Nutri. Sec.	Rajendra Machavaram and Virendra Kumar Tewari	TAFE
2.	Instrumented Road for Traffic & Str. Health Monitoring	Transportation	Swati Maitra and Bharath Aithal	Ultratech Cements Ltd. and PWD
3.	Cloud Controlled Robotic Mfg. Proc.	Manufacturing	Cheruvu Siva Kumar and Surjya Kanta Pal	Siemens, TCS
4.	AI enabled Smart Hospital at Dr. BCRIMSR, IIT Kgp	Healthcare	Satadal Saha, Suman Chakraborty, Anirban Mukherjee, Debdoot Sheet	Tata Medical Center Kolkata
5.	Smart Automotive Drive System for Smart Cities	Transportation	Siddhartha Mukhopadhyay, Pallab Dasgupta, Soumyajit Dey, Sudeshna Sarkar	Tata Motors Ltd.
6.	Wastewater Engineering Plant	Environment & Pollution	Makarand Madhao Ghangrekar, Brajesh Kumar Dubey, Sudip Misra	
7.	Energy Smart Building Microgrid	Infrastructure & Energy	Siddhartha Mukhopadhyay, Prabodh Bajpai	Shell
8.	AI enabled Mobile Unit for Remote Care	Healthcare	Suman Chakraborty, Satadal Saha, Debdoot Sheet, Nirmalya Ghosh	AIIMS Bhubaneswar
9.	Instrumented Classroom	Education	Rajlakshmi Guha, Sudeshna Sarkar, Partha Pratim Chakrabarti	TCS
10.	Smart Beamforming for Next Gen Wireless	Communication	Debarati Sen, Pallab Dasgupta, Debdoot Sheet	Ericsson

The Live Testbeds shall feature the following attributes on being implemented.

1. **ADAS for Tractor and Applicator:** The purpose of an autonomous tractor or unmanned tractor is to reduce human effort and provide efficient operation in the field. The real-time data monitoring system will be a building block for an autonomous tractor. The two-way real-time data monitoring system will play an essential role in the proper functioning of an autonomous tractor. In the absence of a monitoring system, an operator or a supervisor cannot take appropriate action in case of a malfunctioning of the system. It can cause a halt of the operation. This will lead to a reduction in overall productivity. Also, there are problems associated with the autonomous tractors without a real-time monitoring system such as numerous performance parameters of the tractor during agricultural operations are inaccessible for accurate utilization, and unauthorized human intervention cannot be detected. These constitute some of the major challenges faced by tractor operators and turns out to be a demanding innovation sector for the manufacturers.

   There are several ways in which the farm manager can manage spatially. Not all of them require advanced technology. One way is for the fields to be reorganized according to the soil properties. Contour or strip farming is an example of this. However, there are problems with this in practice due to the constraints on field size and shape for efficient field operations, as well as the difficulty in assigning just a single set of field boundaries for all of the field variabilities. Another way is for the farmer to manually operate his equipment in such a way that it responds properly to the spatial variabilities. However, in this case it is difficult for a human to successfully perform such control with reasonable accuracy. Operators without direct financial stake in the performance may also lack the motivation to perform the frequent, accurate control.

   Approach: This shall include to develop a real-time tractor position tracking and performance monitoring system using AI-ML, develop and evaluate the performance of sensor based variable rate fertilizer, herbicide and pesticide application systems, design and develop a robot for planting and harvesting of vegetable and commercial crops using AI, real-time tractor operator advisory system, Precise variable rate applicators for fertilizer, herbicide and pesticides.

   Impact: The developed technologies could save up to 50% of chemical as compared to the continuously spraying systems. His major thrust areas related to the present proposal are implementation of AI-ML based variable rate fertilizer, pesticide and herbicide applicators to save the amount of chemicals to be applied based on the requirement and protection of environment with over dosage. Development of a low cost drone – farmer's drone for application of crop disease specific pesticide using image processing technique for detection of diseases and use of AI for applying suitable amount of pesticide based on the intensity of the disease. Using the proposed method the fuel

consumption can be reduced up to 15%. It can further lead to the development of a real-time tractor operator advisory stem for guiding the operator for proper matching of implement with power source (tractor) to increase the work output.

Figure 8.2: Current physical systems on tractor drawn sensor based sugarcane planter, and an ultrasonic sensor based pesticide applicator, which shall be made IoT enabled and R3 Cloud Connected to be provisioned as a Live Testbed.

2. **Instrumented Road for Traffic & Structural Health Monitoring:** Performance evaluation is an important management measure for built infrastructure. Road infrastructure is subjected to continuous traffic of varying frequencies, axle type and load magnitude. As a result, roads deteriorate and their functional and structural performances are reduced significantly over time. This causes poor riding quality and loss of structural strength resulting in a decrease in overall service life of the pavement. Therefore, performance evaluation of in-service pavements is extremely important in order to implement suitable and timely maintenance and rehabilitation measures so that it can perform better and longer. Real time condition monitoring is an advanced, systematic and proactive approach for performance measuring of pavements. In this system, the pavement is instrumented with a number of embedded sensors to capture the in-situ pavement responses and by analysing the sensor outputs, the real time pavement conditions are evaluated. The objective of the proposed project is to develop an artificial intelligence based real time performance monitoring and management system for concrete pavement.

   Approach: A pilot project has been carried out in collaboration with The Public Works Department, Government of West Bengal and M/s Ultratech Cement Ltd. on Thin Whitetopping: A Pilot Study for Design, Construction and Performance Evaluation. Whitetopping or concrete overlay is a type of concrete pavement and is constructed over an existing bituminous road as its strengthening and rehabilitation measure (IRC:SP:76-2015). In this project, the behavior and performance of thin whitetopping (TWT) or concrete overlay are investigated as a retrofitting measure for distressed bituminous roads (Design Report, 2019). The work involves analysis and design of thin whitetopping, construction of TWT over a selected stretch and its performance monitoring using

instrumentation. The construction of whitetopping has just been completed on a 1.0 km stretch of a 10.0 m wide Major District Road near Kharagpur, within the state of West Bengal. The road has a two-lane undivided carriageway of width 10 m having shoulders on both sides. Traffic on the road is heterogeneous with a combination of commercial vehicles, passenger cars and non-motorised vehicles. More than 100 nos. of various sensors have been embedded within the carriageway at critical locations on both lanes of the pavement. The sensors are static and dynamic strain gauges, temperature sensors, pressure gauges and crack meters. The sensors are placed on a stretch of 15 m and are replicated in three such locations on each lane with a total length of 100 m within the road. The road is subjected to moving traffic and weathering effects (variation of temperature and moisture conditions throughout the day and also seasonal), due to which tensile and compressive stresses and strains are developed onto the pavement slab. The sensors are placed at critical strain locations to get the pavement responses under moving loads. All the sensors are connected to a data logger which is placed within a control room situated at the side of the road. The real time responses are collected and recorded at every minute throughout the day and are transferred to the laboratory at IIT Kharagpur through modem. The pavement is recently open to traffic, so the responses due to moving traffic and varied climatic conditions are being captured as real time data. Huge amount of this data will now be utilized for analysis and performance evaluation of the newly constructed concrete road over years. With these real time data from a live project, it is now proposed to develop an artificial intelligent based real time pavement monitoring and management system for the newly constructed pavement.

Figure 8.3: Instrumented 100m road with sensors for static and dynamic strain gauges, temperature sensors, pressure gauges and crack meters to be used for the Live Testbed.

Impact: Real time performance monitoring and management system for smart concrete road. The real time large database of the newly constructed whitetopping concrete road will be utilized for this purpose. The work will actually be a meaningful continuation of the previous pilot project. We rarely get such real time field data for various AI applications.

3. **Cloud Controlled Robotic Manufacturing Process:** Factory 4.0 can be seen as a vertical integration between human-machine, quality, and maintenance. However, it is essential to note that Factory 4.0 alone can't add much value to a firm's initiative on digitization if it is not integrated horizontally with its supply chain thorough logistics network and business models. This has given birth to concepts of Supply Chain 4.0. It is not surprising that Factory 4.0 integrated with its value chain network of Supply Chain 4.0 is becoming a strategic initiative for firms to distinguish itself from its competitors by way of becoming accurate, faster, flexible, transparent, and efficient. In the context of supply chain (SC), adoption of interoperable ICT in physical devices, sensors actuators etc. with network connectivity-IoT through cloud has shifted the SC decision making process from heuristics based approach to data driven approach. Ever growing use of Internet of Things (IoT) and Information and Communication Technology (ICT) enabled technologies can be enabler in making real-time smart decisions in the field of freight transportation. IoT has enabled SC networks to generate inundated data and transmit it over the Internet for analysis and decision making collectively led to the rise of the big data era.

   Approach: Keeping the above in mind, we propose to develop an integrated framework for Factory-2-SupplyChain 4.0, which will be demonstrated through live test beds by creating a prototype digital supply chain ecosystem integrating smart factory and supply chain 4.0 at the enterprise level. To accomplish the above, we propose to use our two existing lab facilities at CoE AMT, IIT Kharagpur namely, the Smart FMS Lab and Smart robotic flexible welding lab as suppliers in the proposed supply chain. We further propose to develop a smart collaborative human-robot assembly line with a small warehouse setup for flexible assembly to handle multiple product models. It will be treated as an original equipment manufacturer (OEM) engaged in assembling the parts manufactured at the two aforementioned suppliers-cum-labs. We also propose to develop a digital twin framework based on machine learning to support the design, development and real-time tracking and monitoring of the different operations in the above smart factory. For logistics, we propose to do route planning using AGVs and drones. Finally, since integration of logistics is key for a holistic framework creation, we propose to develop a value chain by integrating smart factories with logistics at enterprise level. Low cost robot ASYSTR 600 developed for industry use by Systemantics India Private Limited is a test bed robot, which is capable of being used for collaborative human interaction. While collaborative interfaces are relatively easy they still need a lot of human interfaces to do real industry jobs. It is proposed that we will develop and make voice controlled, natural language interfaces for such robots with AL and Machine learning techniques to be used in industry such data collected from the robot and commands being given by industry users / experts for different applications on a cloud based platform. It will be a service based platform available on demand that will be customized for various kinds of robots.

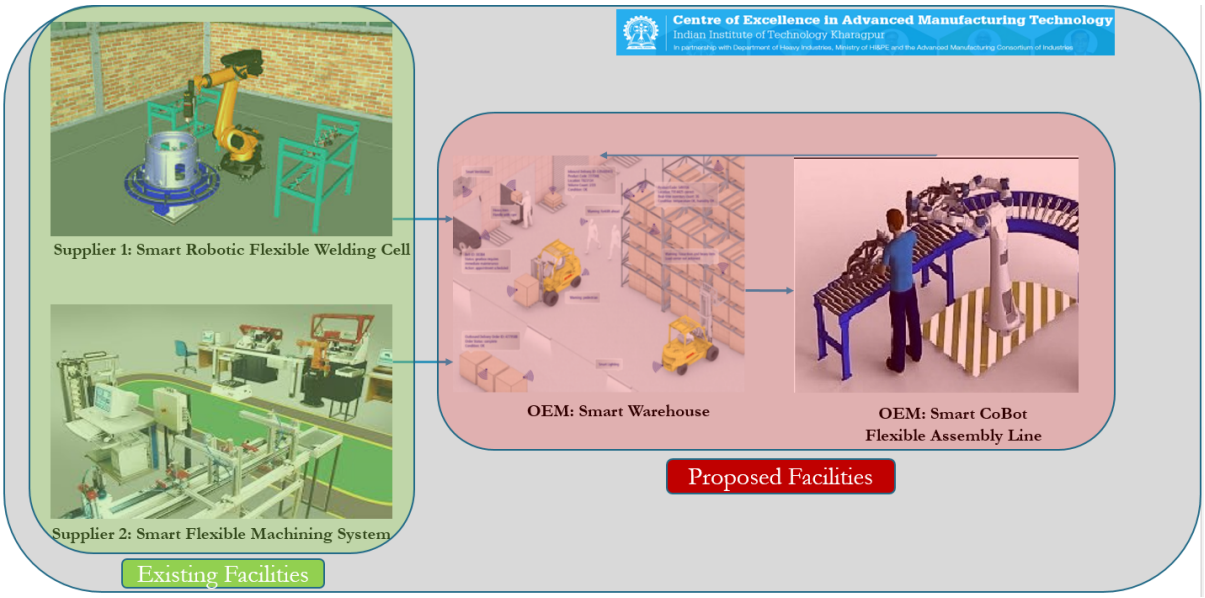


Figure 8.3: An impression of the proposed Cloud connected live testbed on Factory 4.0 and Supply Chain 4.0.

Impact: Developed live testbeds and digital twins can be used for any manufacturing company to carry out POCs for their supply chains and manufacturing. Further, a plug-n-play software developed based out of this research can be used as an add-on to existing enterprise software for intelligent recommendations. There is a broad spectrum of companies that will be benefited from our offerings such as Startups, MSMEs, and well established large manufacturing and supply chain firms.

4. **AI enabled Smart Hospital at Dr. BCRIMSR:** Cutting across the entire spectrum of health systems (rural and urban, institutional and community levels) we have multiple other problem areas – cancer care, eye care, diabetes, anaemia and under-nutrition, pregnancy care etc. The litany of woes is endless; or, in other words, the opportunity is limitless. Incremental developments will not work anymore – too little, too late. We need a mechanism that enables the healthcare system to leapfrog into a genre where equity, access, quality and affordability become an integral part of the value-entitlement. In our proposal, we will examine how AI and ML can address the fundamental barriers to be able to reach our desired objective of "Health for a Billion".

   Approach: We will leverage AI & ML to address the core issues that will have an impact on the entire health system – at rural communities reducing disease burden through evidence-based primary care and public health solutions; and at healthcare institutions, by enabling access to advanced technologies that will mitigate pressing clinical areas such as pulmonary diseases, antimicrobial resistance, tuberculosis etc.

   Shortage of doctors & other health workers: India has a deficit of 600,000 doctors, 2.0 million nurses and over 5.0 million other health workers. Over 80% of

'medical' practitioners in rural India are 'quacks'. There is a staggering mismatch in distribution of doctors and other health workers between rural and urban areas. The only way to reach healthcare to the over 70% Indian rural population is to adopt "E-health" solutions as being an equally (if not more) effective alternative to traditional across-the-table methods. The Government of India has lent credence to this hypothesis by formulating the National Digital Health Blueprint 2017. An EHR (Electronic Health Record) constitutes the backbone of any digital health model. This will be in the form of an integrated decision-support system.

Evidence-based practice: 'Medicine' is an imperfect science; even in the best of hands and facilities, there will be variation in outcome. Imagine what happens in the myriads of prescriptions being given to millions of patients everyday by medical practitioners with training in widely divergent conditions. Through reliance on this system we will never be able to improve 'quality' of care; and thus achieve better outcome and cost-reduction in the current environment. It is a well-documented fact that improvement of quality leads to rationalisation and in most cases, reduction of cost of care. We will apply AI & ML to provide a solution where through deep learning from available and emerging data, certain standards of governance and clinical practice will be set which will guide practitioners for generations.

Public health research & deeper understanding of diseases: We really do not understand much about human physiology, how the brain functions being a case in point. We also do not know far simpler things. For example, certain population segments living in a particular area with certain dietary habits and genetic patterns may be more susceptible to Diabetes and require a modified intervention than another diabetic population segment but in a biologically different context. India has 77.0 million diabetics (2nd highest in the world). Deeper understanding of these questions, unravelling the biological basis of common diseases in our country's context, linking influence of environment and diet practices to genetic composition of our population and analyzing the data through Deep-learning and Artificial intelligence will be the key to defining better, more cost-effective and penetrative public health policies and better utilisation of precious government resources. Even as we spend resources on developing newer generations of insulins and anti-diabetics, AI-enabled research into why diabetes happens and how to address those factors might be much more beneficial for the country. We will leverage AI & ML to transform public health research & policies from being epidemiology-driven to founded on deep-science biology.

Technology misfit: 80% of all diagnostic and therapeutic technologies in healthcare are imported. These do not work in the circumstances that rural India provides. We will not delve into reasons thereof. IIT Kharagpur and our confirmed national and international collaborators have a 'strong room' of disruptive innovations that can truly

transform healthcare delivery; its quality and cost, both. There are multiple areas where AI can be the change agent. For example, we do not have enough Pathologists in the country to be able to interpret all cytology/histology slides if all eligible women presented for cervical smear examination (a screening test for cervical cancer). Could we train a microscope by imparting intelligence to distinguish abnormal from normal and present the doctor only with the abnormal for subsequent interpretation? We are already in the middle of enriching many diagnostic technologies with AI & ML algorithms that will make it more widely available, affordable and reliable.

Impact: The 'healthcare technologies', as a broad basket, will include – (a) Further Development & Deployment of AI & ML-enabled comprehensive clinical algorithm- based Software Ecosystem (EHR) that mimics the doctor's mind and bridges the CHWs to the back-end doctors at other locations; (b) End-stage development (TRL 4 onwards) of multiple diagnostic (body fluids, body signal, imaging) technologies and integration with the AI & ML decision support system for comprehensive clinical care on the same portable and mobile platform. We shall combine the two elements above and build a sustainable, scalable and replicable 'enterprise model' for delivery of primary care, health education and home healthcare through trained youth that can ultimately merge into the planned establishment of 150,000 "Health & Wellness" clinics envisaged by the Government of India.

5. **Smart Drive System for Smart Cities:** Urban mobility is expected to undergo a significant evolution in our country both at the level of vehicular technology and IoT enabled interaction of vehicles with the traffic infrastructure as well as among each other. Many upcoming technologies such as smart traffic light management to reduce congestion in large cities, automated driver assistance systems, aids to minimize risk of collision, adaptive operation of large fleets of vehicles (such as buses for public transportation or on-demand taxi providers) require sensing, communication and actuation actions to happen in real-time via wireless connectivity among vehicles and with cloud/edge compute units. In order to facilitate research and technology development to address the above challenges, a cloud connected live testbed shall be developed.

   Approach: The goal will be to build live application test beds for blending traffic, perception, autonomy and power-train subsystems, set up embedded interfaces and APIs for software subsystems, build repositories of knowledge, processes and prototypes, develop tools for design, manufacturing, test, verification and enable industry practitioners/MSMEs/Start ups to co-develop CPS knowledge resources and IP.

   Impact: The testbed shall be a source of training, research, advisory, certification for OEMs/Fleet Owners/Tier 1 Suppliers and it will support Start-ups/MSMEs with technology and infrastructure. Professional organizations that will benefit include ARAI/ SIAM/ SAE India/ NITI Ayog. In addition to achieving the stated objectives, the testbed will

provide critical insights for urban governance, and serve as a building block for developing platforms for emergency and disaster management, law and order maintenance as well as social infotainment, among others.

6. **Wastewater Engineering Plant:** Typically, larger wastewater treatment plants rely on Supervisory control and data acquisition (SCADA) systems. Usually they are organized with sensors and actuators at the reactor level that are controlled by a Program Logic Controller (PLC) for example a PID controller to reach a present flow rate. On a supervisory level is the SCADA software that allows operators to change operational settings, (i.e. to set the desired flow rate). As a consequence the operators' experience and decision-making are essential to successful operation, but when translating typical "Western" wastewater treatment systems to different socio-economic, educational and cultural contexts it is often forgotten that local operators do not have the same "mind-set" or the environmental conditions are not suitable for the same control strategy.

   Approach: The above background information indicates towards the fact that automated control strategies can enhance the performance of the wastewater treatment plants. Indian Institute of Technology Kharagpur has two installations as pilot treatment units, one 300 m^3/d capacity while the other having 400 m^3/d capacity commissioned under the aegis of WIN Foundation and DST funded Saraswati project respectively. While the first one targets potable quality effluent the other generates effluent which is suitable for non-contact horticulture and irrigation purposes. The third sewage treatment plant of capacity 1.35 MLD is coming up and due for commissioning in the month of May 2020, where it is intended to undertake research to set-up complete automation based on indigenous research outcome of sensors and control system, as a activity very much in line with the activity of Re-water centre set-up at IIT Kharagpur. The construction of this treatment plant has been funded by IIT Kharagpur to be used as a test bed for this project. Further to this another two treatment plants each 100 m^3/d capacity will be constructed in near future under the aegis of the DST project Saraswati 2.0 project.

   Impact: This kind of a unique cloud connected live Testbed shall be of immense interest in facilitating ability to perform tasks including (a) Recommendations on how to implement basic control strategies for pilot plants will be given, (b) Adapt and test a hybrid Model Predictive Control (MPC) system in pilots, (c) Evaluation of basic and advanced control strategies and recommendation towards other pilot plants, amongst others.

7. **Energy Smart Building Microgrid:** The School of Energy Science and Engineering at IIT Kharagpur hosts a hybrid AC-DC micro-grid with local PV generation, wind energy emulator and storage systems. In order to facilitate research and technology development on AI and ML interventions for cyber-physical energy systems to achieve energy efficient operation of smart buildings with local renewable energy generation, a live testbed with cloud connectivity shall be developed augmenting the existing infrastructure.

Approach: The above objectives shall be achieved via the following activities.

a) Synergise existing infrastructure: Research process flows across existing infrastructure with authorisations, upgrades, security and safety installations, maintenance plans shall be carried out. Specifically, the existing micro-grid and distributed generation units on IIT Kharagpur campus shall be equipped with IoT sensors together with a secure communication platform to exchange both sensing and actuation information with edge and cloud servers in real-time.

b) Build comprehensive system integration: Unit and system level testing and verification facilities involving HILS and building live application test beds for blending weather and grid scenarios, occupancy and load sensing, lighting, HVAC and microgrid subsystems shall be carried out.

c) *Build repositories of knowledge, processes and prototypes:* Activities to be carried out are (i) development of tools and processes for design, manufacture, test various subsystems, (ii) being a source of training, research, advisory, certification, and (iii) setting up embedded interfaces (APIs) for software and data.

Impact: The above activities will culminate in the following outcomes with a significant societal and economic impact on the Indian renewable energy sector.

a) Generation of target IP with Venture Collaborators by drawing upon translation-worthy thematic research competence, customising target IP for specific venture collaborators
b) Support for Start-ups/MSMEs with Technology and Infrastructure: Launching a national platform for Startup/MSME engagement in the energy sector, development of programmes for Startup/MSME support, partnering with Startups/MSMEs on TIH owned innovation projects, and providing Start-up services leveraging TIH infrastructure
c) Research and Training: Carrying out demonstrative research inspired by AI/ML/CPS, translational research inspired by industry needs, Co-development of CPS knowledge resources on Energy, Creation of platform to showcase IP of R&D organisations, Support in technology upgradation, adoption, innovation for OEMs/Integrators/Builders/Designers/ Startups, and contribute to certification, standardisation, and policy, among others.
d) Professional Organisations that would benefit: Smart Cities/CBRI/IGBC/ISHRAE.

8. **AI enabled Mobile Unit for Remote Care:** Artificial Intelligence Powered Rural Healthcare Delivery Vehicle: Providing access to technology enabled screening for 1.25 bn people residing across India is challenging with having merely 10 doctors per 10,000 people, while 2/3rd of the population resides in rural areas, requiring them to travel 100's of km at times to gain access to such services. In line with the NITI Aayog 2016 Transforming India report, and building on our works of artificial intelligence (AI) for screening radiology,

ophthalmology, pathology and building mobile scanning units, we propose to develop a modularly integrable and multi-terrain movement compatible mobile screening unit equipped with low-cost and robust X-ray mounted on a robotic arm and combined with a ultrasound/nuclear imaging. The evaluation will be performed through an AI powered "E-doctor" on the van, scalable to cloud connected tele-doctors. This movable and intelligent setup will empower rural primary health centers (PHCs) at the last mile with access to technology enabled screening of preventable diseases.

Approach: The specific objectives we would undertake include:

(a) Develop compute hardware-software infrastructure for Picture Archival and Communication System (PACS) on the mobile containers and synchronization with centralized systems at hospitals, and also for tele-doctor consultation.

(b) Develop and integrate computational methods of multimodal image analysis for creating Artificial Intelligence based E-doctors with standards and PACS integration.

(c) These shall be facilitated to operate on a truck / trailer / rail wagon / water vessel mountable container platform with electrical, communication, water and drainage lines for integrating vibration free modular units. Modular units for patient data collection and registration, primary clinical and physiological investigation, robotic X-ray and Ultrasound/Gamma imaging, on board AI compute for E-doctors, tele-doctors, PACS system, signoff consultation room.

(d) These shall enable a robotic arm based system for X-ray imaging and free hand operator free ultrasound-Gamma imaging hybrid.

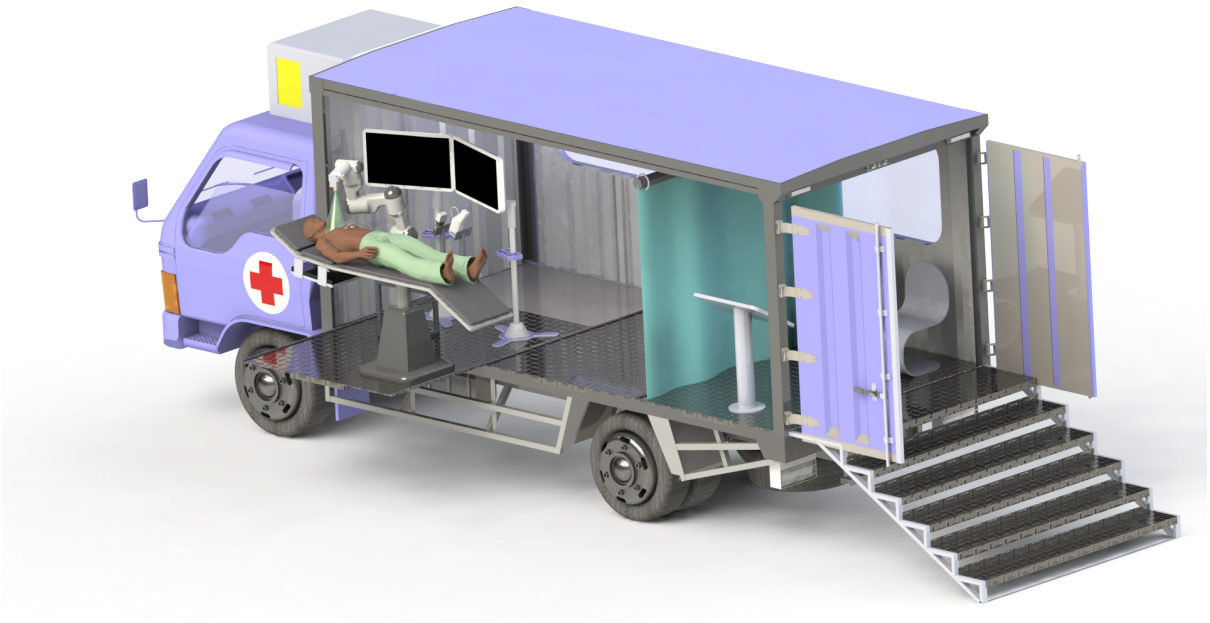


Fig. 8.4: The rendering of the envisaged vehicle to be built up for implementing the testbed for AI+ML assisted healthcare delivery to the last mile to be instituted with the Dr. BCRIMSR. It shall be a fully functional mobile primary healthcare delivery unit. The engineering construction being new in its paradigm shall also require close cognizance with the CoE AMT, Transportation Engineering, CoE Robotics, School of Energy Sciences and Engineering and this shall also be a joint effort of the various sectoral consortiums we shall build as part of this Hub.

Impact: This would provide imaging for a large number of preventable common diseases viz. tuberculosis (TB), lung and breast cancer, pathology of joints and bones, thyroid disease, liver, heart and vascular diseases; which will be combined with a multitude of other tests (ECG, blood, urine, skin, vision, and others) to provide sufficient data for health evaluation, future prognosis leading to present day recommendations, and early detection. The health check-up would be started using a digital input system that will ask standard informations (sex, age, occupation, family status, health problems in family, diagnosed health problems, physical activities, drug use, etc.) resulting in an initial personal health and risk profile that determines the succeeding selection of procedures and tests in the van or other mobile/modular structures. The evaluation will then be performed through an AI powered “E-doctor” on the van, supported by an onsite health professional, scalable to cloud connected tele-doctors. The obtained comprehensive data is integrated into a patient specific health image and data file that is subsequently evaluated by AI and Deep Learning providing a report with current status and recommendations. This movable and intelligent setup will empower rural primary health centers (PHCs) at the last mile with access to technology enabled screening of preventable diseases.

9. **Instrumented Classroom:** Effective teaching and learning can be achieved by adapting the course delivery based on the assessment of student attention, engagement and the assessment of students. The assessment is also necessary to evaluate and grade the student. Automating these can increase the effectiveness of teaching and learning.

   Student attention and engagement is key to understanding why students show low achievement, high boredom levels, high classroom alienation, and high dropout rates. Cognitive engagement is defined as the level of attention and commitment that students have in a lesson. If teachers can instantly identify whether students are attentive they can be suitably reminded to remain focused, thereby improving their learning effects. The course content may also be adapted based on feedback.

   Assessment plays an important role in teaching and learning but may be quite tedious. The New Education Policy (NEP) Draft 2019 has made a set of very significant recommendations concerning assessment in secondary education. The recommendation vouched for the automation of assessment making way for both macro and micro level

analysis of learning progression. In order to develop individualized learning strategy, the NEP policy framework suggested the implementation of formative assessment. The NEP also stressed upon adopting assessment strategies that primarily focus on assessing higher order skills like critical thinking, analysis and conceptual clarity.

Approach:

To build an ambient intelligent low cost smart classroom for assessing students' attention and engagement levels.

Effective assessment of attention and student engagement in a large classroom setting demands the use of automated capturing of bio-signals that would be markers of sustained attention and subsequently student engagement in large classroom. There are several high end instruments that may be used for capturing physiological markers for information processing and learning. Some of the popular tools used to capture bio-signals in the classroom are Electroencephalogram, Eye Movement Trackers, Galvanic Skin Response Recorders and high speed cameras. A clicker is a popular device for Classroom Response. But most of these instruments are expensive and high-contact tools making the assessment tedious and near impossible.

To develop an automatic and adaptive assessment system for student answers (MCQ and text-based) in science domain in Indian language (Hindi) as well as English.

The assessment is performed in two dimensions: 1)Summative assessment: A student answer is assigned a grade considering a standardized scale. 2)Formative assessment: The gaps in student answers are marked along with hints to remediate those. The staggering scale of enrollment of students poses a huge challenge to the automated assessment system and the introduction of assessment on demand. MCQs are not suitable for testing the basic knowledge, understanding, critical thinking skills. These needs require administering Constructed-Response Written Assessment involving assessment of text- based short answers written by students to open-ended questions. The open-ended questions have potential to demand students' conceptual clarity about specific topics or to test logical reasoning, critical thinking or analysis skills of students. Conforming to the recommendations by the NEP 2019, the envisaged system proposes to address the following problems concerning automated assessment in the secondary level. (a) The assessment of text-based answers at the scale that matches the gross enrollment in the secondary level. (b) The formative assessment of the student answers to support learning strategies that focus on nurturing higher order skills in students.

Strategy: A viable smart classroom must be low cost and will automate assessment of students' attention and learning in real time. It should be able to capture multi-modal signals with minimal contact with the student. Our objective is to use cost-effective instruments to capture bio-signals for assessment of sustained attention and engagement of students in a classroom, that may act as a feedback to the teacher to

identify student engagement in class and also effectively modulate the instructional design for improved learning. We plan to use pervasive computing technology to model the sustained attention and class engagement by integrating mobile, handheld and wearable devices, with fixed computing infrastructures, such as sensors like EEG signals, cameras and Classroom Response Systems.

While there have been several efforts in the automated grading domain, research in automatic formative assessment problems (Second Problem) is sparse even in English. The scopes concerning the second problem domain include:

Development of dataset: A gap annotated student answers both in Indian language (Hindi) and English will be developed. The set of answers will have representations from different question types, namely, concept completion, definition and most importantly explanation or reasoning- based.

Development of gap identification models: The gap identification models will mark the propositions or statements in the student answers with appropriate feedback categories. These categories will indicate whether a statement in a student answer is understood, incorrect or missing.

Impact: The primary deliverable of the project is an adaptive assessment system that will help the teachers to conduct both summative and formative assessment in Hindi and English. The assessment system envisaged to have support for both MCQ and text-based answers. The system can be operated in adaptive mode where the student will be presented with assessment items based on his/her performance level. The system will provide micro and macro level feedback of learning progression to appropriate stakeholders (teacher, policy makers, etc.) through a dashboard.

10. **Smart Beamforming and Waveforming for Next Gen Wireless:** As IoT and wireless devices grow by the numbers and are being increasingly connected in a ubiquitous manner with large number of sensors and devices, and quite often are also connected to edge compute devices for close to sensor inference with AI and ML, the need for perennial power supply is also growing. This required forms of engineering for easy energy delivery through wireless power transfer (WPT), such that the antennas serve the purpose of both communication and power transfer. While MIMO systems for communication have started exploring the multi-path effect for waveforming and beamforming for communication, there is an increase in demand for developing such solutions for power harvesting and WPT as well.

    Approach: This cloud connected live testbed shall consist of MIMO Tx/Rx systems, capable of multi-band communication and WPT on a concurrent feature, featuring cloud controlled radio networking units, antenna units, pervasive monitors of ambient wireless power profiles, signal profiles, as well as programmable radio-amplifiers and sensors.

    Impact: This work shall lead to creation of a live testbed for performing

experimental trials of AI methods and techniques for wireless communication, with real-time pervasive monitoring and active control of physical components of the Radio Units.

Projects of Innovation and Collaborative Research Interests

This following set of projects shall be undertaken through PhD positions, projects on PG and UG programs in ICPS, PostDocs, International Collaborative Research and through external funded schemes.

Robotics in Agriculture

Rajendra Machavaram and Virendra Kumar Tewari

In the present scenario most of the countries do not have sufficient skilled man power in the agricultural sector and that affects the growth of developing countries. It is estimated that the percentage of agricultural workers of the total work force would drop to 25.7% by 2050 from 58.2% in 2001. Therefore farmers have to use upgraded technology for cultivation activity (digging, seed sowing, fertilizing, spraying etc.) to eliminate the requirement of laborers and also avoid the wastage of seeds. The plug system for seedling propagation has been adopted in recent years by bedding plant growers to minimize labor costs, increase crop uniformity, and reduce cropping duration. Many growers are specialized in seedlings production in plugs and the time required for seedling to reach a transplantable size determines greenhouse utilization efficiency and greatly affects the production costs. Worker has to deposit one by one seed in each plug. Worker has to perform this tedious task for a long time which needs patience and ability to retain concentration for a long time. Such complex and hectic operation leaves workers with severe ergonomic effects such as back ache, pains in fingers and arm, which is why workers are apprehensive about the sowing task. Automation in the seeder will help in reducing the wastage of the costly seeds, time required for sowing and it will indirectly affect the cost of vegetables and fruits through minimizing the workers expenses.

Agricultural field operations are complex, diverse, labour-intensive, and crop-directed. Agricultural productivity has significantly and continuously increased over the centuries as a result of mechanization, intensification. Important targets for the application of the various technologies designed to improve crop yields, are reduced cost and reduced environmental impact. The advent of agricultural robots has the potential to raise the quality of fresh produce, lower production cost, reduce the drudgery of manual labour and to compensate for the unavailability of manpower for agricultural operations. Robots are perceptive programmable machines that perform a variety of agricultural tasks, such as cultivation, transplanting, spraying, and selective harvesting. However, agricultural robots operating in dynamic and unstructured environments often still produce inadequate results due to the inherent uncertainties, unknown operational settings and the unpredictable environmental conditions. These shall include development of technology for (a) Farmer's drone for pesticide application and crop insurance and (b) An Agribot for crop planting and harvesting.

AI-ML based Designer Food Formulation

Rintu Banerjee

Nutrient value of food is very much dependent and always getting altered by the kind of processing it undergoes. The water-soluble vitamins are most vulnerable during processing. Commercially, the main reason to process food is to eliminate pathogenic microorganisms and to extend its shelf-life. Simply cooking and combining a food with other food stuffs for creating a recipe is also considered a form of food processing. During cooking, nutrients can be lost in two ways, firstly, through degradation which can occur by destruction or other chemical changes such as oxidation etc., and secondly, by leaching into the cooking medium. Thus, there lies a big challenge for the food scientists to preserve the nutritional compounds of the food during and post processing. Through the proposed project, an effort has been undertaken to preserve the nutrients by adopting conventional as well as innovative processing technologies so as to resist nutrient loss during processing. Nutrients which are extremely difficult to retain during processing are phytochemicals. Now-a-days, scientists are artificially fortifying food by incorporating additional nutrients that are getting lost during processing. Thus, dietary fibre can be added in food products in the form of resistant starch that can have a beneficial impact on human health. Any starch granule, irrespective of its source is composed of amylose and amylopectin. Structural morphology differentiates these two biomolecules, which in turn determines their digestibility pattern within the human system. Based on the digestibility pattern and compositional content, the glycemic index of any starch granule changes, which in turn categorizes starch into three types namely, rapidly digested starch (high glycemic index), slowly digested starch (medium–low glycemic index) and resistant starch (low glycemic index). Hence, an in-silico study on nutrient retainment and its impact on overall digestibility is essential.

Machine Vision and Robotics in Identification and Removal of Defective Eggs

Asish Kumar Dutta

According to the Integrated Sample Survey, the total egg production in India has increased from 27.33 billion from 2015-16 to 29.09 billion during 2016-17 registering a growth of 6.42%. The production of eggs is largely contributed by commercial poultry farms with nearly 75.75% and remaining production is from household/backyard poultry. Factors that influence this growth are the low cost of production and the rise in domestic consumption. The leading egg-producing states in India are Andhra Pradesh, Telangana, Tamil Nadu, Maharashtra, Haryana, and Punjab. This huge quantity of eggs calls for the need to introduce careful management techniques to handle the eggs. Egg processing industries play a major role in the quality of eggs reaching the markets. Eggs from different poultries are collected by the egg processing industries and are checked for their quality and freshness before reaching the consumers. One of the major parts of

egg processing includes crack/defect detection on eggshells. Eggshells are susceptible to develop cracks either during handling or transportation. These cracks attract pathogens and contaminate the eggs making them harmful for consumption. Such eggs should be keenly assessed and excluded from reaching consumers. Dirt on eggshell and blood spots inside the eggs are other defects. This project aims at developing a continuous system that can detect defects on eggs and remove such eggs from a conveyor belt. The defects include micro-cracks on eggs that are difficult to be identified using naked eye, dirt and blood spots if any.

Food Formulation, Processing & Quality Monitoring

Hari Niwas Mishra

The Food Chemistry and Technology Laboratory (FCTL), Agricultural and Food Engineering (AgFE) Department, is a research and analysis laboratory that is devoted to the excellence in learning and research in the field of food science and technology. It is equipped with state of the art analytical instruments such as Rheometer, Hyper-spectral Imaging, Antioxidant Analyser, Rancimat, E. Nose, Colorimeter, Texture Analyzer, Fermenter, Sonicator, GC-MS, HPLC, FT-NIR, and AAS, and process equipment like Spray/ Vacuum/ Freeze/ Microwave dryers, SCF extractor, UV-US-Vacuum-MW extraction system, UF & MF membrane unit, HPP unit, Twin-screw extruder etc., and PLC controlled pilot scale units for processing and packaging of (i) High Energy RTE Food Paste, (ii) Iron Fortified Rice, and (iii) CA/MA storage of fruits and vegetables. Details of the laboratory can be found at http://www.fctliitkgp.co.in/. Five micronutrient fortified RTE-FP formulations have been developed in accordance to the UNICEF requirements for treating SAM children. The Pilot Scale Unit has a production capacity of 100 kg/day @ 8h shift for the manufacture of the developed RTE-FP (520 - 530 kcal/100g). The photograph of plant and machinery installed in the pilot scale unit has been presented in Figure below.

Figure 8.5. RTE Food Pilot Scale Unit at Department of AgFE, IIT Kharagpur.

There is a regress need for conceptual and customised food that is focused on the special nutrition requirements of pre-school and school-going children along with the nourishing mothers. India is lacking new specialised nutritious formulations that are based on targeted nutrient delivery to every age group as per the need and wish. Although the different formulation has expanded rapidly in the past two decades, driven by an intent to improve nutrition outcomes. But technological innovation regarding their formulation and controlled micronutrient fortification dosage has remained elusive. The challenges inherent in fortification and formulation of these products lack aggregate emphasis on innovative technologies like AI-ML or 3D printing.

Insect infestation is the major cause of food grain loss (7.5%) during post-harvest. The insects damage the grain causing severe loss in weight, nutrients, and viability; heavily infested grains are unfit for human consumption. Moreover, the insect larvae are hard to detect and mark the onset of food spoilage during storage. Internationally, FAO has set the limit of impurities of animal origin (including dead insects) to be maximum of 0.1% mass/mass for food grain (CODEX International Food Standard, 2017). Therefore, rapid and sensitive detection of infestation for early detection of spoilage and deterioration of food grains is need of the hour.

The human body is complex and varies from person to person depending on age, sex, health status and type of meal. Testing the efficacy of newly developed delivery systems depends on the availability of digestion models that accurately simulate the complex physicochemical and physiological events that occur in the human GI tract. In-vivo feeding methods, using animals or humans are time-consuming and costly, which is why much effort should be devoted to the development of in-vitro procedures. In principle, in-vitro digestion systems provide a useful alternative to animal and human models by rapidly screening food ingredients. However, there is no ideal in vitro digestion method that would provide accurate results in a short time. Thus, an AI-ML based food digestion system mimicking complex human digestion processes could serve as a tool for rapid screening foods or delivery systems with different compositions and structures. These problems can be resolved with developing nutritionally balanced 3D printed foods, a biosensor for detection of insect infestation and AI coupled human digestion systems.

CAD and Manufacturing

Cheruvu Siva Kumar, Nirmalya Ghosh, Debdoot Sheet, Arijit Mandal

CAD software uses several design decisions that are often expert driven and only after many design iterations it gets optimized to serve end use requirements. It is planned to use generative techniques and AI/ML based approaches to be embedded as 3rd party apps to the CAD software to decree the lead time in the design phase of mechanical engineering design automation. A similar approach with tools for manufacturing automation is required by the industry. It is proposed to use such tools on leading industry software like NX CAD and NX CAM along with

manufacturing automation software and give end users the service over a cloud based service platform.

Industry Partner: Siemens, Dassault Systems

Stroke and Rehabilitation

Cheruvu Siva Kumar, Manjunatha Mahadevappa and Nirmalya Ghosh

Stroke being a major life threatening disease in India and accounting for one of the highest death rates needs considerable attention from doctors all over the country. Through an Imprint project we have collected data of several for actual first time stroke patients in clinical settings along with CMC Ludhiana. CMC also has lots of data for patients across the country. We propose to use this for 3 phases of stroke treatment, i. Pre-stroke early warning and detection, ii. Efficacy of during stroke treatment procedures in short time spans, and iii. Post-stroke rehabilitation treatment using intelligent exercise therapies. These all will be AI and ML based with a cloud based service platform.

Clinical Partner: CMC Ludhiana

Biomedical Robotics

Cheruvu Siva Kumar, Manjunatha Mahadevappa and Nirmalya Ghosh

A higher degree of freedom robot (7-DOF) from Kuka that is medical grade is being procured to develop post stroke rehabilitation exercises. The exercises are supposed to be human friendly and executed by nurses/ therapists. An easy medical grade interface and cloud based tool using AI and ML approach will be developed and made available to end users in India and across the world as a service in this project.

Industry Partner: KUKA Robotics

Court Management System and Judicial Decision Making

Uday Shankar, Padmavati Manchikanti and Saptarshi Ghosh

Generally, it has been observed that the resource scarcity, manual or infrastructure, inter alia is a major factor for high pendency of litigation in the Indian Courts. Access to justice is very vital for orderly society. It can be effectively attained with the support of technology. Technology is assisting to inform, support and advise people involved in the justice system (supportive technology). Second, technology can replace functions and activities that were previously carried out by humans (replacement technologies). Finally, at a third level, technology can change the way that judges work and provide for very different forms of justice (disruptive technology), particularly where processes change significantly and predictive analytics may reshape the adjudicative role.

Technology has the potential to reshape the process of judging and judicial process. Notably, the role of a judge is a complex one. It can incorporate activism, complex interactions with people, dispute settlement, case management, public and specific education activities, social commentary as well as adjudicatory functions that might be conducted with other judges or less commonly in some jurisdictions with lay people (juries). Thus, it is a daunting task to supplement or supplant the role of judges by technological intervention. Already, the technology is assisting in practice of law. The question remains on the viability or aptness of the use in the court management system and judicial decision-making.

Problem 1: Legal services come with considerable cost for individuals. Individuals will make a considerate decision to litigate based upon the prediction of decision on an issue at hand. How a dispute would get settled and the prediction of judicial decisions could be useful for access to justice. Possibly, it would also encourage individuals to explore alternative dispute mechanisms in place of the traditional judicial system.

Problem 2: Higher judiciary, largely, transacts business in English language whereas the subordinate judiciary uses the regional language. If the decision/interim order of the subordinate judiciary is assailed before the appellate court/higher judiciary, then it requires the translation of the judgments and documentary evidence in English language. Such translation also raises a concern of authenticity and accuracy. Technology driven translation would ease the processes involved in reviewing the decisions of the lower judiciary.

Problem 3: In case of scanning of documents and digitalization of filings and classification of documents into electronic files, matching of the similar cases, identification of relevant laws, cases becomes automated then procedural documents such as notices to the parties and distribution of cases to judges would be undertaken with least intervention of the judges. AI tasks together into a work stream that can reduce court staff and judges' workloads.

Problem 4: Judicial decision-making involves a wide range of processes. These processes contribute in delaying the settlement of disputes. In civil litigation such as family matters, debt, employment and consumer litigation, AI could play an instrumental role in improving the efficiency of the legal system. The volume of information supplied by the litigating parties consumes considerable time of the judges. The classification of case docket, the chronological events in a case, the claims made, whether the law supports it and to evaluate competing claims may get strengthened with computational methods. The judges have to take complex decisions with little support. AI may be able to gather and examine the big set of information, identify the patterns, predict optimal strategies, identify anomalies and prepare the documents so that the judicial system becomes more accessible to people.

In criminal cases, the details of cases such as number of accused, date of filing charge sheet, number of witnesses examined during evidence state, witness turning hostile, reasons for adjournments, FIR details and quantum of punishment could be analyzed automatically to assist judges to make better strategic decisions.

Development of a regulatory mechanism for AI based drug development and Healthcare

Padmavati Manchikanti

India yet does not have a mechanism for regulation AI in drug development and healthcare under the purview of the Drugs and Cosmetics Act. At least 50 start-up companies are working in the area of providing AI based solutions for drug discovery and development and in the healthcare segment (some in the collaborative mode). Predominantly AI based tools/software as medical devices (SAMD) are being used by hospitals largely in relation to radiology for certain diseases. The US has begun to develop a regulatory pathway for SAMDs and discussions are ongoing in other countries on the need to develop a regulatory framework. Development of a domestic regulation is imperative if India needs to enhance its exports on AI based drugs/tools to other countries. Preliminary analysis of about 6 companies in India reveals important facets of why there is a need to develop regulation of AI based drugs/tools/devices in India. The development of a regulatory framework is the need of the hour. For the drug regulator: AI based tool developed will assist the drug regulator to draw inferences, track the approval as well review of a AI based tool. For the common man: The development of a tool will help for spreading the potential of AI. Further, through a participatory process, the common man can monitor AI tool information as well as submit pharmacovigilance information.

Common Fever Panel on a CD-based microfluidic device

Suman Chakraborty

The Compact Disc (CD) technology has drawn considerable attention over the last few decades for applications in medical diagnostics. Its numerous advantages include the centrifugal actuation of the device by the mere act of spinning, multiple disease diagnosis on a single disc, portability of the device and a biodegradable disc. Owing to such advantages, we have developed certain basic prototypes for some of the components of a Common Fever Panel (CFP) test. Even though a comprehensive CFP test will include the determination of CBC (complete blood count), ESR (erythrocyte sedimentation rate), SGPT (serum glutamic pyruvic transaminase), Widal test and Urine Routine test, we have developed basic prototypes for some of these tests. These are CBC and ESR. Due to the multiplexing functionality of the disc, it is envisaged that the rest of the tests would be seamlessly integrated within the existing framework. This hope is further strengthened by the fact that a precise control of the spinning speed of the disc offers a precise control of the

fluid's propagation in the disc. Not only this, the disc also allows for the reagent storage and pre-loading (immobilizing) of any antibodies that may be necessary. Therefore, a single drop of blood should be potentially able to yield the comprehensive Common Fever Test results.

Pulmonary diseases

Satadal Saha

The second is an optical endomicroscopy device, Versicolour, which has been developed and validated at the University of Edinburgh. Versicolour has undergone stage 0/1 clinical trials within the Edinburgh Royal Infirmary, but is not yet commercially available. Versicolour is a system which enables fluorescence based imaging deep inside of the lung using a disposable optical fibre, which was also developed in-house, this imaging technique enables the alveolar space to be visualized. Specific contrast agents, known as SmartProbes can be instilled directly within the imaging field of view – deep within the lung, and these can report on the presence of disease. For example, the SmartProbes can be used to identify aberrant enzymatic action (such as MMP upregulation within fibrosis/scarring or tumor margins), or in the identification of bacteria in cases of suspected ventilator pneumonia. The SmartProbes have also been developed in house at the University of Edinburgh, and undergone rigorous validation and achieved approval for human clinical use (within trials). To date the analysis of clinical data sets have been evaluated manually or with basic algorithms.

We anticipate that this device will be used to generate data from the field and from within clinical settings. The data will be available to machine learners and AI engineers, who can develop further sophisticated tools to add functionality and improve the robustness of outputs, thus enhancing their value.

International Collaborator: University of Edinburgh

Optical imaging & diagnostics

Satadal Saha

The following provides examples of both low and high end point-of-care diagnostic platforms, one for use within the rural community primary care setting, and the other with tertiary, hospital based scenarios. Both devices have been developed and prototyped by the project partners, and now they will be validated within the Indian context for two areas of great need; ophthalmology and pulmonology. The first is a pocket ophthalmoscope, Arclight. This low cost (Rs. 1000 per device) instrument has been widely implemented across Africa, and has shown to be suitable for use by CHWs. The device enables monitoring of red-reflex (the lack thereof can indicate cataract or retinoblastoma), examination of the anterior segment (to identify debris/ulcer), and examination

of the fundus; which can highlight abnormalities of the retina, including early detection of asymptomatic diabetic retinopathy. Importantly, the Arclight can be coupled to a smartphone to record the complete examination of the eye, enabling diagnosis to be assessed via telemedicine. Moreover, clinical features could be used for AI and ML automated diagnosis or monitoring of the same patient over time. In addition to the deployment of Arclight across the E-health Clinics, a package of CHW training and subsequent learning/adoption attitudes will be monitored which can feed directly back into other implementation and device design strategy. We anticipate that this device will be used to generate data from the field and from within clinical settings. The data will be available to machine learners and AI engineers, who can develop further sophisticated tools to add functionality and improve the robustness of outputs, thus enhancing their value.

Spatiotemporal monitoring of injury progression and therapeutic effectiveness

Nirmalya Ghosh and Debdoot Sheet

Small cohort animal studies with longitudinal MRI data and with/without therapy (hypothermia, stem-cell implantation, etc.) have been published demonstrating injury progression and therapeutic effectiveness for ischemic cerebral stroke and traumatic brain injury (at TRL-2 stage). This project proposes to validate this concept in larger animal studies and human pathophysiology – including (but not limited to) cerebral stroke, breast cancer and myocardial ischemia.

(a) From longitudinal medical imaging data and injury topology across different anatomical regions derived from individual imaging time-points, estimate injury progression model (using AI-ML) for different anatomical regions, and predict functional impairment over time. AI-ML application: Complexity of the data, with potentially missing and/or cross-format data, signal features, and clinical annotations would be synergistically assimilated to develop anatomy-specific AI-ML models of disease progression and gradual functional impairments or recovery trends for different diseases.

(b) Similar to above in (a), for different therapy (drugs, physiotherapy, environmental settings) in isolation or in different combination, in different orders, time-points, dosage, duration and sites, estimate therapeutic footprint model across different anatomy and over time (using AI-ML) to predict effectiveness of the treatment plan. Potential customers: pharmaceutical companies, tertiary care hospitals. AI-ML application: Models developed under (a) above would be now extended and tuned/learned with different therapeutic (1) combinations, (2) sequences, (3) dosage, (4) sites, (5) time-point, and (6) duration as well as their treatment effect in different anatomical regions and functional recovery for different diseases and different therapies.

Chapter 9: Management

Implementation Mechanism

The following organizational structure is proposed for operation of AI4ICPS

- Hub Governing Body (HGB) and the Scientific Advisory Body (SAB)
- Board of Directors (BOD)
- Executive Council
- Chair Professors (CHANAKYA Chair Professor)
- Chief Executive Officer (CEO)
    - Chief Innovation Officer (CIO)
        - Academic Fellows
        - Entrepreneurship, Innovation and Startup Ecosystem Team
        - Executive Secretary
    - Chief Technology Officer (CTO)
        - Engineering Managers
            - Project Engineers
            - Technical Support Executives
        - Product Managers
            - Project Engineers
            - Technical Support Executives
        - Executive Secretary
    - Chief Operating Officer (COO)
        - General Manager - Human Resources (GM-HR)
            - Accountants
            - Corporate Communications
        - General Manager - Finance (GM-Finance)
            - Business Associates
            - Marketing Associates
        - General Manager - Legal and Intellectual Property (GM-Legal)
            - Legal Associates
            - IP Managers
        - Executive Secretary

Roles and Responsibilities

Hub Governing Body (HGB) - It shall be an upto 10 voting member committee with the Director IIT Kharagpur as the Chairperson. This committee shall have the Project Director AI4ICPS as one of the members, along with upto 4 more members from Faculty of IIT Kharagpur. It shall induct upto 3 members from Alumni of IIT Kharagpur who are professionally well established and are from Industry, Government Administration or Academia. It shall induct a representative of the SERB, and upto 2 members from Industry representative bodies. The CEO of AI4ICPS shall be a non voting Member Secretary to the committee. The committee shall meet at least once per year. Members render pro bono voluntary service.

Advisory Board - Shall be constituted of distinguished representatives across Research and Industry sectors of interest for AI4ICPS who shall provide non-binding guidance and recommendation to the HGB/BOD in guiding the roadmap. No member of the Advisory Board shall be a voting member of the HGB, but may be special invitees as needed. The committee shall meet at least once per year for an audit of the AI4ICPS activities and provide recommendations. Members render pro bono voluntary service.

Executive Council - Shall be constituted of members of Faculty of IIT Kharagpur who are actively involved with ongoing projects at AI4ICPS and shall have the Project Director AI4ICPS as the Chairperson. The council shall meet at least 6 times per year with regular periodic meetings to assess closely the working of the Hub activities and projects, and based on need shall seek advice from Advisory Board members, and report these meetings to the Chairperson of the HGB. The CEO, CIO, CTO, CFO shall be members of this Council. Members render pro bono voluntary service.

Chair Professors (CHANAKYA Chair Professor) - Shall be Faculty members of IIT Kharagpur involved with actively participating in innovation programs and hand holding activities of AI4ICPS, who shall also be academic promoters of its programs, and provide active knowledge guidance.

Chief Executive Officer (CEO) - Shall be the administrative and organizational head of the AI4ICPS and is responsible for executing all the earmarked programs. The CEO shall independently coordinate activities in TRL1-3 viz. HRD and Skill Development and Entrepreneurship, Innovation and Startup Ecosystem through the CIO. Activities in TRL4-6 in Technology Development and International Cooperation shall be coordinated through the CTO. Administrative roles including HR, Contracts, Legals, Finances, Business, Marketing, IP, etc. coordinated with the COO.

Chief Innovation Officer (CIO) - Shall be responsible for administration and operationalization of the TRL 1-3 activities on HRD and Skill Development managing the activities of the Academic Fellows, and TRL 4-9 activities under Entrepreneurship, Innovation and Startup Ecosystem. The CIO is reporting manager for these teams. This office shall directly manage programs of Promotion and Acceleration of Young and Aspiring Technology Entrepreneurs (CPS-PRAYAS), Entrepreneur in Residence (CPS-EIR), CPS Startup Ignition, Seed Support System (CPS-SSS).

Chief Technology Officer (CTO) - Shall be responsible for administration and operationalization of the TRL 4-6 activities under Technology Development and International Cooperation. The CTO is reporting manager for these teams. The CTOs office shall consist of Engineering Managers specialized in core and enabling technologies of AI and ML and Product Managers specialized in CPS sectors for which AI and ML interventions are being developed.

Chief Operating Officer (COO) - Shall be responsible for matters related to operation of the Hub including matters of HR, Contracts, Legals, Finances, Business, Marketing, IP, etc. The COOs office shall consist of one General Manager each for Human Resources, Finance, and Legal.

Engineering Manager (EM) - Shall be responsible for product development in core areas of AI and ML as well as in enabling technologies. An EM shall specialize in a set of areas viz. Search, Heuristics, Planning; or Logic, Reasoning, Formal methods, Verification; or Vision, Graphics, Software as a Service. Each EM shall report to their managers viz. CIO or CTO. Each EM shall be having a team of Project Engineers (PE) and Technical Support Executives for execution of the assigned tasks.

Product Manager (PM) - Shall be responsible for product development in CPS industry sectors viz. Healthcare, Precision Agriculture, Manufacturing, etc. Each PM shall report to their managers viz. CIO or CTO. Shall be responsible for post delivery support. Each PM shall be having a team of Project Engineers (PE) and Technical Support Executives for execution of the assigned tasks.

General Manager (GM) - Shall be responsible for Operation Administration and Management of the AI4ICPS and report directly to the COO. There shall be a GM for Human Resources (GM-HR), Finance (GM-Finance), Legal and IP (GM-Legal). The GM-HR shall have a team of Accountants and Corporate Communication Executive Secretaries for execution of the assigned tasks. GM-Finance shall have a team of Business Associates and Marketing Associates for execution of the assigned tasks. GM-Legal shall have a team of Legal Associates and IP Managers for execution of the assigned tasks.

Academic Fellows shall be a team primarily involved with TRL1-3 activities and working closely with the Technology Development teams as well. They include the CHANAKYA-Faculty, CHANAKYA-PD, CHANAKYA-DF, CHANAKYA-PG, CHANAKYA-UG. (Roles elaborated in

Fellowship Program Details) The CIO shall be the administrative reporting manager for them. The Research and Academic mentors/supervisors for each of the fellows shall be their reporting authority in respect of their intellectual activities.

Entrepreneurship, Innovation and Startup Ecosystem team shall consist of separate teams for managing the programs. Grand Challenges and Competitions (CPS-GCC) team shall constitute a Project Engineer and an Executive Secretary. Technology Business Incubator (CPS-TBI) shall be a team of Marketing Associate, Legal Associate, Accountant and Technical Support Executive. Dedicated Innovation Accelerator (CPS-DIAL) shall have a team of Business Manager, Legal Associate, IP Manager, Accountant, Executive Secretary and Technical Support Executive.

Project Engineer (PE) shall be executing product development responsibility. They shall be specializing in at least one primary and a few secondary sectors/sub-sectors of the areas of interest of AI4ICPS including both core AI and ML and enabling technologies, as well as in the CPS application sectors. EM and PM shall be submitting demand requests on specializations of PE needed by them to the CTO/CIO for creating their teams. (Details in List of Sectors and Sub-sectors)

Business Associate shall be responsible to assisting the GM-Finance in meeting the requirements of commercial activity and due diligence of AI4ICPS. They shall also be responsible for delivering the components of Entrepreneurship, Innovation and Startup Ecosystem which shall require Business related interventions and hand holding for new enterprises and startups. Their role is prominent is identifying commercializability of inventions and products, directly contributed by the Hub as well as through its incubatees.

Marketing Associate shall be responsible for assisting the GM-Finance in serving the outreach and brand building activities of AI4ICPS to the external world. This shall include inventions and products, directly contributed by the Hub as well as through its incubatees.

Legal Associates shall be responsible for assisting the GM-Legal in executing contracts of the AI4ICPS, which shall include and not limited to employee contracts, Fellowship agreements, Non Disclosure Agreements (NDA), Memorandum of Understanding (MoU), Agreement of Collaboration, Business Contrasts, Incubatee Contracts, etc.

IP Manager shall be responsible for assisting the GM-Legal in identifying potential IPs of AI4ICPS and having them filed. They shall be engaging with Marketing Associates and Business Associates to assess commercial value of IPs and potential IPs, and as well as engage with Legal Associates for framing contracts associated with IP.

Technical Support Executive shall be working on coordination with the PE under reporting supervision of EM and PM. They shall specialize in maintaining IT equipment, CPS systems,

Mechatronics, Web Services, etc. which are required to keep the backbone of AI4ICPS operations working. They shall also have field engineering assignments during deployment of developed technologies.

Accountants shall be responsible for financial accounting on matters related to income, expenditure, employee benefits, etc. of AI4ICPS as coordinated and managed by the GM-HR. They shall also be handling financial auditing and compliance jobs as needed by the GM-Finance which may be requested of them. Their administering reporting is to the GM-HR and shall report tasks based matters to GM-Finance and other offices of COO/CIO/CTO as assigned to their services.

Executive Secretary shall be responsible for executing secretarial jobs at AI4ICPS including corporate communication, internal communication, event management, meetings, program management, etc, and shall report administratively to the GM-HR and report task completion and assignments to their respective reporting managers like to CEO, COO, CIO, CTO, EM, etc. as based on their assignment.

Human Resources Requirements

Table 9.1: HR requirements for undertaking the different programs under AI4ICPS supported by SERB NM-ICPS component of the funding.

	General Admin. & Mgmt.	Tech. Dev.	HRD and Skill Dev.	Entrep., Innov. & Startup Ecosystem	Intl. Coop.	Total
Chief Exec. Officer (CEO)	1					1
Chief Innov. Officer (CIO)	1					1
Chief Tech. Officer (CTO)	1					1
Chief Operat. Officer (COO)	1					1
Engineering Manager (EM)		6				6
Product Manager (PM)		6				6
General Manager (GM)				3		3
Project Engineer (PE)		18		2		20
Business Associate	1			1		2
Marketing Associate	2					2
Legal Associate	1			1		2
IP Manager	1			1		2
Tech. Support Executive (TSE)	1	4				5
Accountant	2					2
Executive Secretary	2	1		3		6
CHANAKYA Faculty			6			6
CHANAKYA Post Doc.			25			25
CHANAKYA Doctoral			25			25
CHANAKYA PG			28			28
CHANAKYA UG			68			68

Table 9.2: Positions occupied across years for undertaking the different programs under AI4ICPS supported by SERB NM-ICPS component of the funding. Year 6 indicates continuing programs.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Chief Exec. Officer (CEO)	1	1	1	1	1	
Chief Innov. Officer (CIO)	1	1	1	1	1	
Chief Tech. Officer (CTO)	1	1	1	1	1	
Chief Operat. Officer (COO)	1	1	1	1	1	
Engineering Manager (EM)	6	6	6	6	6	
Product Manager (PM)	6	6	6	6	6	
General Manager (GM)	3	3	3	3	3	
Project Engineer (PE)	20	20	20	20	20	
Business Associate	2	2	2	2	2	
Marketing Associate	2	2	2	2	2	
Legal Associate	2	2	2	2	2	
IP Manager	2	2	2	2	2	
Tech. Support Executive (TSE)	5	5	5	5	5	
Accountant	2	2	2	2	2	
Executive Secretary	6	6	6	6	6	
CHANAKYA Faculty	2	4	6	4	2	
CHANAKYA Post Doc.	5	20	25	20	5	
CHANAKYA Doctoral	5	20	25	25	20	5
CHANAKYA PG	10	22	24	26	28	14
CHANAKYA UG	68	68	68	68	68	
CHANAKYA Chair Professor	2	4	6	4	2	
Entrepreneur in Res. (CPS-EIR)	20	20	20	20	20	

Table 9.3: Positions occupied across years for undertaking the different programs under AI4ICPS to be supported by external revenue streams viz. project based funding and programs.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Chief Exec. Officer (CEO)						1
Chief Innov. Officer (CIO)						1
Chief Tech. Officer (CTO)						1
Chief Operat. Officer (COO)						1
Engineering Manager (EM)		1	4	4	4	10
Product Manager (PM)		1	4	5	5	11
General Manager (GM)						3
Project Engineer (PE)	1	6	11	16	16	36
Business Associate			1	1	1	3
Marketing Associate			1	1	1	3
Legal Associate						2
IP Manager						2
Tech. Support Executive (TSE)		1	4	5	5	10
Accountant			1	1	1	3
Executive Secretary						6
CHANAKYA Faculty				2	4	6
CHANAKYA Post Doc.				5	15	25
CHANAKYA Doctoral					5	15
CHANAKYA PG						14
CHANAKYA UG						68
CHANAKYA Chair Professor				2	4	6
Entrepreneur in Res. (CPS-EIR)						20

Table 9.4: Projectized matrix structure of engagement of employees for Technology Development. Any project shall be a crossover point on this matrix and the Executive Secretary shall be the secretarial connect for each of the projects.

			CTO			
			PM1	PM2	PM3	PM4
			PE x1, TSE x1	PE x1, TSE x1	PE x1, TSE x1	PE x1, TSE x1
CTO	EM1	PE x2				
	EM2	PE x2				
	EM3	PE x2				
	EM4	PE x2				
	Exec. Secy.					

PE x2 denotes 2 positions for Project Engineers, TSE x1 denotes 1 position for Technical Support Executive.

Monitoring Arrangements

The work to be undertaken by the different employees and financial beneficiaries of AI4ICPS shall be of the following nature.

- **General Administration** shall consist of activities to coordinate between various units and roles to keep the programs of AI4ICPS operational. This shall also include external stakeholder engagement and communication. The CEO, CIO, CTO, COO, GM, Legal Associate, Accountant, Executive Secretary shall be major contributors to these activities. This shall include all activities under Entrepreneurship, Innovation & Startup Ecosystem.
- **Professional Development** shall consist of activities undertaken by employees for improving their professional skills and abilities. These can include MOOCs, Online certifications, Training programs, Conferences and Workshops, including those conducted by AI4ICPS as well.
- **Technology Development** shall consist of TRL4-6 level activities.
- **Technology Consulting** shall consist of paid consulting activities primarily in TRL4-6.
- **Innovation and New Knowledge** creation shall consist of TRL1-3 level activities.
- **Skill Development** shall consist of up-/re-skilling activities within the HRD and Skill Development component of the activities of AI4ICPS.

Table 9.5: Sectorized work responsibility allocation matrix.

	General Admin.	Prof. Dev.	Tech. Dev.	Tech. Consult.	Innvo.& New Know.	Skill Dev.
Chief Exec. Officer (CEO)	90%		2%	2%	5%	1%
Chief Innov. Officer (CIO)	70%	5%		5%	10%	10%
Chief Tech. Officer (CTO)	70%	5%	10%	10%		5%
Chief Operat. Officer (COO)	70%	5%	5%	5%	5%	10%
Engineering Manager (EM)		5%	75%	10%		10%
Product Manager (PM)	5%	5%	75%	10%		5%
General Manager (GM)	80%	5%			10%	5%
Project Engineer (PE)		5%	25%	25%	25%	20%
Business Associate	10%	5%	10%	10%	35%	30%
Marketing Associate	10%	5%	5%	10%	50%	20%
Legal Associate	80%	5%	5%	10%	10%	
IP Manager	5%	5%	20%	20%	50%	
Tech. Support Executive (TSE)		5%	25%	25%	25%	20%
Accountant	95%	5%				
Executive Secretary	95%	5%				
CHANAKYA Faculty	5%		20%	15%	50%	10%
CHANAKYA Post Doc.	5%		30%	15%	35%	15%
CHANAKYA Doctoral	5%		15%	10%	50%	20%
CHANAKYA PG			45%		45%	10%
CHANAKYA UG			45%		45%	10%
CHANAKYA Chair Professor	5%		20%	15%	45%	15%

The nominal estimate of man-hours per year to be committed by the following positions to AI4ICPS for the salaried positions are derived accordingly. The positions include CEO, CIO, CTO, COO, EM, PM, GM, PE, Business Associate, Marketing Associate, Legal Associate, IP Manager, TSE, Accountant, Executive Secretary, CHANAKYA Faculty, CHANAKYA Post Doctoral Fellow, CHANAKYA Doctoral Fellow.

Table 9.6: Nominal hours of employment at AI4ICPS per year for the employees and fellows.

	No. of days / Year	**No. of hours / Year**
Workable Time (8 Hrs/Day)	365	2,920
Less: Weedends (Sat+Sun)	104	832
Less: Scheduled holidays	16	128
Less: Leaves (Casual+Earned)	20	160
Less: Professional travels	10	80
Total Productive Time	215	1,720

The nominal estimate of man-hours per year to be committed by CHANAKYA Chair Professor, CHANAKYA UG and CHANAKYA PG are as follows.

Table 9.7: Nominal hours of fellowship at AI4ICPS per year.

	No. of hours / Week	**No. of hours / Year**
CHANAKYA Chair Professor (52 weeks/year)	4	208
CHANAKYA UG (40 weeks/year)	8	320
CHANAKYA PG (1st Year) (No project year)	0	0
CHANAKYA PG (2nd Year) (40 weeks/year)	40	1,600

The **Key Performance Indicator (KPI)** of the AI4ICPS shall be objectively measured for monitoring success of each of the programs. The envisaged programs to be undertaken within the initial 5 years supported by SERB NM-ICPS are detailed in Aim and Objectives. The KPI monitoring shall be done using (a) Employee Goals declaration, (b) Weekly monitoring of progress using SMART Goals Reporting, (c) Project specific Action Plan, (d) Project monitoring using Project Goals and Objectives SMART Planning and Reporting, (e) Revenue Goal Planning and Reporting.

Table 9.8: Employee Goals Declaration sample template, to be submitted at start of tenure or project. It shall be refined periodically based on review.

Employee Name, Designation, Emp. Code, Team						
Goal						
Benchmarks for Success						
Evaluation Plan						
Strategic Action Description	Party / Team Responsible	Date to Begin	Due Date	Resources Required	Potential Hazards	Desired Outcome
Additional Notes						

Table 9.9: SMART Goal Reporting template for periodic review of sub-components of a project. Shall be submitted separately for each sub-component by a team or individual.

Employee Name, Designation, Emp. Code, Team		
Initial Goal	Write the goal you have in mind	
Specific	What do you want to accomplish? When do you want to do this? Why is this a goal?	
Measurable	How can you measure progress and know if you have successfully met your goal?	
Achievable	Do you have the skills required to achieve the goal? If not, can you obtain them? What is the motivation for this goal? Is the amount of effort required on par with what the goal will achieve?	
Relevant	Why am I setting this goal now? Is it aligned with overall objectives?	
Time-bound	What is the deadline and is it realistic?	
SMART Goal	Review aht you have written, and craft a new goal statement based on what the answers to the questions above have revealed.	

Table 9.10: Project specific Action Plan template to be used for different components of AI4ICPS.

Project Name				Project Manager		
Action	Responsible	Priority	Status	Start	End	Notes
Goal 1.1		High				
Goal 1.2		Medium				
Goal 2		Low				

Table 9.11: Project Goals and Objectives SMART Planning and Reporting template to be used for a program or project of AI4ICPS.

SMART Goals	**S**pecific	**M**easurable	**A**ction-Oriented	**R**elevant	**T**ime-Oriented
Define Goals	1.	2.	3.	4.	5.
Small Measurable and Attainable Steps for each Goal					
	Step Description		Time Required		Set Deadline
Goal 1					
1.1					
1.2					
Goal 2					
2.1					
2.2					
Further Planning					
Detail Resources Required					
Define Potential Obstacles					
Plans for Overcoming Obstacles					
Desired Outcome					
Define Measurements for Success					
Describe Outcome of Achieved Goal					

Table 9.12: Revenue Goal Planning and Reporting template for AI4ICPS.

Fiscal Year Start Date						
Program Name		Q1	Q2	Q3	Q4	Total
Item 1	Year Prior					
	Revenue Goal					
	% of Change					

Chapter 10: Finance

Cost Estimate

Table 10.1.1: Consolidated budget of **AI4ICPS** in Crores of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Recurring	13.25	28.00	33.00	30.00	24.15	128.40
Non-Recurring	9.00	10.00	12.00	6.00	4.60	41.60
Total	**22.25**	**38.00**	**45.00**	**36.00**	**28.75**	**170.00**

Table 10.1.2: Detailed Expenditure on **AI4ICPS** in Lakhs of INR to be met from SERB NM-ICPS.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower	757.99	1,323.43	1,615.66	1,610.41	1,323.28	6,630.77
Travel	134.30	338.30	384.30	282.30	181.30	1,320.50
Contingency	83.90	183.65	141.40	123.40	110.15	642.50
Consumables	58.50	88.50	103.50	78.50	53.50	382.50
Miscellaneous Recurring	133.70	684.70	855.70	695.70	530.70	2,900.50
Overhead	31.00	42.00	47.00	42.00	32.00	194.00
Rent[35]	126.00	138.60	152.46	167.70	184.48	769.24
Equipment	392.60	607.70	808.95	405.20	272.60	2,487.05
Misc. Non-Recurring	43.90	49.55	49.55	49.55	49.15	241.70
Furnishing & Lab Space	463.50	330.25	335.25	145.25	138.25	1,412.50
Recurring	**1,325.39**	**2,799.18**	**3,300.02**	**3,000.01**	**2,415.41**	**12,840.01**
Non-Recurring	**900.00**	**1,000.00**	**1,200.00**	**600.00**	**460.00**	**4,160.00**
Total	**2,225.39**	**3,799.18**	**4,500.01**	**3,600.01**	**2,875.41**	**17,000.01**

[35] Rent for 30,000 sq. ft. of constructed space leased to the TIH by the Host Institute for its operation, charged a monthly rent of Rs. 35.00 per sq. ft. and 10% increment per year.

Table 10.1.3: Program wise Expenditure on **AI4ICPS** in Lakhs of INR to be met from SERB NM-ICPS

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Tech. Dev. (Table 10.2)	783.00	651.70	796.79	785.87	779.09	3,796.45
HRD & SD (Table 10.3)	344.74	1,088.84	1,226.96	892.36	590.40	4,143.30
Enter., Innov. (Table 10.4)	846.65	1,375.04	1,528.80	1,299.06	1,241.43	6,291.00
Int. Collab. (Table 10.5)	125.00	545.00	795.00	455.00	80.00	2,000.00
Total	**2,099.39**	**3,660.58**	**4,347.55**	**3,432.29**	**2,690.92**	**16,230.75**

Table 10.2: Expenditure on **Technology Development** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower	354.00	389.40	428.34	471.17	518.29	2,161.20
Travel	20.70	20.70	20.70	20.70	20.70	103.50
Contingency	9.90	9.90	9.90	9.90	9.90	49.50
Consumables	15.50	15.50	15.50	15.50	15.50	77.50
Miscellaneous Recurring	6.90	6.90	6.90	6.90	6.90	34.50
Overhead	16.00	16.00	16.00	16.00	16.00	80.00
Equipment	195.00	193.30	299.45	245.70	191.80	1,125.25
Furnishing & Lab Space	165.00	-	-	-	-	165.00
Recurring	**423.00**	**458.40**	**497.34**	**540.17**	**587.29**	**2,506.20**
Non-Recurring	**360.00**	**193.30**	**299.45**	**245.70**	**191.80**	**1,290.25**
Total	**783.00**	**651.70**	**796.79**	**785.87**	**779.09**	**3,796.45**

This table is prepared by consolidating the sub-component wise expenditure incurred in this activity as detailed in

- T.1: Development of Products and Prototypes from Existing Knowledge (Table 10.6)
- T.2: Development of Technology or Product Delivery in Specific Sectors (Table 10.7)
- T.3: Expert Driven Research (Table 10.8)

Table 10.3: Expenditure on **HRD and Skill Development** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower	90.59	461.89	622.16	596.56	350.05	2,121.26
Travel	18.00	132.00	168.00	156.00	105.00	579.00
Contingency	8.00	13.75	19.50	17.50	11.75	70.50
Consumables	-	-	-	-	-	-
Miscellaneous Recurring	10.00	41.00	77.00	77.00	57.00	262.00
Overhead	-	1.00	1.00	1.00	1.00	4.00
Equipment	149.60	284.40	279.50	29.50	50.80	793.80
Misc. Non-Recurring	8.55	13.55	13.55	13.55	13.55	62.75
Furnishing & Lab Space	60.00	141.25	46.25	1.25	1.25	250.00
Recurring	**126.59**	**649.64**	**887.66**	**848.06**	**524.80**	**3,036.76**
Non-Recurring	**218.15**	**439.20**	**339.30**	**44.30**	**65.60**	**1,106.55**
Total	**344.74**	**1,088.84**	**1,226.96**	**892.36**	**590.40**	**4,143.31**

This table is prepared by consolidating the sub-component wise expenditure incurred in this activity as detailed in

- H.1: High End Skill Development (Table 10.9)
- H.2: Under-Graduate Fellowship (CHANAKYA-GI) (Table 10.10)
- H.3: Post-Graduate Fellowship (CHANAKYA-PG) (Table 10.11)
- H.4: PhD Fellowship (CHANAKYA-DF) (Table 10.12)
- H.5: Post Doctoral Fellowship (CHANAKYA-PD) (Table 10.13)
- H.6: Research Assistant Professor (CHANAKYA Faculty) (Table 10.14)
- H.7: Chair Professor (CHANAKYA Chair Professor) (Table 10.15)
- H.8: New PG Programme (Table 10.16)

Table 10.4: Expenditure on **Entrepreneurship, Innovation & Startup Ecosystem** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower	263.40	322.14	365.15	392.67	404.93	1,748.29
Travel	55.60	55.60	55.60	55.60	55.60	278.00
Contingency	56.00	130.00	72.00	66.00	78.50	402.50
Consumables	33.00	33.00	33.00	33.00	33.00	165.00
Miscellaneous Recurring	106.80	556.80	631.80	531.80	456.80	2,284.00
Overhead	10.00	10.00	10.00	10.00	10.00	50.00
Equipment	48.00	30.00	30.00	30.00	30.00	168.00
Misc. Non-Recurring	35.35	36.00	36.00	36.00	35.60	178.95
Furnishing & Lab Space	238.50	201.50	295.25	144.00	137.00	1,016.25
Recurring	**524.80**	**1,107.54**	**1,167.55**	**1,089.07**	**1,038.83**	**4,927.79**
Non-Recurring	**321.85**	**267.50**	**361.25**	**210.00**	**202.60**	**1,363.20**
Total	**846.65**	**1,375.04**	**1,528.80**	**1,299.06**	**1,241.43**	**6,290.99**

This table is prepared by consolidating the sub-component wise expenditure incurred in this activity as detailed in

- E.1: Grand Challenges and Competitions (CPS-GCC) (Table 10.17)
- E.2: Promotion and Acceleration of Young and Aspiring Technology Entrepreneurs (CPS-PRAYAS) (Table 10.18)
- E.3: Entrepreneur in Residence (CPS-EIR) (Table 10.19)
- E.4: CPS Startup Ignition (Table 10.20)
- E.5: Technology Business Incubator (CPS-TBI) (Table 10.21)
- E.6: Dedicated Innovation Accelerator (CPS-DIAL) (Table 10.22)
- E.7: Seed Support System (CPS-SSS) (Table 10.23)

Table 10.5: Expenditure on **International Collaborations** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower	50.00	150.00	200.00	150.00	50.00	600.00
Travel	40.00	130.00	140.00	50.00	-	360.00
Contingency	10.00	30.00	40.00	30.00	10.00	120.00
Consumables	10.00	40.00	55.00	30.00	5.00	140.00
Miscellaneous	10.00	80.00	140.00	80.00	10.00	320.00
Overhead	5.00	15.00	20.00	15.00	5.00	60.00
Equipment	-	100.00	200.00	100.00	-	400.00
Misc. Non-Recurring	-	-	-	-	-	-
Furnishing & Lab Space	-	-	-	-	-	-
Recurring	**125.00**	**445.00**	**595.00**	**355.00**	**80.00**	**1,600.00**
Non-Recurring	**-**	**100.00**	**200.00**	**100.00**	**-**	**400.00**
Total	**125.00**	**545.00**	**795.00**	**455.00**	**80.00**	**2,000.00**

Expenditure Phasing of Programs

Table 10.6: Expenditure on **T.1: Development of Products and Prototypes from Existing Knowledge** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower (Annexure T.1)	121.80	133.98	147.38	162.12	178.32	743.60
Travel[36]	6.00	6.00	6.00	6.00	6.00	30.00
Contingency	4.00	4.00	4.00	4.00	4.00	20.00
Consumables	6.00	6.00	6.00	6.00	6.00	30.00
Miscellaneous	2.00	2.00	2.00	2.00	2.00	10.00
Overhead	2.00	2.00	2.00	2.00	2.00	10.00
Equipment (Annexure T.1)	110.00	107.30	233.45	179.70	145.80	776.25
Furnishing & Lab Space	50.00	-	-	-	-	50.00
Recurring	**141.80**	**153.98**	**167.37**	**182.12**	**198.32**	**843.60**
Non-Recurring	**160.00**	**107.30**	**233.45**	**179.70**	**145.80**	**826.25**
Total	**301.80**	**261.28**	**400.82**	**361.82**	**344.12**	**1,669.85**

[36] Domestic travel only is supported.

Table 10.7: Expenditure on **T.2: Development of Technology or Product Delivery in Specific Sectors** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower(Annexure T.2)	100.20	110.22	121.24	133.37	146.70	611.73
Travel[37]	3.00	3.00	3.00	3.00	3.00	15.00
Contingency	2.00	2.00	2.00	2.00	2.00	10.00
Consumables	3.00	3.00	3.00	3.00	3.00	15.00
Miscellaneous	1.00	1.00	1.00	1.00	1.00	5.00
Overhead	1.00	1.00	1.00	1.00	1.00	5.00
Equipment(AnnexureT.2)	45.00	60.00	40.00	40.00	20.00	205.00
Furnishing & Lab Space	45.00	-	-	-	-	45.00
Recurring	**110.20**	**120.22**	**131.24**	**143.37**	**156.70**	**661.73**
Non-Recurring	**90.00**	**60.00**	**40.00**	**40.00**	**20.00**	**250.00**
Total	**200.20**	**180.22**	**171.24**	**183.37**	**176.70**	**911.73**

[37] Domestic travel only is supported.

Table 10.8: Expenditure on **T.3: Expert Driven Research** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower(Annexure T.3)	132.00	145.20	159.72	175.69	193.26	805.87
Travel[38]	11.70	11.70	11.70	11.70	11.70	58.50
Contingency	3.90	3.90	3.90	3.90	3.90	19.50
Consumables	6.50	6.50	6.50	6.50	6.50	32.50
Miscellaneous	3.90	3.90	3.90	3.90	3.90	19.50
Overhead	13.00	13.00	13.00	13.00	13.00	65.00
Equipment(AnnexureT.3)	40.00	26.00	26.00	26.00	26.00	144.00
Furnishing & Lab Space	70.00	-	-	-	-	70.00
Recurring	**171.00**	**184.20**	**198.72**	**214.69**	**232.26**	**1,000.87**
Non-Recurring	**110.00**	**26.00**	**26.00**	**26.00**	**26.00**	**214.00**
Total	**281.00**	**210.20**	**224.72**	**240.69**	**258.26**	**1,214.87**

[38] Domestic travel only is supported.

Table 10.9: Expenditure on **H.1: High End Skill Development** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower (AnnexureH.1)	13.95	20.25	20.25	13.95	13.95	82.35
Equipment (AnnexureH.1)	-	4.50	0.90	-	-	5.40
Misc. Non-Recurring (AnnexureH.1)	8.55	8.55	8.55	8.55	8.55	42.75
Recurring	**13.95**	**20.25**	**20.25**	**13.95**	**13.95**	**82.35**
Non-Recurring	**8.55**	**13.05**	**9.45**	**8.55**	**8.55**	**48.15**
Total	**22.50**	**33.30**	**29.70**	**22.50**	**22.50**	**130.50**

Table 10.10: Expenditure on **H.2: Under-Graduate Fellowship (CHANAKYA-GI)** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower (Annexure H.2)	20.00	82.00	94.00	68.00	50.00	340.00
Miscellaneous (Annexure H.2)	10.00	41.00	47.00	47.00	25.00	170.00
Equipment (Annexure H.2)	42.00	2.00	2.00	2.00	2.00	50.00
Furnishing & Lab Space	25.00	77.50	15.00	-	-	117.50
Recurring	**30.00**	**123.00**	**141.00**	**141.00**	**75.00**	**510.00**
Non-Recurring	**67.00**	**79.50**	**17.00**	**2.00**	**2.00**	**167.50**
Total	**97.00**	**202.50**	**158.00**	**143.00**	**77.00**	**677.50**

Table 10.11: Expenditure on **H.3: Post-Graduate Fellowship (CHANAKYA-PG)** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower (Annexure H.3)	-	22.32	44.64	46.12	71.42	184.51
Miscellaneous (Annexure H.3)	-	-	30.00	30.00	32.00	92.00
Equipment (Annexure H.3)	-	116.50	18.00	4.10	4.20	142.80
Furnishing & Lab Space	-	18.75	18.75	1.25	1.25	40.00
Recurring	**-**	**22.32**	**74.64**	**76.12**	**103.42**	**276.51**
Non-Recurring	**-**	**135.25**	**36.75**	**5.35**	**5.45**	**182.80**
Total	**-**	**157.57**	**111.39**	**81.47**	**108.87**	**459.31**

Table 10.12: Expenditure on **H.4: PhD Fellowship (CHANAKYA-DF)** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower (Annexure H.4)	7.44	74.40	93.96	102.60	117.60	396.00
Travel	6.00	60.00	75.00	75.00	84.00	300.00
Equipment	2.20	20.00	7.50	2.50	2.50	34.70
Furnishing & Lab Space	2.50	22.50	6.25	-	-	31.25
Recurring	**13.44**	**134.40**	**168.96**	**177.60**	**201.60**	**696.00**
Non-Recurring	**4.70**	**42.50**	**13.75**	**2.50**	**2.50**	**65.95**
Total	**18.14**	**176.90**	**182.71**	**180.10**	**204.10**	**761.95**

Table 10.13: Expenditure on **H.5: Post Doctoral Fellowship (CHANAKYA-PD)** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower (Annexure H.5)	19.20	193.92	261.31	261.88	58.08	794.40
Travel	6.00	60.00	75.00	69.00	15.00	225.00
Equipment	2.20	20.00	7.50	2.30	2.50	34.50
Furnishing & Lab Space	2.50	22.50	6.25	-	-	31.25
Recurring	**25.20**	**253.92**	**336.31**	**330.88**	**73.08**	**1,019.40**
Non-Recurring	**4.70**	**42.50**	**13.75**	**2.30**	**2.50**	**65.75**
Total	**29.90**	**296.42**	**350.06**	**333.18**	**75.58**	**1,085.15**

Table 10.14: Expenditure on **H.6: Research Assistant Professor (CHANAKYA Faculty)** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower (Annexure H.6)	30.00	60.00	90.00	60.00	30.00	270.00
Travel	6.00	12.00	18.00	12.00	6.00	54.00
Contingency	2.00	4.00	6.00	4.00	2.00	18.00
Equipment	2.20	2.40	2.60	0.60	0.60	8.40
Furnishing & Lab Space	30.00	-	-	-	-	30.00
Recurring	**38.00**	**76.00**	**114.00**	**76.00**	**38.00**	**342.00**
Non-Recurring	**32.20**	**2.40**	**2.60**	**0.60**	**0.60**	**38.40**
Total	**70.20**	**78.40**	**116.60**	**76.60**	**38.60**	**380.40**

Table 10.15: Expenditure on **H.7: Chair Professor (CHANAKYA Chair Professor)** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower (Annexure H.7)	-	9.00	18.00	18.00	9.00	54.00
Contingency (Annexure H.7)	-	3.75	7.50	7.50	3.75	22.50
Overhead (Annexure H.7)	-	1.00	1.00	1.00	1.00	4.00
Recurring	**-**	**13.75**	**26.50**	**26.50**	**13.75**	**80.50**
Non-Recurring	**-**	**-**	**-**	**-**	**-**	**-**
Total	**-**	**13.75**	**26.50**	**26.50**	**13.75**	**80.50**

Table 10.16: Expenditure on **H.8: New PG Programme** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Contingency (Annexure H.8)	6.00	6.00	6.00	6.00	6.00	30.00
Equipment (Annexure H.8)	101.00	119.00	241.00	18.00	39.00	518.00
Misc. Non-Recurring (Annexure H.8)	-	5.00	5.00	5.00	5.00	20.00
Furnishing & Lab Space	-	-	-	-	-	-
Recurring	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**30.00**
Non-Recurring	**101.00**	**124.00**	**246.00**	**23.00**	**44.00**	**538.00**
Total	**107.00**	**130.00**	**252.00**	**29.00**	**50.00**	**568.00**

Table 10.17: Expenditure on **E.1: Grand Challenges and Competitions (CPS-GCC)** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower (Annexure E.1)	16.20	17.82	19.60	21.56	23.72	98.90
Travel (Annexure E.1)	40.00	40.00	40.00	40.00	40.00	200.00
Consumables (Annexure E.1)	20.00	20.00	20.00	20.00	20.00	100.00
Miscellaneous (Annexure E.1)	80.00	130.00	155.00	155.00	130.00	650.00
Misc. Non-Recurring	20.00	20.00	20.00	20.00	20.00	100.00
Furnishing & Lab Space	25.00	-	-	-	-	25.00
Recurring	**156.20**	**207.82**	**234.60**	**236.56**	**213.72**	**1,048.90**
Non-Recurring	**45.00**	**20.00**	**20.00**	**20.00**	**20.00**	**125.00**
Total	**201.20**	**227.82**	**254.60**	**256.56**	**233.72**	**1,173.90**

Table 10.18: Expenditure on **E.2: Promotion and Acceleration of Young and Aspiring Technology Entrepreneurs (CPS-PRAYAS)** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Travel (Annexure E.2)	2.00	2.00	2.00	2.00	2.00	10.00
Consumables (Annexure E.2)	1.00	1.00	1.00	1.00	1.00	5.00
Miscellaneous (Annexure E.2)	21.00	21.00	21.00	21.00	21.00	105.00
Misc. Non-Recurring (Annexure E.2)	10.00	10.00	10.00	10.00	10.00	50.00
Furnishing & Lab Space (Annexure E.2)	25.00	85.00	45.00	20.00	25.00	200.00
Recurring	**24.00**	**24.00**	**24.00**	**24.00**	**24.00**	**120.00**
Non-Recurring	**35.00**	**95.00**	**55.00**	**30.00**	**35.00**	**250.00**
Total	**59.00**	**119.00**	**79.00**	**54.00**	**59.00**	**370.00**

Table 10.19: Expenditure on **E.3: Entrepreneur in Residence (CPS-EIR)** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower (Annexure E.3)	36.00	72.00	90.00	90.00	72.00	360.00
Furnishing & Lab Space	12.50	12.50	6.25	-	-	31.25
Recurring	**36.00**	**72.00**	**90.00**	**90.00**	**72.00**	**360.00**
Non-Recurring	**12.50**	**12.50**	**6.25**	**-**	**-**	**31.25**
Total	**48.50**	**84.50**	**96.25**	**90.00**	**72.00**	**391.25**

Table 10.20: Expenditure on **E.4: CPS Startup Ignition** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Miscellaneous (Annexure E.4)	-	100.00	150.00	150.00	100.00	500.00
Furnishing & Lab Space	-	-	-	-	-	-
Recurring	**-**	**100.00**	**150.00**	**150.00**	**100.00**	**500.00**
Non-Recurring	**-**	**-**	**-**	**-**	**-**	**0.00**
Total	**-**	**100.00**	**150.00**	**150.00**	**100.00**	**500.00**

Table 10.21: Expenditure on **E.5: Technology Business Incubator (CPS-TBI)** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower (Annexure E.5)	44.40	48.84	53.72	59.09	65.01	271.06
Travel (Annexure E.5)	3.60	3.60	3.60	3.60	3.60	18.00
Contingency (Annexure E.5)	46.00	120.00	62.00	56.00	68.50	352.50
Consumables (Annexure E.5)	12.00	12.00	12.00	12.00	12.00	60.00
Miscellaneous (Annexure E.5)	5.80	5.80	5.80	5.80	5.80	29.00
Equipment (Annexure E.5)	30.00	30.00	30.00	30.00	30.00	150.00
Misc. Non-Recurring (Annexure E.5)	5.35	6.00	6.00	6.00	5.60	28.95
Furnishing & Lab Space (Annexure E.5)	36.00	104.00	244.00	124.00	112.00	620.00
Recurring	**111.80**	**190.24**	**137.12**	**136.49**	**154.91**	**730.56**
Non-Recurring	**71.35**	**140.00**	**280.00**	**160.00**	**147.60**	**798.95**
Total	**183.15**	**330.24**	**417.12**	**296.49**	**302.51**	**1,529.51**

Table 10.22: Expenditure on **E.6: Dedicated Innovation Accelerator (CPS-DIAL)** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Manpower (Annexure E.6)	166.80	183.48	201.83	222.01	244.21	1,018.33
Travel (Annexure E.6)	10.00	10.00	10.00	10.00	10.00	50.00
Contingency (Annexure E.6)	10.00	10.00	10.00	10.00	10.00	50.00
Overhead (Annexure E.6)	10.00	10.00	10.00	10.00	10.00	50.00
Equipment	18.00	-	-	-	-	18.00
Furnishing & Lab Space	90.00	-	-	-	-	90.00
Recurring	**196.80**	**213.48**	**231.83**	**252.01**	**274.21**	**1,168.33**
Non-Recurring	**108.00**	**-**	**-**	**-**	**-**	**108.00**
Total	**304.80**	**213.48**	**231.83**	**252.01**	**274.21**	**1,276.33**

Table 10.23: Expenditure on **E.7: Seed Support System (CPS-SSS)** in Lakhs of INR.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Miscellaneous (Annexure E.7)	-	300.00	300.00	200.00	200.00	1000.00
Furnishing & Lab Space	50.00	-	-	-	-	50.00
Recurring	**-**	**300.00**	**300.00**	**200.00**	**200.00**	**1,000.00**
Non-Recurring	**50.00**	**-**	**-**	**-**	**-**	**50.00**
Total	**50.00**	**300.00**	**300.00**	**200.00**	**200.00**	**1,050.00**

Cost Sharing and Cost Recovery Mechanism

In each of the projects to be undertaken, measures are being implemented to share the cost through investments raised from Industry partners. These shall be in the form of either equipment sponsorship, equipment donation, manpower cost sharing, rental agreements, etc. The mechanism of revenue generation and cost sharing shall be implemented in a phased manner in order to be able to cover for the cost in gradually phased manner of supporting manpower demands and phasing over to self sustainable components. Table 9.3 illustrates the gradual phasing plan of supporting manpower over the years through financial sources other than the NM-ICPS in order to be able to reach a complete phasing over from the NM-ICPS support indicated in Table 9.2 in Year 6. In the period beyond the support phasing of NM-ICPS, the Hub shall implement revenue generation mechanisms for its sustainability as indicated below. The industry partners for the activities under Technology Development are also listed per project wise in Table 8.1 and Table 8.2.

Project Sustainability

Measures shall be implemented to make the Hub financially sustainable from Year 6 onwards. Every of the activities to be carried on by the hub shall be contributing towards this effort. The following measures shall be implemented for the purpose.

Table 10.24: Phased revenue stream projection for **Technology Development** in Lakhs of INR

	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**
Recurring	423.00	458.40	497.34	540.17	587.29	646.00
Non-Recurring	360.00	193.30	299.45	245.70	191.80	90.00
Rent (30% contribution)	-	-	-	-	-	60.90
Total Expenditure	**783.00**	**651.70**	**796.79**	**785.87**	**779.09**	**796.90**
NM-ICPS (Table 10.2)	783.00	651.70	796.79	785.87	779.09	-
Projected Revenue	**-**	**-**	**450.00**	**500.00**	**670.00**	**740.00**
EBITDA	-	-	450.00	500.00	670.00	-56.90
Cumulated Surplus	-	-	450.00	950.00	1,620.00	1,563.10

Table 10.25: **Revenue** from activities of **Technology Development** in Lakhs of INR

	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**
NKP	-	-	200.00	225.00	300.00	330.00
AI Cloud for CPS	-	-	50.00	50.00	75.00	90.00
Codebase, APIs, Data	-	-	50.00	50.00	75.00	90.00
Digital Twins	-	-	100.00	125.00	150.00	150.00
Live Testbeds	-	-	50.00	50.00	70.00	80.00
Total	**-**	**-**	**450.00**	**500.00**	**670.00**	**740.00**

Revenue shall be raised through certification and content royalty access on NKP, rental services for the AI cloud for CPS, licensing fees on Codebase, APIs and Datasets, rental charges on Digital Twins and Live Testbeds.

Table 10.26: Phased revenue stream projection for **HRD and Skill Development** in Lakhs of INR

	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**
Recurring	126.59	649.64	887.66	848.06	524.80	577.28
Non-Recurring	218.15	439.20	339.30	44.30	65.60	72.16
Rent (20% contribution)	-	-	-	-	-	40.60
Total Expenditure	**344.74**	**1088.84**	**1226.96**	**892.36**	**590.40**	**690.04**
NM-ICPS (Table 10.3)	344.74	1088.84	1226.96	892.36	590.40	-
Projected Revenue	**50.00**	**100.00**	**290.00**	**320.00**	**352.00**	**592.00**
EBITDA	50.00	100.00	290.00	320.00	352.00	-98.04
Cumulated Surplus	50.00	150.00	440.00	760.00	1,112.00	1,013.96

Table 10.27: **Revenue** from activities of **HRD and Skill Development** in Lakhs of INR

	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**
High End Skill Dev.	50.00	80.00	150.00	170.00	190.00	250.00
Technology Consulting	-	20.00	80.00	85.00	90.00	190.00
Research Earnings	-	-	60.00	65.00	72.00	152.00
Total	**50.00**	**100.00**	**290.00**	**320.00**	**352.00**	**592.00**

Revenue shall be raised through workshops and certificate education programs on Up-/Re-skilling involving Industry professionals and professional studies students. These shall include the ones offered in-person either at the Hub or at the site of the Professional when such engagements are brought in by a sector specific Industry.

Table 10.28: Phased revenue stream projection for **Entrepreneurship, Innovation & Startup Ecosystem** in Lakhs of INR

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Recurring	524.80	1,107.54	1,167.55	1,089.06	1,038.83	1,142.71
Non-Recurring	321.85	267.50	361.25	210.00	202.60	222.86
Rent (50% contribution)	-	-	-	-	-	101.50
Total Expenditure	**846.65**	**1,375.04**	**1,528.80**	**1,299.06**	**1,241.43**	**1,467.07**
NM-ICPS (Table 10.4)	846.65	1,375.04	1,528.80	1,299.06	1,241.43	-
Projected Revenue	-	-	**375.00**	**375.00**	**535.00**	**1,300.00**
EBITDA	-	-	375.00	375.00	535.00	-167.07
Cumulated Surplus	-	-	375.00	750.00	1,285.00	1,117.93

Table 10.29: **Revenue** from activities of **Entrepreneurship, Innovation & Startup Ecosystem** in Lakhs of INR

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
CPS Startup Ignition	-	-	75.00	75.00	85.00	300.00
CPS Seed Support Sys.	-	-	300.00	300.00	450.00	1,000.00
Total	-	-	**375.00**	**375.00**	**535.00**	**1,300.00**

Revenue shall be raised through equity sales. The standard assumption is to be able to raise 25% surplus over investment in Ignition and 50% over investments through Seed Support. The cumulation of the amount raised across the years shall be invested further to generate more revenue. Market linked risks are however existing and strategies shall have to reviewed and revised in a phased manner for upkeeping the targets.

Table 10.30: Phased revenue stream projection for **International Collaborations** in Lakhs of INR

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Recurring	125.00	445.00	595.00	355.00	80.00	-
Non-Recurring	-	100.00	200.00	100.00	-	-
TIH Sponsored Proj.[39]	-	-	-	312.00	953.00	1,125.00
Total Expenditure	**125.00**	**545.00**	**795.00**	**455.00**	**1,033.00**	**1,125.00**
NM-ICPS (Table 10.5)	**125.00**	**545.00**	**795.00**	**455.00**	**80.00**	-
Projected Revenue	-	-	-	**312.00**	**953.00**	**1,125.00**
EBITDA	-	-	-	-	-	-
Cumulated Surplus	-	-	-	-	-	-

Table 10.31: **Revenue** from activities of **International Collaborations** in Lakhs of INR

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
TIH Internal Investment[40]	-	-	-	100.00	300.00	350.00
External Proj. Funding[41]	-	-	-	212.00	653.00	775.00
Total	-	-	-	**312.00**	**953.00**	**1,125.00**

[39] This contribution shall be for keeping the 3 year phased projects continuing, with new projects being awarded from Year 4. This shall be through accumulated surplus sharing from other activities, and through sponsorships including CSR from external agencies.
[40] Commissioned by Technology Development to create TRL1-3 in niche areas which are potential to raise technology commercialization revenue in the future.
[41] Funding from Companies/CSR, graduate Startups of the TIH, Government funding programs, etc.

Stakeholder Commitment

The stakeholders associated with each project and activity are identified in Table 5.3. The cost sharing mechanism and revenue generating activities are identified there, and the phased projection of Revenue to be raised from the different activities towards Project Sustainability have also been analysed. The sectorized activity wise commitment of human resources employed at the Hub is discussed in Table 9.5.

Operation and Maintenance of Assets

All assets including those of capital nature including furniture and office equipment, and scientific and technical equipment shall be under Insurance, Annual Maintenance Contract. The costs towards these components are accounted within the budget component per activity. The phasing of manpower requirement also accounts for employees of the Hub responsible for operating the equipment. The cost of rent, utilities including internet and electricity to keep the assets operational have also been accounted for appropriately in the budget.

Chapter 11: Time Frame

Timeline and Milestones

Table 11.1: Phased indicator of development timeline of the different activities to be undertaken for **Technology Development**. The description of deliverables are detailed in Chapter 8: Technology and Annexures T.1, T.2 and T.3.

Ref. No.	Task Name	YEAR 1				YEAR 2				YEAR 3				YEAR 4				YEAR 5			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
T.1	**Dev. of Prod. & Prototypes from Existing Knowledge**																				
	NKP																				
	AI Cloud for CPS																				
	Codebase, APIs																				
	Digital twins hosted via NKP																				
	Cloud connected live testbeds																				
T.2	**Dev. of Tech. or Prod. Delivery in Sector Specific**																				
	ADAS for Tractor and Applicator																				
	Instru. Road for Traff. & Str. Health																				
	TIH-Industry-Academic JV Testbed 1																				
	Cloud Controlled 3D Printing																				
	AI enabled Smart Hospital																				
	Smart Drive System for Smart Cities																				
	TIH-Industry-Academic JV Testbed 2																				
	Wastewater Engineering Plant																				
	Energy Smart Building Microgrid																				
	AI enabled Mobile Remote Care																				
	Instrumented Classroom																				
	Smart Beamform. Next Gen Wireless																				
	TIH-Industry-Academic JV Testbed 3																				
	TIH-Industry-Academic JV Testbed 4																				
T.3	**Expert Driven Research**																				
	SM: Tractor ADAS																				

	SM: Traffic & Road Health																						
	TIH-Industry-Academic JV DT 1																						
	DT: 3D Printing																						
	SM: Smart Hospital																						
	SM: Smart Drive System																						
	TIH-Industry-Academic JV DT 2																						
	DT: Wastewater Plant																						
	DT: Smart Building Microgrid																						
	SM: Human Phy. & Pathology																						
	Chatbots for Legal Aid																						
	DT: Next Gen Wireless																						
	TIH-Industry-Academic JV DT 3																						

Table 11.2: Phased indicator of development timeline of the different activities to be undertaken for **HRD and Skill Development**. The description of deliverables are detailed in Annexures H.1, H.2, H.3, H.4, H.5, H.6, H.7, H.8.

Ref. No.	Task Name	YEAR 1				YEAR 2				YEAR 3				YEAR 4				YEAR 5				YEAR 6			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
H.1	High-end Skill Development																								
	Workshops	1				1				1				1				1							
	ASTI					1																			
H.2	Chanakya UG																								
	Number of Fellows	20				82				94				94				50							
	Number of projects	10				41				47				47				25							
H.3	Chanakya PG																								
	Y1 Fellowships					15				15				16				16							
	Y2 Fellowships									15				15				16				16			
	Number of projects					15				15				16				16							
H.4	Chanakya PhD (DF)																								
	Y1 Fellowships	2				18				5															
	Y2 Fellowships					2				18				5											
	Y3 Fellowships									2				18				5							
	Y4 Fellowships													2				18				5			

H.5	Chanakya Post-doctoral																							
	Y1 Fellowships	2				18				5														
	Y2 Fellowships					2				18				5										
	Y3 Fellowships									2				18				5						
H.6	Chanakya Faculty																							
	Y1 Positions	2				2				2														
	Y2 Positions					2				2				2										
	Y3 Positions									2				2				2						
H.7	Chanakya Chair Prof.																							
	Y1 Positions					3				3														
	Y2 Positions									3				3										
	Y3 Positions													3				3						
H.8	New PG Laboratory																							

Table 11.3: Phased indicator of development timeline of the different activities to be undertaken for **Entrepreneurship, Innovation and Startup Ecosystem**. The description of deliverables are detailed in Annexure E.

Ref. No.	Task Name	YEAR 1				YEAR 2				YEAR 3				YEAR 4				YEAR 5			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
E.1	CPS-GCC																				
	Enrolment																				
	Training																				
	Competition																				
	Grand Challenge																				
E.2	CPS-PRAYAS																				
	Enrolment																				
	Training																				
	Maker Phase																				
	Venture Phase																				
E.3	CPS-EIR																				
	Enrolment																				
	Training																				
	Idea to Realization																				

E.4	CPS Startup Ignition																			
E.5	CPS-TBI																			
E.4	CPS-DIAL																			
E.5	CPS-SSS																			

Table 11.4: Phased indicator of development timeline of the different activities to be undertaken for **International Collaborative Research Program**. The description of deliverables are detailed in Annexure C.

Ref. No.	Task Name	YEAR 1				YEAR 2				YEAR 3				YEAR 4				YEAR 5			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
C	Collaborative Program																				
	Y1 Programs	1				2				1											
	Y2 Programs					1				2				1							
	Y3 Programs									1				2				1			

Project Evaluation and Review Technique

The projects and activities undertaken shall be periodically reviewed in a phased manner, both internally by the stakeholders and the Program Manager of the concerned programs, as well as by a Progress Review and Steering Group (PRSG) consisting of external to project technical and scientific and business experts in related fields. The details of such mechanisms are described in Chapter 15: Evaluation.

Chapter 12: Cost Benefit Analysis

Table 12.1: Cost of activity per component wise and the summary of deliverables or beneficiary including HR supported both directly and indirectly through each component.

Component	Activity and Deliverables	Cost in Lakhs of INR	HR/ Beneficiary Type	No. HR/ Beneficiary Supported
Technology Development	T1: Development of Products and Prototypes from Existing Knowledge	1,669.85	Employee	10
	T2: Development of Technology or Product Delivery in Specific Sectors	911.73	Employee	9
	T3: Expert Driven Research	1,214.87	Employee	13
	DELIVERABLE: No. of Technologies	-	-	32
	DELIVERABLE: Technology Products	-	-	32
	DELIVERABLE: Publications, IPR, other Intellectual Activities	-	-	90
HRD and Skill Development	H1: High End Skill Development	130.50	External	630
	H2: Under-Graduate Fellowship (CHANAKYA-GI)	677.50	Fellowship	340
	H3: Post-Graduate Fellowship (CHANAKYA-PG)	459.31	Fellowship	62
	H4: PhD Fellowship (CHANAKYA-DF)	761.95	Fellowship	25
	H5: Post Doctoral Fellowship (CHANAKYA-PD)	1,085.15	Fellowship	25
	H6: Research Assistant Professor (CHANAKYA Faculty)	380.40	Employee	6
	H7: Chair Professor (CHANAKYA Chair Professor)	80.50	Honorarium	6
	H8: Laboratory for New PG Programme	568.00	H3: CHANAKYA-PG	62

Entrepreneurship, Innovation and Startup Ecosystem	E1: Grand Challenges and Competitions (CPS-GCC)	1,173.90	External	100
			Employee	3
	E2: Promotion and Acceleration of Young and Aspiring Technology Entrepreneurs (CPS-PRAYAS)	370.00	External	10
	E3: Entrepreneur in Residence (CPS-EIR)	391.25	External	100
	E4: CPS Startup Ignition Grant	500.00	External	50
	E5: Technology Business Incubator (CPS-TBI)	1,529.51	Employee	6
	E6: Dedicated Innovation Accelerator (CPS-DIAL)	1,276.33	Employee	16
	DELIVERABLE: CPS Startups and Spinoff Companies	-	-	60
	E7: Seed Support System (CPS-SSS)	1,050.00	External	10
International Collaboration	Collaborative Research Programme	2,000.00	Projects	4

Chapter 13: Risk Analysis

Organizational Risk Matrix

AI4ICPS as an organization may be subject to exposure of the following risk factors, which shall have to be mitigated for its sustenance. The risks are spread across a spectrum of

Table 13.1: Probability and Impact of the different risk factors which are detailed subsequently. The priority of mitigating these risks is based on their indicators for Low, Medium and High.

Risk Impact	Severe	Reputation	Legal	Data Mgmt.	Operational
	Major	Organization	Strategy	Proj. Mgmt.	Finance
	Minor	Environment	Compliance	HR	Technology
	Negligible	Geo-Political	Market	Competition	Know. Mgmt.
		Improbable	Remote	Occasional	Frequent
		Risk Probability			

General Administration and Project Management Risks

Organization Structure

Risk: Speed of communication across all stakeholders and project team members is an essential requirement for an organization like AI4ICPS which is primarily Technology driven, and shall be competing against world-class research organizations from all over the world. Technology in the area of AI & ML is developing very rapidly and every stakeholder of the Hub shall have to act accordingly, to remain competitive and of value. In a traditional centralized organization structure, rapid flow of information and instructions and communication get impacted in the mesh of hierarchy.

Mitigation Plan: To address the above challenges, the organizational engagement structure for the Project management at the Hub has been designed as a Projectized – Matrix structure (Table 9.4), wherein all activities of development will be carried out in a Project mode and all supporting resources, including Engineers, Technical Support, and Fellows will be in a matrix structure and whose knowledge and expertise would be utilised by the Projects on a “pull” basis. Such a structure ensures that the company is fast, agile and adaptable in executing

projects. Communications are also rapid and fast in execution teams, without need for much escalation of every matter through hierarchy.

Knowledge Management

Risk: Academic fellows including CHANAKYA-Faculty, CHANAKYA-Chair Professor, CHANAKYA-PD, CHANAKYA-DF, CHANAKYA-PG, CHANAKYA-UG Research Assistant Faculty Fellows, Chair Professors and Research scholars are funded for the first five years. Their major contribution would be towards Knowledge generation. Sixth year onwards, with these funding's not available, Knowledge generation shall get heavily impacted. While academic fellows may graduate out within this time, CHANAKYA-Faculty position being supported for only 3 years, and unavailability of continuous stream of funds for other positions engaged in TRL1-3 activities, shall impact this phase associated with HRD and Skill Development, significantly from the 6th year onwards.

Mitigation Plan: Members associated with activities of knowledge generation and management, who are primarily serving HRD and Skill Development and also Technology Development on a role sharing basis as outlined in Table 9.5, shall have their cost to salary/manpower/program proportionately supported from the revenue earned through these activities. Activities of Technology Development shall lead to revenue generation by IP sales which shall contribute to proportional contribution for future programs. There is also a need to define salary structure on a performance linked increment basis for CHANAKYA-Faculty, and promotion/selection schemes for them to the designations of Associate Professor, Professor, etc. which shall serve as a career advancing motivation, and enable AI4ICPS to attract talents in the space. Other options shall be for supporting these positions through Industry funded grants or CSR grants. Such flexible approaches shall be required to sustain these critical activities.

Human Resources Risk

Risk of Employee Management: The major risks in this domain pertain to activities like recruitment and hiring, compensation, resource availability, employee retention and minimizing the attrition rate.

Mitigation Plan: Dedicated resources required by the Hub for undertaking projects are mapped and indicated. Hourly engagement planning for each resource is also calculated (Table 9.6 and Table 9.7) and activities shall be distributed accordingly to a planned proportion (Table 9.5) obeying the nominal hours available per person. IIT Khragpur Faculty shall be engaging on a project to project basis as PI of the project, with their time dedication and a worked out plan of engagement. However, IIT Kharagpur Faculty shall be engaged as a facilitator and custodian or knowledge and not directly responsible for execution. The primary project execution responsibility towards sustainability of the Hub shall be shouldered by the HR of the Hub.

Risk due to lack of Training and Upskilling: Other risk is with continuity on use of legacy technology where the Hub and its employees are not able to adapt themselves with rapidly changing Technology environment. Due to constant competitor risk and demand fluctuations, an organization loses out on its critical and key resources.

Mitigation Plan: Ensuring re-skilling, upskilling and mentoring programs for employees shall be a very effective mitigation. Such professional development activities are accounted for in their time distribution across activities (Table 9.5), including also such components for administrative and management staff cadre, to keep up with current age best practices of organizational administration. Performance measurement parameters including Key Performance Indicators (KPI), Management by Objective (MBO), are part of the Monitoring Arrangements in order to ensure high efficiency and optimal use of available resources. A predefined credit system would be followed for employees which would highlight Key Results Areas (KRA) for that specific year and shall be monitored as standard HR practice.

Strategic and Technology Management Risks

Strategy Risks

Risk: The Hub shall face a significant challenge faced by most technology driven organizations in their nascent stage, associated with uncertainty in identifying the right customer base, mapping the demand fluctuations and forecasting future demand and growth projections.

Mitigation Plan: While the initial focus in on few identified Sectors and Sub-Sectors of core and applied AI and ML and few CPS Industry sectors, period exercises of demand mapping and assessment of AI based start-up industry in the country and using extensive frameworks like PESTEL and SWOT analysis would be undertaken by the management team to identify and forecast. Mapping organizations strength, new areas of opportunities and taking preventive and preemptive steps to control internal and external challenges.

Technology Management Risks

Risk of Technology and Data Management: Among the major risks for technology companies which have potential to impact the entire organization operations, are factors including data management, data privacy, data confidentiality, legacy technology risk and IT security vulnerabilities. These risks can potentially have high impact and can deeply affect the business operations.

Mitigation Plan: These risks can be minimized by setting up a comprehensive plan for minimum data-quality requirement, descriptive statistics and detecting anomaly early on in order to identify potential quality issues and model-access requirements, including prevention of unauthorized sensitive data download and limiting access potential to be a threat.

Risk due to absence of a definite Policy and Guidelines: Lack of any comprehensive policy and regulations on AI and related risks shall lead to a lot of uncertainty in activities being undertaken, which can lead to unintended consequences and frequent business interruptions, as well as lack of a roadmap for sustainability of activities of the Hub.

Mitigation Plan: Organization wide well defined policy on use of approved AI and ML use cases based on mission, vision and values shall be able to reduce such risks. Independent review of model purpose, proposed analytic methods, anticipated variables, and intended use coupled with self-regulation allows to mitigate these risks and ensures Physical safety, Digital Safety and Privacy and Data Protection. All the Hub's projects would have a project specific list of potential AI & ML related risks. Necessary steps would have to be taken as per well defined guidelines to ensure risk mitigation.

Operational and Management Risks

Operational Risks can be due to several factors with different degrees of alertness, according to the following matrix structure. These have been identified and

Table 13.2: Probability and Impact of the different operational risk factors which are detailed subsequently. The priority of mitigating these risks is based on their indicators for Low, Medium and High.

Risk Impact	Severe	License	Legal	Data Theft	Demand
	Major	Volatility	Legacy Tech.	IT Sys. Failure	Revenue
	Minor	Environment	Regulatory	Health &Safe.	Resources
	Negligible	Geo-Political	Market	Info. Dissem.	Know. Mgmt.
		Improbable	Remote	Occasional	Frequent
		Risk Probability			

Geo-Political Risk: Profitability shall suffer due to circumstances related to unexpected changes, including events involving political revolutions, elections, political and regional conflicts etc. which shall risk the steady state economics of peace time and volatilize the market. These also include challenges with worker unionization, etc.

Market Risks: Losses in positions arising from changes in market factors like prices and demand, and lower quotes from competitors, if the Hub is not kept updated with market trends.

Environmental Risks: These can have an environmentally driven impact on the business, viz. chemical hazards, heating and operating environment, etc.

Information Dissemination: Important for organization to ensure dissemination of information from top to bottom to ensure employee efficiency and autonomy.

Volatility Risk: Factors such as fluctuations in demand, prices or sector specific Industry / Market volatility viz. Disruptive changes with advent of a new technology or practice.

Regulatory Risks: Ensuring adoption to new regulations and adherence to current age norms and regulations. There shall also be variation of such regulations across market Geography, viz. variations across North America, Latin America, Europe-MiddleEast-Africa (EMEA), East Asia, etc. This shall also be addressed through engagements on International Collaborative Research with partners in these target geographic locations.

Licenses and Certifications: It is of relevance to ensure that all Legal, Regulatory, Governmental and Technology Licenses and Certifications obligations are being satisfied.

Knowledge Management: It is important to ensure new knowledge generation, dissemination and preservation. This shall have to be done by creating a mechanism of financially sustaining operations, and academic positions on the long run, to maintain a steady inflow of TRL1-3 indeas to the Hub for working on their innovation and commercialization.

Legacy Technology: Hub and its employees should be encouraged to adapt and absorb the latest technology through re-skilling and up-skilling, by participating in internal or external programs. These activities are accounted for in their responsibilities matrix in (Table 9.5).

Health and Safety: It is an important responsibility to ensure health and safety of its employees and its stakeholders by providing a safe and secure workplace environment and adherence to all regulations. Occupational health and safety shall be part of standard workplace offering, policy matters and infrastructure shall have to be formulated for the purpose.

Resource Management: The Hub shall ensure that all its critical resources like its employees and equipment are available with provision for a back-up to ensure operational continuity of the business. This shall be done through creating teams with multiple employees with similar or overlapping skill sets.

Legal Risks: The Hub shall strive to ensure protection of its copyrights, IP, trademarks and trade secrets. This shall be undertaken through having a dedicated Legal and IP team under the office of the GM - Legal to ensure action to restrict any of such infringements due to operational reasons, including those from past employees and project collaborations in effect or expired.

IT System Failure: This risk has high probability and impacts the business operations severely. Provisions to ensure functioning of a dedicated IT system and data backup provision shall have

to be made. This shall be done through redundancy in IT infrastructure, including use of off-station data centre and rack / IT rental services, Cloud based services.

Data Theft: It is a high risk that directly impacts business and goodwill of the Hub, and shall require provisions for data management, data privacy, data confidentiality along with a comprehensive plan for minimizing such breaches through firewall protection.

Revenue and Credit Risk: It is necessary to ensure consistent revenue generation and diversification of revenue streams to ensure regular cash inflows. This shall be possible by having a goal oriented annual revenue planning for short term, and an overall long term revenue planning available in hand. Tying activities to revenue streams shall be a good practice to create a parity in activities and revenue streams.

Demand Risk: Ensuring demand forecasting and growth projections to mitigate challenges due to demand fluctuations and new market competitors. The Hub shall need to revise its annual operational plans, goals, and activities to match the dynamic nature of the demands.

Data Management

Risk: This includes risk associated with infrastructural lapsation leading to loss of data not just limited to loss of experimental data, 3rd party data due to IT infrastructure losses, but also including loss and leakage of internal trade secrets, business data, etc.

Mitigation Plan: The Hub to the best possible extent shall ensure its legal and IP policies are strict to prevent such. The data including internal confidential information shall not be shared on public clouds, and the Hub shall put into place geographically distributed hosting of encrypted redundant copy of data. Such data shall also include business process and financial matters. The public datasets and likes of codes, APIs shall be hosted on private and public trunks using the Nation wide redundant network of IT infrastructure that shall support the KNP on AI4ICPS.

Project Management

Risk: Challenges with ownership and timely delivery of projects is a challenge in such competitive environments. Teams should have to take ownership, individuals shall have to define their goals, and collectively work towards satisfying the mission and vision of the Hub, while delivering products and innovations to maintain the revenue stream. Complex web of reporting structure and loss of reporting structure has to be worked out.

Mitigation Plan: A lean management structure bot at the top level and base of project management has to be worked out. Such practices of lean reporting and management which are included in the Hub for its progress monitoring shall address this challenge, through quick communication across stakeholders.

Legal Compliance Risks

Compliance to Regulators

Risk: Absence of definitive policy or defined regulations by the Government and Regulators on AI and related technology use in CPS may have serious consequences during man-machine interactions. Such an undefined set may lead to unintended ramifications which can deeply impact an organization's operations and market reputation.

Mitigation Plan: Absence of a guiding National policy on regulating AI technology and products regulation in India, the Hub shall be adhering to NITI Aayog recommendations for AI based products, technologies and businesses. Practices on ensuring self-regulation practices for AI related activities and technology development and testing and ensuring adherence to Fairness, Accountability, Transparency and Ethics (FATE). Also, we would be referencing and standardizing along the globally accepted GDPR, HIPPA, etc. like rules to ensure uniform regulations for any sale and purchase of our IP and copyrights across various locations.

Legal

Risk: Among the major risks for any organization are copyright issues, IP and trademark infringement and guarding of Trade secrets which can impact its long-term revenue and growth. These risks usually have massive costs associated with them and are time consuming which can hamper organizations goals and targets due to re-allocation of limited resources.

Mitigation Plan: Hub would be having a dedicated Legal team under leadership of GM-Legal, to handle all Legal and IP related issues. All copyrights, and trademarks would be registered and any infringement would be dealt using the relevant laws under Indian Penal Code. Any infringement would be dealt using the established practices of notices, negotiations and arbitration for settling of disputes, and in case of no result, all legal remedies would be used.

Financial Management Risks

Cash Flows

Risk due to absence of parity in Income and Expenses: In order for an organization to grow and capture new markets and invest in latest technologies and its products it is necessary to have net positive cash flows over long sustained periods. Any extra costs viz. operational expenses, taxes which might lead to exceed the total revenue can be a major financial risk for the firm which can impact its viability and survival.

Mitigation Plan: The initial budget grant supports the Hub for a period of only five years and from that period onwards the Hub should have to be financially self-sufficient and self-reliant to support any future cost escalations and investments in technology. The Hub can diversify its

sources of revenue and increase its engagement with industry and customers. The current revenue projections show net positive income from sixth year, through these external revenue sources, which come in through all of its activities.

Cash Flow at Risk (CFaR): These include the extent to which future cash flows may fall short of expectations as a consequence of changes in market variables like price changes, new technology etc. and other stress scenarios.

Mitigation Plan: In order to ensure self-sufficiency of the Hub, the revenues must at least be equal to the expenditures from sixth year, with an annual growth in revenue that should be greater and exceeding the market hindrance rate (viz. cost of borrowing). There would be a separate contingency fund for unexpected expenses and cost escalations. As per projections the revenue growth from sixth year would be approx. 10.3% which shall be the maximum tolerable cash flow at risk for the sixth year. Such exercises shall have to be revised periodically by the leadership team to ensure sustainability.

Revenue and Growth

Risk: In order for an organization to be self sustainable over time, it is necessary to have a diversified portfolio of sources of revenue and the revenues must grow at a rate greater than costs and hindrance rate. If a firm relies heavily on only one source of revenue it is prone to high risk due to any demand or market fluctuations.

Mitigation Plan: The Hub would be focussing on diversifying its revenue streams viz. Raising revenue by Reskilling and Up-skilling programs and services in initial years and then would be utilizing its core competency by ensuring revenue sources from Industry buyouts (like adoption of our technology and services) and the consultancy services which are anticipated to together form more than 50% of our revenues by year 5. Hub would lay focus on establishing long term partnerships with industry and emerging start-ups and other institutions for consultancy services. Hub would create diversified revenue channels to ensure no over-reliance on a single source of revenue. In the later years, there shall also be revenue sources through return on pre-series A Equity investments made on startups, which shall be used for extending more capital investments.

Industry Sector Risks

Market

Risk: There shall be challenges associated with dynamics of the market itself. These include disruption due to advent of new technologies, gradual saturation of opportunities, short of the revenue centre of gravity to new Industry sectors, change in mood of the market investors.

Mitigation Plan: The Hub shall be regularly updating its business policies and activity

roadmap to match such dynamics of the market. This shall enable gradual re-skilling of internal workforce to adopt into new CPS Sectors, new technologies getting adopted into AI and ML, and also keep an open eye to the dynamics and threat to saturation of the core sector on AI and ML itself. These shall also require us to strengthen the overall product delivery sphere by also aligning and joining hands with other TIH's which specialize in aligned technologies like cyber-security, IoT, etc. that also play an integral part to the fabric of product delivery.

Competition

Risk: This challenge shall be associated with the rise of another TIH or a similar themed business unit which develops AI and ML technology and innovation for ICPS.

Mitigation Plan: This can be mitigated by collaborating with them early on, and focussing on nische areas where others would take longer time to up-skill internally. Some of the focus areas viz. Engineering of CPS and compute units for AI and ML implementation are some of such niche areas to specialize. Over the span of time, it shall be imperative to upskill to prevent such runover from potential competitors.

External Risks

Reputational Risks

Risk: This is a low probable but high risk where the loss in reputation to deliver on promises or reputation as an employer and collaborator shall cause irreparable harm to the Hub.

Mitigation Plan: All caution should be exercised to keep a balance between ambition and risk of delivery of projects. Projects where the team of people if not committed shall be refrained from being taken up. HR management shall be done meticulously and the GM-HR shall be responsible for managing the non-project related aspects, including emotional health, workplace emotional hazards, bringing in needed interventions at early stages, involving technical managers to keep up with the reputation of a good employer. Employees shall also need to be acknowledged for their contribution and special track schemes implemented to encourage them with keeping up with extra efforts needed for exponential growth of the organization.

Geo-Political Risks

Risk: These include change in political ideology and political leanings impacting market and industry.

Mitigation Plan: Regular engagement to understand such trends to adapt to change.

Environmental Risks

Risk: These include adverse impacts like storms, etc. as well as massive earth transformations.

Mitigation Plan: Shall require strategy to not disturb the environment..

Chapter 14: Outcomes

Milestones

AI4ICPS aspires to achieve the following tangible deliverables on a 5 year timeline.

Table 14.1: Tangible targets for AI4ICPS that constitutes the phased distribution of milestones to be achieved in terms of quantifiable outcomes.

Component	Activity	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Technology Development	Development of Products and Prototypes from Existing Knowledge			1	2	2	5
	Development of Technology or Product Delivery in Specific Sectors			3	4	7	14
	Expert Driven Research			3	4	6	13
	No. of Technologies			7	10	15	32
	Technology Products			7	10	15	32
	Publications, IPR, other Intellectual Activities	5	15	20	25	25	90
	Increase in CPS Research Base	6	20	24	25	30	105
HRD and Skill Development	High End Skill Development	90	180	180	90	90	630
	Under-Graduate Fellowship (CHANAKYA-GI)	20	82	94	94	50	340
	Post-Graduate Fellowship (CHANAKYA-PG)		15	15	16	16	62
	PhD Fellowship (CHANAKYA-DF)	2	18	5			25
	Post Doctoral Fellowship	2	18	5			25

	(CHANAKYA-PD)						
	Research Assistant Professor (CHANAKYA Faculty)	2	2	2			6
	Chair Professor (CHANAKYA Chair Professor)		3	3			6
	Laboratory for New PG Programme	1					1
Entrepreneurship, Innovation and Startup Ecosystem	Grand Challenges and Competitions (CPS-GCC)	1	1	1	1	1	5
	Promotion and Acceleration of Young and Aspiring Technology Entrepreneurs (CPS-PRAYAS)	2	2	2	2	2	10
	Entrepreneur in Residence (CPS-EIR)	8	8	8	8	8	40
	CPS Startup Ignition Grant	10	10	10	10	10	50
	Technology Business Incubator (CPS-TBI)	1					1
	Dedicated Innovation Accelerator (CPS-DIAL)	1					1
	CPS Startups and Spinoff Companies	12	12	12	12	12	60
	Seed Support System (CPS-SSS)	2	2	2	2	2	10
	Job Creation	750	2,500	3,000	3,125	3,750	13,125
International Collaboration	Collaborative Research Programme	1	2	1			4

Comparison with Baselines for Measure of Success

Table 14.2: Objective measures of outcomes and comparison with baselines set as target by NM-ICPS.

Component	Activity	Envisaged Deliverables	Baseline Target Set by NM-ICPS
Technology Development	Development of Products and Prototypes from Existing Knowledge	5	-
	Development of Technology or Product Delivery in Specific Sectors	14	-
	Expert Driven Research	13	-
	No. of Technologies	32	32
	Technology Products	32	30
	Publications, IPR, other Intellectual Activities	90	90
	Increase in CPS Research Base	105	105
HRD and Skill Development	High End Skill Development	630	630
	Under-Graduate Fellowship (CHANAKYA-GI)	340	340
	Post-Graduate Fellowship (CHANAKYA-PG)	62	62
	PhD Fellowship (CHANAKYA-DF)	25	25
	Post Doctoral Fellowship (CHANAKYA-PD)	25	-
	Research Assistant Professor (CHANAKYA Faculty)	6	6
	Chair Professor (CHANAKYA Chair Professor)	6	6
	Laboratory for New PG Programme	1	-
Entrepreneurship, Innovation and Startup Ecosystem	Grand Challenges and Competitions (CPS-GCC)	5	1
	Promotion and Acceleration of Young and Aspiring Technology Entrepreneurs (CPS-PRAYAS)	10	1

	Entrepreneur in Residence (CPS-EIR)	40	31
	CPS Startup Ignition Grant	50	-
	Technology Business Incubator (CPS-TBI)	1	1
	Dedicated Innovation Accelerator (CPS-DIAL)	1	1
	CPS Startups and Spinoff Companies	60	52
	Seed Support System (CPS-SSS)	10	1
	Job Creation	13,125	13,125
International Collaboration	Collaborative Research Programme	4	1

Success Evaluation Criteria

The evaluation of success shall be according to criteria and method outlined in Chapter 15: Evaluation.

Chapter 15: Evaluation

Schedule of Assessment

Table 15.1: Phased evaluation of progress in activities undertaken in **Technology Development**. The external review period is indicated in Red and shall be conducted through constituting a Project Review and Steering Group (PRSG) consisting of external scientific and business expert members and stakeholders in the activities of the Hub.

Ref. No.	Task Name	YEAR 1				YEAR 2				YEAR 3				YEAR 4				YEAR 5			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
T.1	**Dev. of Prod. & Prototypes from Existing Knowledge**																				
	NKP																				
	AI Cloud for CPS																				
	Codebase, APIs																				
	Digital twins hosted via NKP																				
	Cloud connected live testbeds																				
T.2	**Dev. of Tech. or Prod. Delivery in Sector Specific**																				
	ADAS for Tractor and Applicator																				
	Instru. Road for Traff. & Str. Health																				
	TIH-Industry-Academic JV Testbed 1																				
	Cloud Controlled 3D Printing																				
	AI enabled Smart Hospital																				
	Smart Drive System for Smart Cities																				
	TIH-Industry-Academic JV Testbed 2																				
	Wastewater Engineering Plant																				
	Energy Smart Building Microgrid																				
	AI enabled Mobile Remote Care																				
	Instrumented Classroom																				
	Smart Beamform. Next Gen Wireless																				
	TIH-Industry-Academic JV Testbed 3																				
	TIH-Industry-Academic JV Testbed 4																				
T.3	**Expert Driven Research**																				

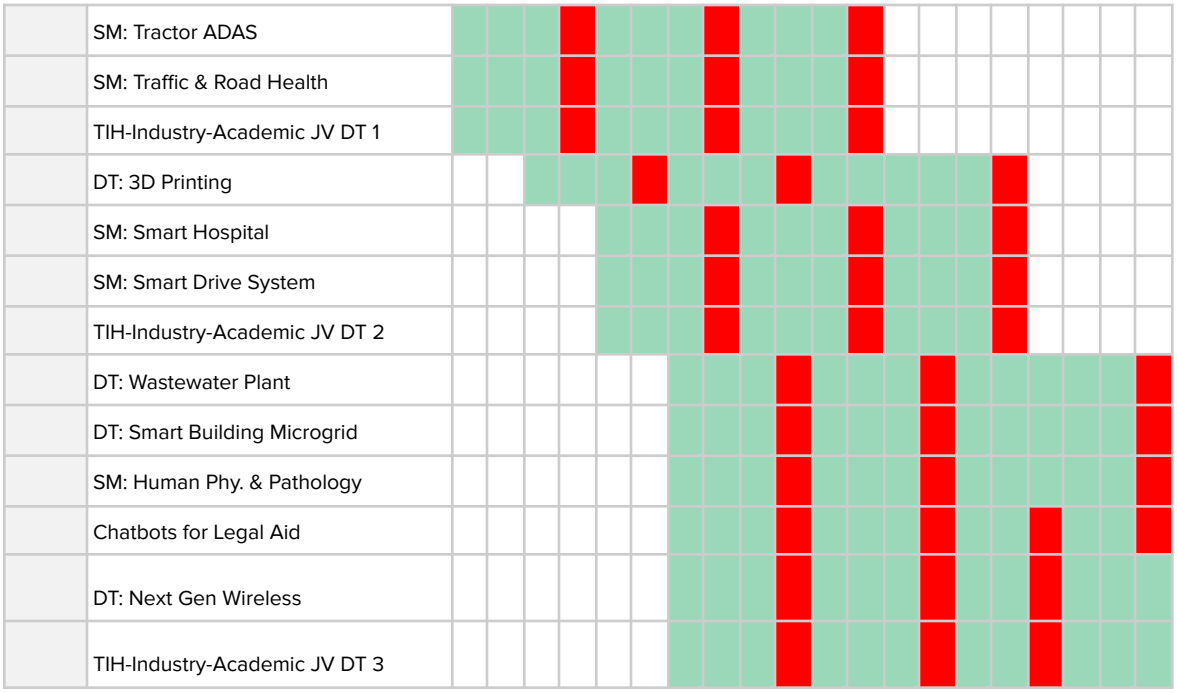


Table 15.2: Phased evaluation of progress in activities undertaken in **HRD and Skill Development**. The external review period is indicated in Red.

Ref. No.	Task Name	YEAR 1				YEAR 2				YEAR 3				YEAR 4				YEAR 5				YEAR 6			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
H.1	High-end Skill Development																								
	Workshops	1				1				1				1				1							
	ASTI					1																			
H.2	Chanakya UG																								
	Number of Fellows	20				82				94				94				50							
	Number of projects	10				41				47				47				25							
H.3	Chanakya PG																								
	Y1 Fellowships					15				15				16				16							
	Y2 Fellowships									15				15				16				16			
	Number of projects					15				15				16				16							
H.4	Chanakya PhD (DF)																								
	Y1 Fellowships	2				18				5															
	Y2 Fellowships					2				18				5											
	Y3 Fellowships									2				18				5							
	Y4 Fellowships													2				18				5			

H.5	Chanakya Post-doctoral																							
	Y1 Fellowships	2				18				5														
	Y2 Fellowships					2				18				5										
	Y3 Fellowships									2				18				5						
H.6	Chanakya Faculty																							
	Y1 Positions	2				2				2														
	Y2 Positions					2				2				2										
	Y3 Positions									2				2				2						
H.7	Chanakya Chair Prof.																							
	Y1 Positions					3				3														
	Y2 Positions									3				3										
	Y3 Positions													3				3						
H.8	New PG Laboratory																							

Table 15.3: Phased evaluation of progress in activities undertaken in **Entrepreneurship, Innovation and Startup Ecosystem**. The external review period is indicated in Red.

Ref. No.	Task Name	YEAR 1				YEAR 2				YEAR 3				YEAR 4				YEAR 5			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
E.1	CPS-GCC																				
	Enrolment																				
	Training																				
	Competition																				
	Grand Challenge																				
E.2	CPS-PRAYAS																				
	Enrolment																				
	Training																				
	Maker Phase																				
	Venture Phase																				
E.3	CPS-EIR																				
	Enrolment																				
	Training																				
	Idea to Realization																				
E.4	CPS Startup Ignition																				
E.5	CPS-TBI																				

E.4	CPS-DIAL																				
E.5	CPS-SSS																				

Table 15.4: Phased evaluation of progress in activities undertaken in the **International Collaborative Research Program**. The external review period is indicated in Red.

Ref. No.	Task Name	YEAR 1				YEAR 2				YEAR 3				YEAR 4				YEAR 5			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
C	Collaborative Program																				
	Y1 Programs	1				2				1											
	Y2 Programs					1				2				1							
	Y3 Programs									1				2				1			

Tools of Review

Table 15.5: SMART Goal Reporting template for periodic review of sub-components of a project. Shall be submitted separately for each sub-component by a team or individual.

Employee Name, Designation, Emp. Code, Team		
Initial Goal	Write the goal you have in mind	
Specific	What do you want to accomplish? When do you want to do this? Why is this a goal?	
Measurable	How can you measure progress and know if you have successfully met your goal?	
Achievable	Do you have the skills required to achieve the goal? If not, can you obtain them? What is the motivation for this goal? Is the amount of effort required on par with what the goal will achieve?	
Relevant	Why am I setting this goal now? Is it aligned with overall objectives?	
Time-bound	What is the deadline and is it realistic?	
SMART Goal	Review aht you have written, and craft a new goal statement based on what the answers to the questions above have revealed.	

Table 15.6: Project specific Action Plan template to be used for different components of AI4ICPS.

Project Name				Project Manager		
Action	Responsible	Priority	Status	Start	End	Notes
Goal 1.1		High				
Goal 1.2		Medium				
Goal 2		Low				

Table 15.7: Project Goals and Objectives SMART Planning and Reporting template to be used for a program or project of AI4ICPS.

SMART Goals	**S**pecific	**M**easurable	**A**ction-Oriented	**R**elevant	**T**ime-Oriented
Define Goals	1.	2.	3.	4.	5.
Small Measurable and Attainable Steps for each Goal					
	Step Description		Time Required		Set Deadline
Goal 1					
1.1					
1.2					
Goal 2					
2.1					
2.2					
Further Planning					
Detail Resources Required					
Define Potential Obstacles					
Plans for Overcoming Obstacles					
Desired Outcome					
Define Measurements for Success					
Describe Outcome of Achieved Goal					

Table 15.8: Revenue Goal Planning and Reporting template for AI4ICPS.

Fiscal Year Start Date						
Program Name		Q1	Q2	Q3	Q4	Total
Item 1	Year Prior					
	Revenue Goal					
	% of Change					

Annexure A.1: Policy on Human Resources

Staffing structure

AI4ICPS shall follow a hierarchical structure for job reporting which follows the organizational structure. Nonetheless, each role has a pre-specified and called out engagement as shall be defined at the start of the tenure, and each role shall be guided by the goal based Monitoring Arrangements. All matters not related to assignment reported shall be reported to GM - HR.

Recruitment policy

The staff recruitment shall follow an on demand based recruitment call and all recruitments shall be for a fixed tenure, subject to renewal post review. It is preferred to have a recruitment for at least a period of 1 year. All recruitment advertisements and employee joining formalities shall be preferably made through the GM - HR. It shall be through an open advertisement call.

Compensation and Wages policy

The recruited staff shall be paid a consolidated amount per month, guided by prevailing industry standards to keep it competitively fair. Nonetheless, each position shall be mitied by the maximum pay as defined in Table A.1.1. Fairness to the extent possible shall be maintained in accordance with Code on Wages, 2019. No additional benefits shall be admissible, and no breakup of the Cost to Company (CTC) shall be admissible for arriving at the pay structure. Notwithstanding any of these, the HGB shall have the final right of decision and modifications to the terms and conditions from time to time as deemed required. An employee shall not disclose their play structure with another.

The positions CHANAKYA Faculty, CHANAKYA Post Doc., CHANAKYA Doctoral, CHANAKYA PG, CHANAKYA UG, CHANAKYA Chair Professor shall draw a consolidated Fellowship / Honorarium guided at fixed rates per the table, and are not guided by the terms of Salary. These shall be guided according to engagement terms laid out in

- Annexure H.2: Under-Graduate Fellowship (CHANAKYA-GI)
- Annexure H.3: Post-Graduate Fellowship (CHANAKYA-PG)
- Annexure H.4: PhD Fellowship (CHANAKYA-DF)
- Annexure H.5: Post Doctoral Fellowship (CHANAKYA-PD)
- Annexure H.6: Research Assistant Professor (CHANAKYA Faculty)
- Annexure H.7: Chair Professor (CHANAKYA Chair Professor)

Table A.1.1: Consolidated pay structure per month in Lakhs in INR. Indicates max. pay and incr./yr

	Year 1	Year 2	Year 3	Year 4	Year 5	PA Incr.
Chief Exec. Officer (CEO)	3.00	3.30	3.63	3.99	4.39	10%
Chief Innov. Officer (CIO)	1.80	1.98	2.18	2.40	2.64	10%
Chief Tech. Officer (CTO)	1.80	1.98	2.18	2.40	2.64	10%
Chief Operat. Officer (COO)	1.80	1.98	2.18	2.40	2.64	10%
Engineering Manager (EM)	1.50	1.65	1.81	1.99	2.20	10%
Product Manager (PM)	1.50	1.65	1.81	1.99	2.20	10%
General Manager (GM) Finance	1.00	1.10	1.21	1.33	1.46	10%
GM - Legal	0.75	0.83	0.91	0.99	1.10	10%
GM - Human Resources	0.75	0.83	0.91	0.99	1.10	10%
Project Engineer (PE)	0.50	0.55	0.60	0.67	0.73	10%
Business Associate	0.75	0.83	0.91	0.99	1.10	10%
Marketing Associate	0.75	0.83	0.91	0.99	1.10	10%
Legal Associate	0.50	0.55	0.60	0.67	0.73	10%
IP Manager	0.50	0.55	0.60	0.67	0.73	10%
Tech. Support Executive (TSE)	0.35	0.38	0.42	0.47	0.51	10%
Accountant	0.35	0.38	0.42	0.47	0.51	10%
Executive Secretary	0.35	0.38	0.42	0.47	0.51	10%
CHANAKYA Faculty	1.25	1.25	1.25	-	-	-
CHANAKYA Post Doc.	0.80	0.88	0.96	-	-	10%
CHANAKYA Doctoral	0.31	0.31	0.35	0.35	-	-
CHANAKYA PG	0.12	0.12	-	-	-	-
CHANAKYA UG	0.10	-	-	-	-	-
CHANAKYA Chair Professor	0.25	0.25	0.25	-	-	-

Training and Professional Development policy

All employees shall undergo annual training, organized by GM-HR, including HR management, innovation thinking, inclusive workspaces, corporate communication. Non-technical employees shall undergo internal training to appraise them about AI, ML and ICPS which forms the core of the organization and every employee is expected to have a basic understanding of them. Based on their nature of their roles, employees shall also undergo specialized training from external agencies and benefit from AI4ICPS upskilling workshops for professional development. Technical employees shall undergo training on financial practices, Law, IP matters.

Payroll and Timekeeping policy

Wages shall follow needs for minimum wage, fair wage, living wage. Standard deductions on Payroll shall include standard Taxes as governed by the Laws of the Land which shall include but are not limited Income Tax, Professional Tax. They shall be revised based on revisions in the applicable Laws of the Land. In case of any additional benefits being provided by the Employer which shall require either a co-pay or deduction, such shall also be applicable and any matters of such policy changes shall be notified in advance to the best extent possible.

Advanced pay and bonus shall not be practiced.

Nominal working hours for an Employee, CHANAKYA Faculty, CHANAKYA Post Doctoral Fellow, CHANAKYA Doctoral Fellow and applicable leaves shall be guided according to Table 9.6. Similarly the guidelines for other positions shall be guided according to Table 9.7.

A work-week shall generally include Monday - Friday, and nominal active working day time shall be 8 AM - 5 PM including an hour of break time. Nonetheless, works on innovation shall require extraordinary considerations on times and schedules per demand of the assignment which shall be accordingly laid out as required for a project. Such needs to be identified by the Reporting manager for an Employee.

Performance Review and Management policy

All employees shall be subject to periodic performance reviews which shall nominally be annual. However based on need there may be mid-term reviews as well. The review shall be based on both professional and workplace conduct. The review of professional performance shall follow use of Key Performance Indicators (KPI) and Key Results Areas (KRA), wish shall be based on per-term Goals declaration (Table 9.8) and mid-term and post-term Reporting (Table 9.9) self submitted by an employee to the Reporting manager. An Employee who is also a Reporting manager shall be collectively also reporting their team performance, and make use of project outcome reports using Table 9.10 and Table 9.11. The General Administration and Management

Team shall also be making use of the Revenue Goal Planning and Reporting using Table 9.12. These proceedings and reports shall be of confidential nature and coordinated by GM - HR for all levels. The General Administration and Management team including CEO, CIO, CTO, COO shall be reviewed by the HGB. A standardized policy on review and management shall be followed and shall be pre-term declared to all Employees including any ratifications to it brought in order to comply with the

Discipline Management policy

Employees shall adhere to a Formal Workplace Dress Code during dealings at AI4ICPS, and as needed for any field engagement they shall adhere to a dress code suited for the assignment. They shall abide by courteous and polite behaviour, and shall encourage maintaining a high class of productivity and work ethics. Background verification of any Employee shall be part of practices to be followed by the Employer and coordinated by GM - HR.

Any disputes or concerns arising in respect of the peer level of an employee on matters of assignments shall be reported to their Reporting manager. Any disputes out of work arising between Employees shall be brought to the notice of the GM - HR at the earliest, including those where one party to the conflict may be on an organizational reporting hierarchy placed above the other. Any matters where the GM-HR is a party to the dispute shall be brought to the notice of the COO including those where one party is the CIO or the CTO. Any matters where the COO and GM-HR is a party to the dispute shall be brought to the notice of the CEO. Any matters where the GM-HR, COO, CEO are party to the dispute shall be brought to the notice of the Chairperson HGB. Detailed policy on dispute resolution and workplace harassment reporting shall be formulated by the HGB and updated periodically to be accommodative of the demand of time. All disputes, disciplinary actions shall be kept documented, but shall not be accessible to anyone not party to such disputes. Parties to keep such communication shall keep it confidential at all times. Any dispute shall not be resolved by the standard mechanism if not reported following the standard reporting measures.

Organization Development policy

The employees shall contribute to the overall target of being able to achieve the goal of self reliance and deliver the nominal set of tangible targets as laid in a phased manner. This shall be achieved by identifying challenges and problems, assessing the situation, planning of actions, implementation of planned actions, gathering intervention related data, analyzing results and providing feedback to stakeholders. Detailed policies shall be framed in due course of operation.

Annexure A.2: Policy on Intellectual Property

AI4ICPS shall abide by all fairness to the extent possible with the Patents (Amendment) Act 2005 and its predecessors, TradeMarks (Amendment) Act, 2010 and its predecessors, Copyright Act, 1957, and its predecessors. It shall also abide by conventions to which the Land is also a signatory including but not limited to Paris Convention for the Protection of Industrial Property, 1883, Patent Cooperation Treaty, 1970, Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), 1995, and to the best extent of any revisions over time.

The policy regarding intellectual property rights shall include obligations thereunder which includes the nature of intellectual property, its ownership, exploitation, technology transfer and confidentiality requirements. It shall address issues in order to safeguard the principles of academic freedom, allocate a fair share of the benefits to all those involved in the creation of intellectual property, and encourage the drive to conduct research, innovate, transfer technology and benefit materially from the generation of intellectual property.

Intellectual property created by Employees and direct beneficiary of AI4ICPS where there is use of usual AI4ICPS resources only shall be assigned to it. Such cases include inventions through the use of AI4ICPS supported resources and which may be commercializable by AI4ICPS. Any intellectual property created through sponsored research where the sponsor does not claim intellectual property rights. In the case of all such property the creator will retain the moral right to be named. Royalty accruing or any type of payment received from the commercialization of AI4ICPS owned intellectual property will be shared per a clearly defined term with all possibility of fairness to prevail. A standardized format of Invention Disclosure shall be used for the purpose of reporting initial findings on innovation to enable IP Managers start IP filing processes.

Separate guidelines shall be laid out for engagement with Incubatees and EIRs who may also be making partial use of such resources.

Any IP owned by IIT Kharagpur or any other institution or entity which is brought down to AI4ICPS for executing a project shall continue to be guided by the exclusive IP rules associated with the owner of such background IP. Benefits of an IP which is created jointly by AI4ICPS along with multiple parties executing a project shall be guided by pre-agreed IP clause terms and conditions.

All discussions, policy matters and their periodic revisions to suit the need of the time, maintenance of IP, commercialization terms shall be undertaken by the GM - Legal along with IP Managers. An agreement to this policy shall be executed with all Employees during joining.

Table A.2.1: Layout of a sample form that may be used for invention disclosure filing.

<table>
<tr><td colspan="2">Title of Invention:</td><td>Principal Inventor</td><td>Discloser</td></tr>
<tr><td colspan="4">Description of the invention
1.
2.
3.</td></tr>
<tr><td>State of prior art</td><td>Prevailing:
1.
2.</td><td>Literature search:
1.
2.</td><td>Patent search:
1.
2.</td></tr>
<tr><td colspan="4">Technical details:
1.
2.</td></tr>
<tr><td>Novelty:
1.
2.</td><td>Inventiveness:
1.
2.</td><td>Advantages:
1.
2.</td><td>Testing:</td></tr>
<tr><td>Inventor 1:</td><td>Inventor 2:</td><td>Inventor 3:</td><td>Inventor 4:</td></tr>
<tr><td rowspan="2">Project and Funding related information</td><td>Sponsor:</td><td>Contract No.:</td><td>PI:</td></tr>
<tr><td colspan="2">Sponsor’s consent to filing of invention:</td><td>Other agreements:</td></tr>
<tr><td colspan="4">Standard clause on truthfulness of this declaration</td></tr>
<tr><td>Signature of Inv. 1:</td><td>Signature of Inv. 2:</td><td>Signature of Inv. 3:</td><td>Signature of Inv. 4:</td></tr>
</table>

Any material transferred to a party outside of AI4ICPS including those to any academic and research institutions which may be potential for commercialization and are of confidential nature in general shall be undertaken using a standard Material Transfer Agreement (MTA), terms and clauses of which shall be laid out by GM - Legal.

GM - Legal shall coordinate and organize regular Professional Development programs for internal stakeholder and employees to appraise them about IP policies and good practices. These shall be compulsory and diligence monitored by GM - HR during annual review process.

Annexure A.3: Policy on Confidentiality and Non Disclosure

A standard policy on confidentiality and non disclosure (CNDA) shall be in place coordinated by GM - Legal, executed by all employees, and any external party with AI4ICPS. The policy and an agreement to that end shall include at least the following terms. Such policy matters shall be updated over time to match the requirements and Law of the Land.

1. Trade Secrets: Recipient understands and acknowledges that Discloser's trade secrets consist of information and materials that are valuable and not generally known by Discloser's competitors. Discloser's trade secrets include:
    a. Any and all information concerning Discloser's current, future and proposed products and services, including, but not limited to, research and invention disclosure or pertinent to intellectual property, unpublished manuscripts or computer code (both source code and object code), contents of web sites, drawings, specifications, notebook entries, laboratory notes, experimental results and discussion, technical notes and graphs, computer printouts, technical memoranda and correspondence, financial analysis, business plans and business strategies.
    b. Information and materials related to Discloser's purchasing, accounting and marketing, including, but not limited to, marketing plans, sales data, unpublished promotional material, cost and pricing information and customer lists.
    c. Information of the type described above which Discloser obtained from another party, and which Discloser treats as confidential, whether or not owned or developed by Discloser.
2. Purpose of Disclosure: Recipient shall make use of Discloser's trade secrets only for the purpose of evaluating Discloser's products and business plans for furthering the Parties' research collaboration relationship.
3. Nondisclosure: In consideration of Discloser's disclosure of its trade secrets to Recipient, Recipient agrees that it will treat Discloser's trade secrets with the same degree of care and safeguards that it takes with its own trade secrets, but in no event less than a reasonable degree of care. Recipient agrees, that without Discloser's prior written consent, Recipient will not:
    a. disclose Discloser's trade secrets to any third party;
    b. make or permit to be made copies or other reproductions of Discloser's trade secrets; or
    c. make any commercial use of the trade secrets.

Recipient will not disclose Discloser's trade secrets to Recipient's employees, business colleagues, agents and consultants, unless (1) they need to know the information in connection with their employment duties; and (2) the Parties personally agree in writing to be bound by the terms of this Agreement.

4. Return of Materials: Upon Discloser's request, Recipient shall promptly (within 30 days) return all original materials provided by Discloser and any copies, notes or other documents in Recipient's possession pertaining to Discloser's trade secrets.
5. Exclusions: This agreement does not apply to any information which:
    a. was in Recipient's possession or was known to Recipient, without an obligation to keep it confidential, before such information was disclosed to Recipient by Discloser;
    b. is or becomes public knowledge through a source other than Recipient, and through no fault of Recipient;
    c. is independently developed by or for Recipient;
    d. is or becomes lawfully available to Recipient from a source other than Discloser; or
    e. is disclosed by Recipient with Discloser's prior written approval.
6. Term: This Agreement and Recipient's duty to hold Discloser's trade secrets in confidence shall remain in effect until the above-described trade secrets are no longer trade secrets or until Discloser sends Recipient written notice releasing Recipient from this Agreement, whichever occurs first.
7. No Rights Granted: Recipient understands and agrees that this Agreement does not constitute a grant or an intention or commitment to grant any right, title or interest in Discloser's trade secrets to Recipient.
8. Warranty: Discloser warrants that it has the right to make the disclosure under this Agreement.
9. Injunctive Relief: Recipient recognizes and acknowledges that any breach or threatened breach of this Agreement by Recipient may cause Discloser irreparable harm for which monetary damages may be inadequate. Recipient agrees, therefore, that Discloser shall be entitled to an injunction to restrain Recipient from such breach or threatened breach. Nothing in this agreement shall be construed as preventing Discloser from pursuing any remedy at law or in equity for any breach or threatened breach of this agreement.
10. Modifications: All additions and modifications to the Agreement must be made in writing and must be signed by both parties.
11. No Agency: This Agreement does not create any agency or partnership relationship between the parties.
12. Applicable Law: This Agreement is made under, and shall be construed to laws of India and Parties submit to jurisdiction of courts at Kharagpur.

Annexure T.1: Development of Products and Prototypes from Existing Knowledge

The primary task to be undertaken under this component is to develop TRL6 for the AI4ICPS product and service delivery backbone. These shall be as described below.

Program Manager: CTO

Table T.1.1: Schedule of delivery of products and processes to meet the targets.

Product No.	Name	Year of Delivery
1.	National Knowledge Portal (NKP)	Year 3
2.	AI Cloud for CPS	Year 4
3.	Codebase, APIs, Datasets for CPS hosted on NKP	Year 4
4.	Digital Twins of 10 CPS hosted through NKP	Year 5
5.	Live Testbeds of 10 CPS with cloud connectivity	Year 5

Table T.1.2: Cost of Manpower for completing requirements of the target. Cost in INR to be calculated according to Table A.1.1.

Designation	Year 1	Year 2	Year 3	Year 4	Year 5
CTO	1	1	1	1	1
EM	4	4	4	4	4
PE	4	4	4	4	4
Exec. Secy.	1	1	1	1	1

Table T.1.3: Specification and Cost (in Lakhs of INR) of Equipments to be procured

Particulars	Specifications	Amount
HPC Nodes	Nodes of Nvidia Tesla v100, 120 TB storage, Intel SKL CPU	452.00
PC and IT equip.	PC, Laptop, Developer Work Stn., Projection Screens	100.00
Edge Comp., IoT	Wireless and fiber optic comm. switch, CAN bus connector	100.00

Annexure T.2: Development of Technology or Product Delivery in Specific Sectors

This set of activities shall be undertaken to service and create TRL4-6 level technology for the 9 CPS industry sectors which are identified as of interest for AI4ICPS. It shall contribute to creating 10 cloud connected Live testbeds across different CPS sectors to be made available through the NKP. These testbeds shall constitute the technology or product for specific sectors.

Program Manager: CTO

Table T.2.1: Schedule of delivery of technology or products in CPS sectors to meet the targets.

Product No.	Name	CPS Application Sector	Year of Delivery
1.	ADAS for Tractor and Applicator	Precision Agri. & Nutri. Sec.	Year 3
2.	Instrumented Road for Traffic & Str. Health	Transportation	Year 3
3.	TIH-Industry-Academic JV Testbed 1[42]	Open	Year 3
4.	Cloud Controlled 3D Printing	Manufacturing	Year 4
5.	AI enabled Smart Hospital	Healthcare	Year 4
6.	Smart Drive System for Smart Cities	Transportation	Year 4
7.	TIH-Industry-Academic JV Testbed 2	Open	Year 4
8.	Wastewater Engineering Plant	Environment & Pollution	Year 5
9.	Energy Smart Building Microgrid	Infrastructure & Energy	Year 5
10.	AI enabled Mobile Unit for Remote Care	Healthcare	Year 5
11.	Instrumented Classroom	Education	Year 5
12.	Smart Beamforming for Next Gen Wireless	Communication	Year 5
13.	TIH-Industry-Academic JV Testbed 3	Open	Year 5
14.	TIH-Industry-Academic JV Testbed 4	Open	Year 5

[42] Shall be selected through open calls and may include Projects of Innovation and Collaborative Research Interests

Table T.2.2: Cost of Manpower for completing requirements of the target. Cost in INR to be calculated according to Table A.1.1.

Designation	Year 1	Year 2	Year 3	Year 4	Year 5
EM	4	4	4	4	4
PE	4	4	4	4	4
Exec. Secy.	1	1	1	1	1

Table T.2.3: Specification and Cost (in Lakhs of INR) of Equipments to be procured

Particulars	Specifications	Amount
CPS Testbed	Sensors, nodes, actuators for Plants with connectivity	150.00
PC and IT equip.	PC, Laptop, Developer Work Stn., Computer Network	34.00
Edge Comp., IoT	Wireless and fiber optic comm. switch, CAN bus connector	25.00

Annexure T.3: Expert Driven Research

This set of activities will be project linked activities to look at translating TRL3 to TRL4 for creating a bouquet of offerable IPs and products. This shall be centered around primarily creating Digital twins of the 10 Live Testbeds to be hosted on the NKP as indicated in T.2. The Project Engineers involved in this component shall also support creating the different components of the primary product and service enablers for AI4ICPS which are indicated in T.1.

Program Manager: CTO

Table T.3.1: Schedule of delivery of expert driven research in CPS sectors to meet the targets. These shall include the Digital Twin of the cloud connected CPS plants in Table T.2.1.

Product No.	Name	CPS Application Sector	Year of Delivery
1.	Simulator of Tractor and Applicator ADAS	Precision Agri. & Nutri. Sec.	Year 3
2.	Road Traffic & Structural Health Simulator	Transportation	Year 3
3.	TIH-Industry-Academic JV Digital Twin 1[43]	Open	Year 3
4.	Digital Twin of 3D Printing Process	Manufacturing	Year 4
5.	Simulator of a Smart Hospital Processes	Healthcare	Year 4
6.	Simulator for Smart Drive System	Transportation	Year 4
7.	TIH-Industry-Academic JV Digital Twin 2	Open	Year 4
8.	Digital Twin of Wastewater Engg. Plant	Environment & Pollution	Year 5
9.	Digital Twin of Smart Building Microgrid	Infrastructure & Energy	Year 5
10.	Simulator of Human Physiology & Pathology	Healthcare	Year 5
11.	Chatbots for Legal Aid	Judiciary, Legal & Law Enf.	Year 5
12.	Digital Twin of Next Gen Wireless	Communication	Year 5
13.	TIH-Industry-Academic JV Digital Twin 3	Open	Year 5

[43] Shall be selected through open calls and may include Projects of Innovation and Collaborative Research Interests

Table T.3.2: Cost of Manpower for completing requirements of the target. Cost in INR to be calculated according to Table A.1.1.

Designation	Year 1	Year 2	Year 3	Year 4	Year 5
EM	2	2	2	2	2
PM	2	2	2	2	2
PE	10	10	10	10	10

Table T.3.3: Specification and Cost (in Lakhs of INR) of Equipments to be procured

Particulars	Specifications	Amount
PC and IT equip.	PC, Laptop, Developer Work Stn., Computer Network	94.00
Edge Comp., IoT	Wireless and fiber optic comm. switch, CAN bus connector	50.00

Annexure H.1: High End Skill Development

This activity shall consist of the following sub-activities

Professional Skill Development Workshop (CPS-PSDW) for up-/re-skilling of existing Industry workforce. This shall be through 2 weeks, 25 hours/week workshop in a batch of at least 90 students. It shall have a mix of taught lectures and hands on practical sessions. Set of 5 workshops shall be organized over the period of 5 years at the least to be supported by SERB NM-ICPS. Additional workshops will be funded through external funding and participant subscription. The workshop shall be conducted by Research Assistant Professor, Chair Professor, PhD and PostDocs, and Engineering teams of AI4ICPS.

Program Manager: CIO

Table H.1.1.1: Component wise cost distribution in this program

Particulars	Details	Amount (INR)
Honorarium for Instructor	Rs. 10,000 per hour x 50 Hours per program	13,95,000.00
Contingency & Misc.	Expenses refreshments, incidentals, travels, etc.	4,00,000.00
Teaching Materials	Preparation of teaching aids, notes, etc.	3,00,000.00
Books, Journals, Cloud	Costs for Books, Journals, Cloud compute, etc.	1,55,000.00
TOTAL		22,50,000.00

Table H.1.1.2: Distribution of workshops and beneficiaries across years

	Year 1	Year 2	Year 3	Year 4	Year 5
No. of Workshop	1	1	1	1	1
No. of Beneficiaries	90	90	90	90	90

Advanced Skill Training Institute (CPS-ASTI) shall be for training graduates from Diploma / Vocational training institutes, in order to prepare them for Industry developing and deploying AI and ML interventions to conventional plants across CPS sectors. This shall be through selecting an Institute through a competitive call, and developing curriculum and labs for them to equip the institute build a comprehensive component of their programs for this new age transition. The target is to train 100 candidates in a span of 2 years.

Program Manager: CIO

Table H.1.2.1: Component wise cost distribution per institute

Particulars	Details	Amount (INR) in Year 2	Amount (INR) in Year 3
Honorarium for Instructors	Rs. 10,000 per hour x 40 Hours minimum	6,30,000.00	6,30,000.00
Contingency & Misc.	Expenses refreshments, incidentals, local travels, etc.	40,000.00	40,000.00
CPS Equipment	AI4ICPS Lab setup in the institute	3,60,000.00	-
Teaching Materials	Preparation of teaching aids, notes, etc.	30,000.00	30,000.00
Books, Journals, Cloud	Costs for Books, Journals, Cloud compute, etc.	20,000.00	20,000.00
TOTAL		6,00,000.00	4,00,000.00

Table H.1.2.2: Distribution of institutes and beneficiaries across years

	Year 1	Year 2	Year 3	Year 4	Year 5
No. of Institutes	-	1	-	-	-
No. of Beneficiaries	-	90	90	-	-

Annexure H.2: Under-Graduate Fellowship (CHANAKYA-GI)

This activity shall consist of awarding 340 UG project fellowships in total, for a period of 10 months for each award, program spanning for 5 years. The fellowship program shall support monthly fellowship and special funds for executing student projects, preferably final year projects which are aligned on AI and ML interventions to ICPS. Projects shall be peer reviewed for selection based on their merit and innovation potential. These projects are in groups of 2 students each. This is to promote innovations on rapidly translatable interventions, which may also be a sub-component of a bigger product, and can be executed in 10 months. This is to promote students to take up careers in innovation while learning about TRL4-6 translation through projects.

Program Manager: CIO

Table H.2.1: Component wise cost distribution per component of the Fellowship

Particulars	Details	Amount (INR)
Fellowship per person	Rs. 10,000.00 per month x 10 months	1,00,000.00
Development Fund	Project to be undertaken in group of 2 students	1,00,000.00
HPC Nodes	Nodes of Nvidia Tesla v100, 120 TB storage, Intel SKL CPU	1,00,00,000.00
PC and Office IT	Desktop PC, Printers, Laptop as needed	1,00,000.00
AMC Charges	AMC of PC and Office IT	10,000.00
Furniture	Furnishing of working space for the students	85,00,000.00

Table H.2.2: Cost of components for completing requirements of the target. Cost in INR to be calculated according to Table A.1.1 and Table H.2.1.

Designation	Year 1	Year 2	Year 3	Year 4	Year 5
Fellowship	20	82	94	94	50
No. of Projects with Dev. Funds	10	41	47	47	25

Annexure H.3: Post-Graduate Fellowship (CHANAKYA-PG)

This activity shall consist of awarding a total of 62 PG program fellowships in total, for a period of 2 years for each award, program spanning for 5 years. The fellowship shall be paid monthly following standard MHRD rates. Additional grant for executing the final year thesis project on AI and ML for ICPS. This activity is anticipated to result in a new PG program leading to the award of a M. Tech degree along the lines of AI and ML for ICPS. Fellowship matched to MHRD guidelines.

Program Manager: CIO

Table H.3.1: Component wise cost distribution per entity of the Fellowship

Particulars	Details	Amount (INR)
Fellowship per head (Y1)	Rs. 12,400.00 per month x 12 months	1,48,800.00
Fellowship per head (Y2)	Rs. 12,400.00 per month x 12 months	1,48,800.00
Development Fund	Project to be undertaken individually	2,00,000.00
HPC Nodes	Nodes of Nvidia Tesla v100, 120 TB storage, Intel SKL CPU	75,00,000.00
PC and IT equip.	PC, Laptop, Developer Work Stn., Computer Network	1,00,000.00
AMC Charges	AMC of PC and Office IT	10,000.00
Edge Comp., IoT	Wireless and fiber optic comm. switch, CAN bus	25,00,000.00
Furniture	Furnishing of working space for the students	35,00,000.00

Table H.3.2: Cost of components for completing requirements of the target. Cost in INR to be calculated according to Table A.1.1 and Table H.3.1.

Designation	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6 [44]
No. of Fellowship (Y1)	-	15	15	16	16	-
No. of Fellowship (Y2)	-	-	15	15	16	16
No. of Projects with Dev. Funds	-	15	15	16	16	-

[44] Cost to be budgeted in Year 5.

Context and Background: One of the key objectives of the NM-ICPS to develop a highly skilled workforce in order to tackle the technological challenges in the broader CPS sector. Designing and implementing a dedicated and focused post-graduate program in the CPS sector is one of the key objectives of the TIHs.

Problems to be Addressed: Propose to initiate a new postgraduate M.Tech. program with a focus on AI and ML for CPS sectors to meet the needs of skilled manpower requirement in the related industry. The following sections elaborate various aspects of the proposed program.

Aims and Objectives:

1. equip incoming students with a diverse and interdisciplinary background with the fundamental knowledge and applied skills in the area of AI and ML for CPS applications,
2. provide state-of-the-art computing infrastructure for honing their skills,
3. engage the students in a year-long project together with an industry partner to deploy AI and ML technologies in a CPS product, among others.

Strategy: IIT Kharagpur has a unique strength in order to initiate the proposed PG program by virtue of having a dedicated Center of Excellence in AI (COE-AI) with eight (including joint) faculty members. Furthermore, departments such as Electrical Engineering, Computer Science and Engineering, Electronics and Electrical Communications Engineering and Mechanical Engineering each have several ongoing PG programs with a broad range of subjects that are being offered every semester which will be immensely beneficial for the students in the proposed program.

The proposed program shall be of duration of two years (fully residential - on campus), and will be hosted by COE-AI. The students are expected to take six core courses and four electives in their first year, followed by a year-long project in the second year.

A tentative list of core subjects and electives are given below. The subjects with an associated course number are already being offered by the IIT, while the ones marked asterisk are planned to be floated in near future.

A combination of core and elective courses will impart a strong foundation of AI and ML for CPS applications, and the breadth of electives will suitably cater to the diverse interests and choices of the incoming students.

The program will start after approval from the authorities of the host institution IIT Kharagpur. The mode of admission, examination and results, accommodation facilities and other factors will be in accordance with the existing policies of IIT Kharagpur.

Annexure H.4: PhD Fellowship (CHANAKYA-DF)

This activity shall consist of awarding a total of 25 Doctoral fellowship, for a period of 4 years for each award, program spanning for 5 years. The fellowship shall be paid monthly following standard SERB JRF/SRF rates. This activity is anticipated to result in training more Doctoral graduates with strong focus along the lines of AI and ML for ICPS, well skilled to accelerate innovation translation TRL1-6. Graduates of this program are expected to create similar technology innovation programs as the AI4ICPS and look at deeper inclusion of AI and ML for ICPS. Fellowship amount to be matched to prevailing SERB guidelines.

Program Manager: CIO

Table H.4.1: Component wise cost distribution per entity of the Fellowship

Particulars	Details	Amount (INR)
Fellowship per head (Y1)	Rs. 31,000.00 per month x 12 months	3,72,000.00
Fellowship per head (Y2)	Rs. 31,000.00 per month x 12 months	3,72,000.00
Fellowship per head (Y3)	Rs. 35,000.00 per month x 12 months	4,20,000.00
Fellowship per head (Y4)	Rs. 35,000.00 per month x 12 months	4,20,000.00
Travel	Conference overseas travel grant per year	3,00,000.00
PC and Office IT	Computer, Printer, Laptop and AMC	1,10,000.00
Furniture	Office furnishing for the fellow	1,25,000.00

Table H.4.2: Cost of components for completing requirements of the target. Cost in INR to be calculated according to Table A.1.1 and Table H.4.1.

Designation	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6[45]
No. of Fellowship (Y1)	2	18	5	-	-	-
No. of Fellowship (Y2)	-	2	18	5	-	-
No. of Fellowship (Y3)	-	-	2	18	5	-
No. of Fellowship (Y4)	-	-	-	2	18	5

[45] Cost to be budged in Year 5

Annexure H.5: Post Doctoral Fellowship (CHANAKYA-PD)

This activity shall consist of awarding a total of 25 Post-Doctoral fellowship, for a period of 3 years for each award, program spanning for 5 years. The fellowship shall be paid monthly following standard SERB RA rates. This activity is anticipated to result in training more Post-Doctoral Fellows with strong focus along the lines of AI and ML for ICPS, consisting of components of relevance to making products and processes along the theme of AI4ICPS, and well skilled to accelerate innovation translation TRL1-6. Fellows shall be working aligned to the technology development projects, working towards TRL1-6 along with Project Engineers, also mentor PhD, PG and UG projects on specific topics. Graduates of this program are expected to create similar technology innovation programs as the AI4ICPS and look at deeper inclusion of AI and ML for ICPS.

Program Manager: CIO

Table H.5.1: Component wise cost distribution per entity of the Fellowship

Particulars	Details	Amount (INR)
Fellowship per head (Y1)	Rs. 80,000.00 per month x 12 months	9,60,000.00
Fellowship per head (Y2)	Rs. 88,000.00 per month x 12 months	10,56,000.00
Fellowship per head (Y3)	Rs. 96,800.00 per month x 12 months	11,61,600.00
Travel	Conference overseas travel grant per year	3,00,000.00
PC and Office IT	Computer, Printer, Laptop	1,00,000.00
AMC	AMC of PC and Office IT per year	10,000.00
Furniture	Office furnishing for the fellow	1,25,000.00

Table H.5.2: Cost of components for completing requirements of the target. Cost in INR to be calculated according to Table A.1.1 and Table H.5.1.

Designation	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
No. of Fellowship (Y1)	2	18	5	-	-	-
No. of Fellowship (Y2)	-	2	18	5	-	-
No. of Fellowship (Y3)	-	-	2	18	5	-

Annexure H.6: Research Assistant Professor (CHANAKYA Faculty)

This activity shall consist of awarding a total of 6 Faculty fellowship, for a period of 3 years for each award, program spanning for 5 years. The fellowship shall be paid monthly following standard INSPIRE Faculty award rates. Faculty fellows shall have a strong focus along the lines of AI and ML for ICPS, consisting of components of relevance to making products and processes along the theme of AI4ICPS, and well skilled to accelerate innovation translation TRL1-6. Faculty Fellows shall be aligned to the technology development projects, working towards TRL1-6 along with Project Engineers, also mentor PostDocs, PhD, PG and UG projects on specific topics. They shall also be driving the Advanced Training schools and programs.

Program Manager: CIO

Table H.6.1: Component wise cost distribution per entity of this program.

Particulars	Details	Amount (INR)
Salary per head (Y1)	Rs. 1,25,000.00 per month x 12 months	15,00,000.00
Salary per head (Y2)	Rs. 1,25,000.00 per month x 12 months	15,00,000.00
Salary per head (Y3)	Rs. 1,25,000.00 per month x 12 months	15,00,000.00
Travel	Conference overseas travel grant per year	3,00,000.00
Contingency	Professional development fund per year	1,00,000.00
PC and Office IT	Computer, Printer, Laptop and AMC	1,10,000.00
Furniture	Office furnishing	5,00,000.00

Table H.6.2: Cost of components for completing requirements of the target. Cost in INR to be calculated according to Table A.1.1 and Table H.6.1.

Designation	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
No. of Positions (Y1)	2	2	2	-	-	-
No. of Positions (Y2)	-	2	2	2	-	-
No. of Positions (Y3)	-	-	2	2	2	-

Annexure H.7: Chair Professor (CHANAKYA Chair Professor)

This activity shall consist of awarding a total of 6 Chair Professor positions, for a period of 3 years for each award, program spanning for 5 years. The honorarium shall be paid monthly following standard Chair Professor recommendation rates of SERB and managed by the Host Institute of the concerned Faculty. This position also shall support a fixed amount for Travel and Contingency towards such costs in promoting activities of AI4ICPS. Chair Professors shall have a strong focus along the lines of AI and ML for ICPS and work towards identifying and scouting new innovations for their TRL1-6 translation, and promote the spirit of AI4ICPS along with overseeing the overall functioning of the Hub. Amongst others, they shall also mentor Faculty Fellows, PostDocs, PhD, PG and UG projects on specific topics. They shall also be driving the Advanced Training schools and programs.

Program Manager: CIO

Table H.7.1: Component wise cost distribution per entity of this program.

Particulars	Details	Amount (INR)
Honorarium per head (Y1)	Rs. 25,000.00 per month x 12 months	3,00,000.00
Honorarium per head (Y2)	Rs. 25,000.00 per month x 12 months	3,00,000.00
Honorarium per head (Y3)	Rs. 25,000.00 per month x 12 months	3,00,000.00
Contingency and TA	Per head per year, incl. International travel	1,25,000.00
Overhead for Host Institute	Paid in total to the HI based on the total bill raised for the complete program in a year	Lower of Rs. 1.0Lc or 10%

Table H.7.2: Cost of components for completing requirements of the target. Cost in INR to be calculated according to Table A.1.1 and Table H.7.1.

Designation	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
No. of Positions (Y1)	-	3	3	-	-	-
No. of Positions (Y2)	-	-	3	3	-	-
No. of Positions (Y3)	-	-	-	3	3	-

Annexure H.8: Laboratory for New PG Programme

This activity shall set up a specialized lab for the new PG program in AI and ML for ICPS. This shall be primarily for teaching purpose and during the spare time the equipment shall be used for students projects. This shall be operations from within AI4ICPS to have strong connections to the innovation ecosystem, and nurture technology innovation in a practical environment.

Program Manager: CIO

Table H.8.1: Component wise cost distribution per entity of the Fellowship

Particulars	Details	Amount (INR)
HPC Nodes	Nodes of Nvidia Tesla v100, 120 TB storage, Intel SKL CPU	2,00,00,000.00
PC and IT equip.	PC, Laptop, Developer Work Stn., Computer Network for Student Lab	50,00,000.00
Edge Comp., IoT	Wireless and fiber optic comm. switch, CAN bus connector, FPGA kits, Edge compute devices	1,00,00,000.00
CPS Testbed	Sensors, nodes, actuators for Plants with connectivity	1,00,00,000.00
Furniture	Furnishing of the laboratory space	20,00,000.00

Table H.8.2: Cost of components (in Lakhs of INR) for completing requirements of the target.

Designation	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Teaching Materials	20.00	-	-	-	-	20.00
Annual Maintenance Charge for Equipments and Contingency	6.00	6.00	6.00	6.00	6.00	30.00

Annexure E: Entrepreneurship, Innovation and Startup Ecosystem

Table E.1: Spectrum of TRL association with different components of this objective.

Program	TRL at Entry	TRL at Exit	Duration	Succession
Grand Challenges and Competitions (CPS-GCC) (Annexure E.1)	TRL 1-2	TRL4	1 Year	CPS-PRAYAS, CPS-EIR, CPS Startup Ignition
Promotion and Acceleration of Young and Aspiring Technology Entrepreneurs (CPS-PRAYAS) (Annexure E.2)	TRL4	TRL5	1 Year	CPS Startup Ignition
Entrepreneur in Residence (CPS-EIR) (Annexure E.3)	TRL1-3	TRL3-4	1 Year	CPS-PRAYAS, CPS Startup Ignition
CPS Startup Ignition (Annexure E.4)	TRL5	TRL6	1-3 Years	CPS-SSS
Seed Support System (CPS-SSS) (Annexure E.7)	TRL6	TRL7	1-3 Years	External Series A

Table E.2: Components to administer and manage the programs.

Component	Programs Managed
Technology Business Incubator (CPS-TBI) (Annexure E.5)	• Grand Challenges and Competitions (CPS-GCC) • Promotion and Acceleration of Young and Aspiring Technology Entrepreneurs (CPS-PRAYAS) • Entrepreneur in Residence (CPS-EIR)
Dedicated Innovation Accelerator (CPS-DIAL) (Annexure E.6)	• CPS Startup Ignition • Seed Support System (CPS-SSS)

Annexure E.1: Grand Challenges and Competitions (CPS-GCC)

These challenges shall be for encouraging early stage and pre-incubated inventions along lines of AI4ICPS, providing them quarterly residential support, training in respect of creating the minimum viable product (MVP) at TRL3, and creating a business model around the product. The Top-5 ideas per quarter shall be financially supported with a product creation grant for scaling their MVP to TRL3. A final competition between each of the Top-5 per quarter shall select the finalist to be funded to support their MVP scaling of TRL3 to TRL4. This shall be able to support every year 20 such ideas TRL3 ready MVP and 4 ideas at TRL4. Over the period of 5 years, this shall be able to support 20 ideas to TRL4. The participants shall be able to apply for other support programs as well, but not participate in any more than one program at a given time. It is anticipated that winners subsequently onboard CPS-PRAYAS.

Program Manager: CIO

Table E.1.1: Cost of Manpower for completing requirements of the target. Cost in INR to be calculated according to Table A.1.1.

Designation	Year 1	Year 2	Year 3	Year 4	Year 5
PE	2	2	2	2	2
Exec. Secy.	1	1	1	1	1

Table E.1.2: Cost (in Lakhs of INR) per unit component of the program per year.

Particulars	Specifications	Amount
Travel & Honorarium	Rs. 10 Lc / competition x 4 competitions/year	40.00
Miscellaneous	Rs. 2 Lc / competition x 4 competitions/year	8.00
Marketing	Rs. 3 Lc / competition x 4 competitions/year	12.00
Networking & Training	Rs. 2.5 Lc / competition x 4 competitions/year	10.00
Consumables	Rs. 5 Lc / competition x 4 competitions/year	20.00
Award for MVP to TRL3	Rs. 5 Lc / team x 5 teams / competition x 4 comp./yr	100.00
Prototyping Grant to TRL4	Rs. 5 Lc / competition winning team x 4 comp. / year	20.00

Table E.1.3: Cost of Components (in number of consumed units) for completing requirements of the target.

Designation	Year 1	Year 2	Year 3	Year 4	Year 5
No. of Competitions	4	4	4	4	4
Grand Challenge	1	1	1	1	1
No. of MVP to TRL3	20	20	20	20	20
No. of MVP to TRL4	4	4	4	4	4

Table E.1.4: Specification and Cost (in Lakhs of INR) of Capital expenditure

Particulars	Specifications	Amount
Furniture and Fixtures	Furnishing of a Lab / Makerspace for Hosting the GCC	25.00

Table E.1.5: Program subcomponents per year

Particulars	Specifications	Time
Enrolment	Call for proposals from Ideas in TRL1-2, 4 Competition Tracks.	Q1
Training	Workshops on Innovation Thinking, Value Proposition, Business Model Canvas, SWOT Analysis.	Q2
Competition	Top-5 ideas at TRL2 per Track specific competition awarded to scale them to TRL3. Total of 20 ideas supported per year for scaling them to TRL3.	Q3
Grand Challenge	Winner per Track is awarded to scale it to TRL4. Total of 4 ideas supported to scale upto TRL4.	Q4

Eligibility: This program shall be open primarily to student or early stage inventors. This shall not be restricted to only students of IIT Kharagpur. Program shall not enrol ideas mature beyond TRL2. Objective assessment procedures to be laid for each competition and challenge. Institutional or Company participations are not permitted.

General Guidelines: No incubation requirements. Workshops and training to be attended in person. Component procurement shall be on the inventor's budget of the award grant. Makerspace accessible to all inventors on this program.

Program Graduates: Shall apply to CPS-PRAYAS or CPS-EIR or CPS Startup Ignition Grant

Annexure E.2: Promotion and Acceleration of Young and Aspiring Technology Entrepreneurs (CPS-PRAYAS)

These activities shall be for on-site incubation for a period of 1 year each, 2 innovations at TRL4 shall be supported for TRL5 scaleup and validation in relevant CPS environments. The live Testbeds shall be extended to support such work. Additional support for technology buildup shall be promoted by the different Engineering staff of AI4ICPS. The Hub shall also be supporting some fabrication, consumables, etc. to these Entrepreneurs through best available resources, and preparing them with Business and Marketspace training support to look at exploring options of raising Ignition Grants and Venture Capital investments. In a period of 5 years, this shall be able to support 10 such Entrepreneurs. The participants shall be able to apply for other support programs as well, but not participate in any more than one program at a given time. Successful graduates may apply subsequently for CPS Startup Ignition Grant.

Program Manager: CIO

Table E.2.1: Cost (in Lakhs of INR) per unit component of the program per year.

Particulars	Specifications	Amount
Seed Grant	Rs. 10 Lc support per Innovation at TRL4 to scale to TRL5. Total of 2 innovations supported per year.	20.00
Travel & Honorarium	Provided to experts for their travel to evaluate ideas.	2.00
Miscellaneous	Incidental expenditures.	1.00
Raw Materials, Spares, etc.	Small component and raw materials for innovators. Rs. 2.5 Lc per innovation. Total of 2 such per year.	5.00
Fabrication, Synthesis, Testing, Consulting, etc.	Small component and raw materials for innovators. Rs. 2.5 Lc per innovation. Total of 2 such per year.	5.00

Table E.2.2: Cost of Components (in number of consumed units) for completing requirements of the target.

Designation	Year 1	Year 2	Year 3	Year 4	Year 5
No. of Entrepreneurs	2	2	2	2	2

Table E.2.3: Specification and Cost (in Lakhs of INR) of Capital expenditure

Particulars	Specifications	Amount
Furniture and Fixtures	Furnishing of a Lab / Makerspace for Hosting the GCC	100.00
Operation and Maintenance	Maintenance of the Makerspace and Incubation Facility. Rs. 20 Lc per year.	100.00

Table E.2.4: Program subcomponents per year

Particulars	Specifications	Time
Enrolment	Call for proposals from Ideas in TRL4	Q1
Training	Workshops on Innovation Thinking, Value Proposition, Business Model Canvas, SWOT Analysis.	Q2
Makerphase	Entrepreneurs work at the Makerspace to scale to TRL5. They engage with EM and CTO's team to work out the product.	Q3
Venturephase	Business Managers of the Hub coach them on Business Modeling, Venture Profiling, Idea pitching. Exit with TRL5.	Q4

Eligibility: This program shall be open primarily to young Entrepreneurs preferable below 45 years of age. This shall not be restricted to only affiliates of IIT Kharagpur. Program will not enroll ideas below TRL3. Program shall not enrol ideas mature beyond TRL4. Objective assessment procedures to be laid in detail. Startup Company participation is permitted.

General Guidelines: Incubation required. Workshops and training to be attended in person. Component procurement shall be on the inventor's budget of the award grant. Makerspace accessible to all inventors on this program. Some facilities in fabrication, testing, certifications, etc. shall be supported by the Hub.

Program Graduates: Shall apply to CPS Startup Ignition Grant.

Annexure E.3: Entrepreneur in Residence (CPS-EIR)

This activity shall support 20 entrepreneurs per year through a 1 year long fellowship program with on-site residency requirements at the AI4ICPS, who shall walk in with ideas at TRL1-3, explore and create MVP at TRL3-4. Candidates are expected to be Graduates in Engineering with a passion for innovation, but shall require hand-holding for understanding technology space in AI and ML intervention to CPS. During this period they shall learn about the nuances of technology development and participate in the various innovation workshops at AI4ICPS. Within this period they are anticipated to have built up a MVP at TRL3 and onboard on the CPS-PRAYAS, CPS Startup Ignition Grant for further scaling. This shall support a total of 100 beneficiaries in the program duration of 5 years. The participants shall be able to apply for other support programs as well, but not participate in any more than one program at a given time.

Program Manager: CIO

Table E.3.1: Cost (in Lakhs of INR) per unit component of the program per year.

Particulars	Specifications	Amount
Stipend	Rs. 30,000 p.m. x 12 months x 1 person	3.60

Table E.3.2: Cost of Components (in number of consumed units) for completing requirements of the target.

Designation	Year 1	Year 2	Year 3	Year 4	Year 5
No. of EIR	20	20	20	20	20

Table E.3.4: Program subcomponents per year

Particulars	Specifications	Time
Enrolment	Call for proposals from Ideas in TRL4	Q1
Training	Workshops on Innovation Thinking, Value Proposition, Business Model Canvas, SWOT Analysis, Venture Profiling, Pitching.	Q1
Idea to Realization	Entrepreneurs work at the Makerspace to scale to TRL5. They engage with EM and CTO's team to work out the product.	Q2-Q4

Table E.3.5: Specification and Cost (in Lakhs of INR) of Capital expenditure

Particulars	Specifications	Amount
Furniture and Fixtures	Furnishing of office space for EIR	25.00

Eligibility: This program shall be open primarily to young full time Entrepreneurs preferable below 45 years of age. Preferable are Graduates taking a year off for exploring Entrepreneurial pursuits. This shall not be restricted to only affiliates of IIT Kharagpur. Program shall not enrol ideas mature beyond TRL3. Objective assessment procedures to be laid in detail. Startup Company participation is not permitted.

General Guidelines: Incubation required. Workshops and training to be attended in person. Component procurement shall not be supported. Use of available infrastructure at the Hub is supported, but cannot be taken away. The thrust is to enable EIR to be competent to apply for other programs of the Hub and programs from Technology Development Board[46], National Science and Technology Entrepreneurship Development Board (NSTEDB)[47], Startup India[48], Biotechnology Industry Research Assistance Council (BIRAC)[49]. Makerspace accessible to all inventors on this program. Some facilities in fabrication, testing, certifications, etc. shall be supported by the Hub.

Program Graduates: Shall apply to CPS-PRAYAS, CPS Startup Ignition.

[46] http://tdb.gov.in/
[47] http://www.nstedb.com/
[48] https://www.startupindia.gov.in/
[49] https://www.birac.nic.in/

Annexure E.4: CPS Startup Ignition

This activity shall support 10 Early stage start-ups per year which have demonstrated a MVP at TRL5 through a funding ignition program without residency requirement, to enable scaling it to TRL6, and virtual incubation support. The participants shall be able to apply for other support programs as well, but not participate in any more than one program at a given time. This shall be for a fixed tenure of 1-3 year in phased support, and performance is monitored. The ignition support shall be met as a venture valued equity investment by AI4ICPS with investor's exit priority on subsequent investment.

Program Manager: CEO

Table E.4.1: Cost (in Lakhs of INR) per unit component of the program per year.

Particulars	Specifications	Amount
Ignition against Equity	Rs. 10 Lc per Startup x 10 Startups / year	100.00

Table E.4.2: Cost of Components (in number of consumed units) for completing requirements of the target.

Designation	Year 1	Year 2	Year 3	Year 4	Year 5
No. of Startups supported	10	10	10	10	10

Table E.4.3: Specification and Cost (in Lakhs of INR) of Capital expenditure.

Particulars	Specifications	Amount
Furniture and Fixtures	Furnishing of office space for EIR	62.50

Eligibility: This program shall be open primarily to Startups established as a Company in India. This shall not be restricted to only affiliates of IIT Kharagpur. Program shall not enrol ideas mature beyond TRL5. Objective assessment procedures to be laid in detail, including process for valuation of a Startup and Equity investment process. Shall be coordinated and services facilitated by the CPS-TBI. Startup Company participation is permitted.

General Guidelines: Incubation required. Workshops and training to be attended in person. Component procurement shall not be supported. Use of available infrastructure including Manpower at the Hub shall be on a cost paid basis.

Program Graduates: Shall apply to CPS-Seed Support System

Annexure E.5: Technology Business Incubator (CPS-TBI)

This shall be for creating the ecosystem for coordinating and organizing the various Incubator programs, supporting the Business ecosystem understanding for new ventures, and for hand holding participants in the CPS-GCC, CPS-PRAYAS, CPS-EIR. This shall be a dedicated unit overseeing the programs including organizing special workshops for marketing, networking, launchpads, and also build and operationalize a common laboratory space, makerspace for supporting these programs.

Program Manager: COO

Table E.5.1: Cost of Manpower for completing requirements of the target. Cost in INR to be calculated according to Table A.1.1.

Designation	Year 1	Year 2	Year 3	Year 4	Year 5
GM - Finance	1	1	1	1	1
Mkt. Assoc.	2	2	2	2	2
Legal Assoc.	1	1	1	1	1
Accountant	1	1	1	1	1
TSE	1	1	1	1	1

Table E.5.2: Cost (in Lakhs of INR) of program components and services.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5
Travel	3.60	3.60	3.60	3.60	3.60
Utilities and Maintenance	19.00	19.00	19.00	19.00	19.00
Marketing, Networking, Publicity	18.00	18.00	18.00	18.00	18.00
Training Programs, Events, Startup Resonators	27.00	27.00	27.00	27.00	27.00
Consumables	12.00	12.00	12.00	12.00	12.00
Miscellaneous	5.80	5.80	5.80	5.80	5.80

Table E.5.3: Cost (in Lakhs of INR) of Equipments and Miscellaneous non-recurring expenses.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5
Edge Comp. & IoT Equipment	20.00	20.00	20.00	20.00	20.00
PC, Laptop and IT Equipment	10.00	10.00	10.00	10.00	10.00
Insurance, AMC, Servicing	6.00	6.00	6.00	6.00	6.00

Table E.5.4: Cost (in Lakhs of INR) of Capital Infrastructure on CPS Equipment.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5
Furniture and Fixture	36.00	24.00	24.00	24.00	12.00
CPS Testbed Facility	100.00	50.00	-	-	-
Edge Comp. & IoT Infrastructure	25.00	25.00	50.00	50.00	25.00
Enterprise/Research IT Equipment	25.00	25.00	50.00	50.00	25.00

Annexure E.6: Dedicated Innovation Accelerator (CPS-DIAL)

This shall be an office manned by the Chief Executive Officer (CEO) along with the Chief Innovation Officer (CIO), Chief Operating Officer (COO), General Managers, etc. and is responsible for administrative operationalization of the AI4ICPS. This program shall create and organize about 5 special programs per year spanning across design innovation thinking, business building, venture profiling, exponential thinking, launchpad and roadshow programs for the AI4ICPS. Also this office shall oversee the sustainability of the activities and strategize on how to create new scope and opportunities for scaling up operations. Shall manage CPS Startup Ignition, CPS-SSS.

Program Manager: CEO

Table E.6.1: Cost of Manpower for completing requirements of the target. Cost in INR to be calculated according to Table A.1.1.

Designation	Year 1	Year 2	Year 3	Year 4	Year 5
CEO	1	1	1	1	1
COO	1	1	1	1	1
CIO	1	1	1	1	1
GM - HR	1	1	1	1	1
GM - Legal	1	1	1	1	1
Business Associate	2	2	2	2	2
IP Manager	2	2	2	2	2
Legal Associate	1	1	1	1	1
Accountant	1	1	1	1	1
Executive Secretary	1	1	1	1	1
TSE	4	4	4	4	4

Table E.6.2: Cost (in Lakhs of INR) of program components and services.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5
Travel	10.00	10.00	10.00	10.00	10.00
Contingency, AMC, Insurance	10.00	10.00	10.00	10.00	10.00
Project Handling & Overhead (5 events per year)	10.00	10.00	10.00	10.00	10.00
PC and Office IT Equipment	18.00	-	-	-	-
Furniture and Fixtures	90.00	-	-	-	-

Table E.6.3: Number of CPS Startups and Spinoff companies nurtured

	Year 1	Year 2	Year 3	Year 4	Year 5
CPS Startups and Spinoff	12	12	12	12	12

Annexure E.7: Seed Support System (CPS-SSS)

This program shall be a mode of debt financing, in the lines of a pre Series A seed investment. This shall be extended to 2 enterprises per year, with virtual incubation requirement, and a total of 10 shall be supported in the program span of 5 years. This may be subsequent to the CPS Startup Ignition. The ignition support shall be met as a venture valued equity investment by AI4ICPS, based on a phased investment manner, with investor's exit priority on subsequent investment. The participants shall be able to apply for other support programs as well, but not participate in any more than one program at a given time.

Program Manager: CEO

Table E.7.1: Cost (in Lakhs of INR) per unit component of the program per year.

Particulars	Specifications	Amount
Incubation Debt against Equity	Rs. 1 Cr per Startup x 2 Startups / year	200.00

Table E.7.2: Cost of Components (in number of consumed units) for completing the target.

Designation	Year 1	Year 2	Year 3	Year 4	Year 5
No. of Startups supported	2	2	2	2	2

Table E.7.3: Furniture for hosting of the supported startups.

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5
Furniture and Fixtures	50.00	-	-	-	-

Eligibility: This program shall be open primarily to Startups established as a Company in India. This shall not be restricted to only affiliates of IIT Kharagpur. Program shall not enrol Startup with less than TRL6. Objective assessment procedures to be laid in detail, including process for valuation of a Startup and Equity investment process. Shall be coordinated and services facilitated by the CPS-TBI. Startup Company participation is permitted.

General Guidelines: Incubation required. Workshops and training to be attended in person. Use of available infrastructure including Manpower at the Hub shall be on a cost paid basis. This program shall be a mechanism for raising revenue to sustain the Hub.

Program Graduates: Shall apply to External Investor Series A funding programs.

Annexure C: International Collaborative Research Program

This shall be through funding of 4 international collaborative research programs for Academic researchers over a period of five years, with each of the project awards spanning a period of 3 years. The project shall support the Indian counterpart for costs for manpower salary at SERB rates, support for International travel, organizing International workshops and conferences, for which the cost component of the Indian counterpart shall be met. Applicable overhead shall also be extended to the Host Institution for meeting the administrative charges. The projects shall be carried in coordination with the AI4ICPS, interacting and utilizing resources including HR and infrastructure to the best extent possible, with strong focus on inclusion of CHANAKYA-Faculty, CHANAKYA-PD, CHANAKYA-DF, and also the projects should be strongly focussed towards building TRL1-3 or if with existing knowledge then on creating TRL4, such that new ventures are formed out of these explorations, or they lead to a direct commercialization of the technology. The projects shall have their Foreign counterparts funded by a National/Funding agency in their own country. Foreign counterparts are preferred to be academic. The program shall be in lines of the DST International Cooperation in S&T programs.

Program Manager: CTO

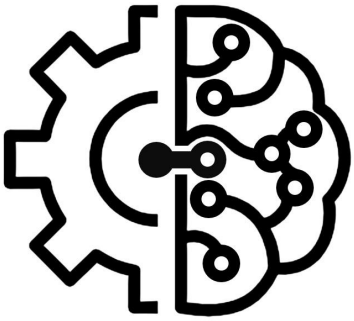
Table C.1: Cost (in Lakhs of INR) per unit component of the program across time span.

Particulars	Year 1	Year 2	Year 3
Manpower (Salary of Project Staff[50])	50.00	50.00	50.00
Contingency	10.00	10.00	10.00
Consumables	10.00	20.00	5.00
Miscellaneous	10.00	10.00	10.00
Travel (International Exchange Program[51])	40.00	50.00	-
Workshop (International Meetings in India[52])	-	50.00	-
Overhead	5.00	5.00	5.00
Equipment	50.00	50.00	-

[50] Structured to follow EM, PM, PE, TSE like structure and following Table A.1.1 and Table 9.4
[51] Supports Foreign Travel to Staff, Scholar and Faculty on the Indian counterpart. Domestic travel support.
[52] Support for organizing the Workshops in India, and can support Inbound Travel of Foreign counterparts.

Table C.2: Component distribution across time span of the program.

Program Component	Year 1	Year 2	Year 3	Year 4	Year 5
Int. Collab. Res. Program (Year 1)	1	2	1	-	-
Int. Collab. Res. Program (Year 2)	-	1	2	1	-
Int. Collab. Res. Program (Year 3)	-	-	1	2	1



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Contact for further details

Virendra Kumar Tewari
Director
director@iitkgp.ac.in

Sudeshna Sarkar
Project Director, AI4ICPS

Debdoot Sheet
Joint Project Director, AI4ICPS
project-director@ai4icps.in

Indian Institute of Technology Kharagpur

Kharagpur, West Bengal, India, 721302