2020-2025

Detailed Project Report

VISION: To be an internationally recognized hub that nurtures HCI research, enables technology translation for the industry, and scales skill development.

IIT MANDI IHUB AND HCI FOUNDATION | iHub Office, North Campus, Indian Institute of Technology Mandi, VPO Kamand, District Mandi, Himachal Pradesh, India-175075

Table of Contents

Executive Summary 3

Cognitive enhancement 3

EEG/BCI-based interactive technologies and neurofeedback 3

Multi-sensory Applications 4

Mandate 5

Vision 5

Overall Deliverables 5

Certificate 7

1. Context/Background 8

2. Problems to be addressed 9

2.1 Four major research areas: 9

2.1.2 EEG/BCI-based interactive technologies and neurofeedback 10

2.1.3 Multi-sensory applications 12

2.1.4 Conversational AI-based social robotics 13

3. Aims and Objectives 18

3.1 Technology Deliverables 18

3.2 Deliverables concerning Grand Problems: 21

3.2.1 Deliverables in the cognitive enhancement domain 22

3.2.2 Deliverables in the EEG/BCI-based interactive technologies and biofeedback 22

3.2.3 Multisensory applications 23

3.3 HRD & Skill Deliverables 24

3.4 International Collaborations 24

3.5 Entrepreneurship and Startups Deliverables 25

4 Strategy 25

4.1 Technology Deliverables 25

4.2 HRD & Skill Deliverables 26

4.3 International Collaborations 26

4.4 Entrepreneurship and Startups Deliverables 27
5 Target Beneficiaries 27
6 Legal Framework 27
7 Environmental Impact 28
8 Technology 28
9 Management 28
10 Finance 31
11 Time Frame 39
12 Cost-Benefit Analysis 42
13 Risk Analysis 48
14 Outcomes 51
14.1 Deliverables with respect to grand problems 53
14.1.1 Deliverables in the cognitive enhancement domain 53
14.1.2 Deliverables in the EEG/BCI-based interactive technologies and biofeedback 53
14.1.3 Deliverable in the multisensory domain 54
14.1.4 Deliverable in the Conversational AI-based social robotics 55
14.2 Evaluation 59
Annexure - 1: Indian companies to be contacted by the iHub for collaborations 60
Annexure - 2: Project descriptions under different domains 62
Annexure - 3: Details of the Online Executive Program 79
Annexure - 4: List of equipment planned to be purchased for HCI research at the iHub 88
Annexure - 5: Cost break-up for HRD and skill development 90
Annexure - 6: IIT Mandi Catalyst Expenses 91
Annexure - 7: Tripartite Agreement 95

Executive Summary

Human-Computer Interaction (HCI) research in India needs to be aligned with India's two-component features: India as a go-to destination for low-cost, high-quality software development; and India as a rapidly growing market of information technology hardware and software products. The proposed Technology Innovation Hub (iHub) in HCI (IIT Mandi iHub and HCI Foundation or iHub; http://ihubiitmandi.in/) at the Indian Institute of Technology (IIT) Mandi under the National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) is planned to make India a leader in HCI research in the world. Based on faculty strengths, industry collaborations, and ongoing projects, the iHub's focus will be on the following: technology (interface) development and evaluation, HRD & skill development, entrepreneurship, and collaborations. Based on proposed objectives, iHub gathered funding support of INR 110 crores from the Department of Science and Technology, Government of India.

The iHub will take up several HCI - related projects at the local, regional, and national levels. The iHub will also include training and generating a skilled workforce in the HCI area of ICPS at graduate, postgraduate, doctoral, post-doctoral, faculty (also via workshops, etc.). Besides, the iHub will also develop and sustain existing and new collaborations with universities and organizations in India and abroad. The iHub is also planning to follow the Knowledge-Development-Translation-Commercialization approach to create a startup ecosystem with IIT Mandi Catalyst, the first TBI housed on the IIT Mandi campus and set up in Himachal Pradesh state.

The iHub intends to address HCI issues and design effective interfaces to solve the grand problems in the following four application domains:

- Cognitive enhancement
- EEG/BCI-based interactive technologies and neurofeedback
- Multisensory applications
- Conversational AI-based social robotics

Cognitive enhancement

Research in the cognitive enhancement domain will primarily focus on the design and development of HCI-enabled portable devices to quantify/handle cognitive impairments. In addition, it will also focus on the development of applications for yoga and other Indian knowledge system practices for improving mental health or cognition and the development of applications via wearable devices and/or immersive experience in 3D apps for human posture improvements.

EEG/BCI-based interactive technologies and neurofeedback

In the present time, most of the emphasis is given to the BCIs. There is some preliminary work done in BCIs where one can convert one's thoughts into words. iHub will understand the human brain and how it can be made to interact with computers via BCIs. BCI not just converts thoughts into words but also transforms the visual image of the thoughts. Also, iHub will work in brain-to-brain communication, such

that current communication modalities can be revolutionized, where thoughts may be transferred from one person to another via BCIs. This will also be one of the Grand problems of the iHub.

Also, there are several training simulators available in the market. These training simulators don't consider the emotional state or fatigue/attention level of the user. iHub would work to develop an adaptable training simulator that will consider the user's emotional, mental, and behavioral states. This simulator will adapt itself to an easy or hard level based upon the feedback from the user's state. This will also be one of the Grand problems of the iHub. iHub will also explore building products that would track the alertness of users in simulated environments and enhance attentiveness using tDCS and EEG neurofeedback.

HCI based Multi-sensory Applications

Most immersive experience devices currently focus on three of the five senses - audio, visual, and tactile. The two remaining senses - taste and smell are not yet tackled effectively. iHub will work in the integration of the five senses, i.e., listening (audio), seeing (visual), touch (tactile), smell (olfactory), and taste (gustatory), into a immersive 3D environment. Some preliminary work is done in odor and taste individually but integrating all five senses is not yet explored. iHub will incorporate all five senses into a single immersive 3D environment as one of its Grand problems.

Conversational AI-based Social Robotics

Social robots are robots that interact with humans and each other in a socially acceptable fashion, conveying intention in a human-perceptible way, and are empowered to resolve goals with fellow agents, be they humans or robots. A number of social robots have been developed (e.g., Furhat, Misty, Otto, Ohbot, Picoh, etc.), which can be utilized for developing applications for education and mental health improvement. For example, the Furhat robot is one kind of social robot, which has a face, a voice, and expressions. It can detect from which direction speech is coming. Since Furhat also moves its head and its eyes independently, it is capable of maintaining user interaction continuously. These things combined make Furhat especially well-suited to multiple use cases like developing learning skills (Math and English) for college students and cognitive behavioral therapy skills for improving depression, stress, and anxiety among poor and underprivileged Himachali youth and women. Similarly, other robots like Otto can be programmed to perform certain skills, which can help people destress. In this theme, iHub proposes to use social robots, including cost-effective ones, to educate youth and women as well as provide effective interventions for stress, anxiety, depression, and medical assistance.

Mandate

The proposed iHub (a section-8 company) was created under the National Mission on Interdisciplinary Cyber-Physical Systems with INR 110 crores' funding support through the DST Science and Engineering Research Board. This quantum of support will last for five years to create technologies at TRL level 6 in the HCI area. The HCI area under the iHub would encompass the development and evaluation of computer interfaces (including associated hardware or software), AI/ML models, or other relevant technologies that power these interfaces. It is believed that the iHub will become self-sustaining after five years.

Vision

The vision is an internationally recognized hub that nurtures HCI research, enabling technology translation for the industry and scaling of skill development.

Overall Deliverables

Table 1 lists the overall deliverable of the iHub across different verticals concerning technology development, HRD and skill development, and entrepreneurship and startup activities.

Table 1. Different goals under the IIT Mandi iHub and HCI Foundation

Description	Goal to be Achieved
Technology Development	
No of Technologies (Patents, IPs)	25
Technology Products	25
Publications	50
Increase in CPS Research Base	450
HRD and Skill Development	
High-end Skill Development (internships and workshops)	1000
Graduate Fellowships	300
Postgraduate fellowships	50
Doctoral Fellowships	50
Post-doctoral fellowships	40
Faculty Fellowships	3
Chair Professors	3
Entrepreneurship and Start-ups	
CPS-GCC Grand Challenges and Competitions	5
CPS - Promotion and acceleration of young and aspiring technology entrepreneurs*	1
CPS - Entrepreneur in Residence	21
CPS-Startups and Spin-Off Companies	140

CPS-Technology and Business Incubator	01 with 140 companies incubated (35 with significant funding)
CPS-Seed support system	1
CPS-Dedicated Innovation Accelerator	01 with 20 companies accelerated
International Collaborations	5
Job Creation	8750

CERTIFICATE

Name of the TIH: IIT Mandi iHub and HCI Foundation

Technology Vertical: Human-Computer Interaction (HCI)

1. This is to certify that the Detailed Project Report (DPR) on the Technology Vertical Human-Computer Interaction (HCI) is prepared and submitted to Mission Office, NM-ICPS, DST as part of the implementation of Technology Innovation Hub (TIH) at the Indian Institute of Technology Mandi under National Mission on Interdisciplinary Cyber-Physical System (NM-ICPS).
2. This is to certify that this DPR has been checked for plagiarism and that the contents are original and not copied/taken from anyone or from any other sources. If some content was taken from certain sources, it is duly acknowledged and referenced accordingly.
3. The DPR will be implemented as per the Terms, References, and Clauses stated in the Tripartite Agreement signed on 16th December 2020 between the Mission Office, DST, Indian Institute of Technology Mandi, and IIT Mandi iHub and HCI Foundation

Date: 16th November 2022

Place: Kamand, HP, India - 175075

Dr. Varun Dutt, Associate Professor, IIT Mandi
Name(s) and Signature(s) of Project Director (s)

Endorsement from the Head of the Institution

1. Certified that the Institute welcomes the participation of Dr. Varun Dutt as the Project Director for the Technology Innovation Hub (TIH) and that in the unforeseen event of discontinuance by the Project Director, the Indian Institute of Technology Mandi will identify and place a suitable faculty as Project Director for fruitful completion of the TIH activities.
2. Certified that the Host Institute shall provide basic facilities, faculty support, and such other administrative facilities as per the Terms and Conditions of the award of TIH, which will be extended to TIH.
3. As per the Tri-partite Agreement, the Host Institute (HI) shall play its role and fulfill its responsibilities for the success of TIH.

Date: 16th November 2022

Place: Kamand, HP, India - 175075

Nov. 16, 2022
Dr. Venkata Krishnan, Dean (SRIC & IR), IIT Mandi
Name and signature of Head of Institution

1. Context/Background

Human-Computer Interaction (or HCI), also referred to as Man-Machine Interaction (MMI) or Human Machine Interaction (HMI), is a comprehensive and multidisciplinary field that aims to improve the interactions between users and computers by making computers more usable and receptive to the users' needs. The area involves decision tasks that require a joint performance by both humans and machines. Some crucial aspects of HCI are user-interface design and user-interface evaluation.

HCI research in India needs to be aligned with two-component features about India: India as a go-to destination for low-cost, high-quality software development, and India as a rapidly growing market of information technology hardware and software products. HCI developed as a nascent research area in India and has passed through three stages in the country. The first stage of HCI practitioners in India included team members of multi-media content producers, e-learning content producers, and subsequently the "dot-com" companies between the years 1990 to 2000. The second stage began in the year 2000, where the mainstream IT industry started hiring many HCI practitioners to improve the usability of their offerings. This industry came from Indian companies such as Tata Consultancy Services, Infosys, Tech Mahindra, and Wipro. Another significant part of the industry consisted of multinational companies such as Microsoft, HP, Yahoo!, ABB, GE, and Google, who set up their global software development centers in India. The HCI practitioners in these companies worked and designed for a worldwide audience. The third stage began in 2005 when certain third-generation companies started developing hardware and software products for the Indian market. It was triggered by the growth in mobile phones and websites for travel and e-commerce. This stage was when many Indian HCI professionals started designing software for Indian users for the first time. Education and research in HCI did not gain much popularity until recently. The first India HCI conference focusing on peer-reviewed research publications was organized in 2009.

The proposed Technical Innovation Hub (iHub) in HCI (IIT Mandi iHub and HCI Foundation (iHub); http://ihubiitmandi.in/) under the National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) is planned to make India a leader in HCI research in the world. Based on faculty strengths, industry collaborations, and ongoing projects, iHub's focus will be on the following: technology (interface) development and evaluation, HRD & skill development, entrepreneurship, and collaborations. Due to the proposed location of the iHub at IIT Mandi, some of the technologies will be focused on the mountain region. A team of experienced faculty and newly joined faculty will participate in the success of the iHub. Also, several industries and academic institutions have committed to being a part of this iHub. The iHub has also made a list of companies in India that are focused on HCI-related research (see Annexure 1). The iHub is in the process of collaborating with these companies to work actively with them on technology (interface) development and evaluation, HRD & skill development, entrepreneurship, and collaborations. Figure 1 shows the different activities planned under the iHub with different goals under each activity. The figure also shows the interdependencies between various activities with link connectors. For example,

technology development depends upon human resources and collaborations, and the deliverables (products) may provide inputs for entrepreneurship and startups. The projects under the technology development will mainly focus on different aspects of user interfaces across several problems in various domains. These domains will include the environment, healthcare, information technology (IT), and Defence & Security, which form important sectors of the Indian economy.

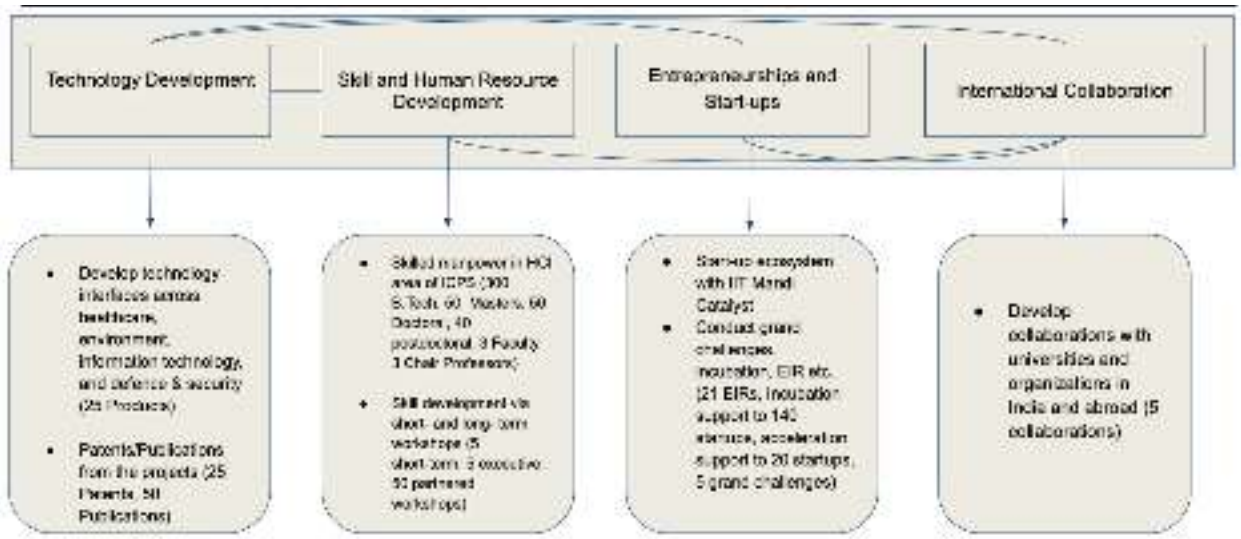


Figure 1. The different activities under the iHub and goals under various activities.

2. Problems to be addressed

A distinct goal for HCI research under the iHub would be developing and testing technology/computer systems that make them usable by human beings. A sub-goal of the iHub would be studying how people use technology/computer systems in different domains (environment, healthcare, information technology, and Defence & security) and making this interaction simpler and efficient. The proposed iHub will take up several HCI - related projects at the local, regional, and national levels. The main problems to be addressed by the iHub will be classified into the following domains (see Figure 2): Environment, Healthcare, Information Technology, and Defence & Security.

2.1 Four major research areas:

The iHub intends to address HCI issues and design effective interfaces to solve the Grand problems in the following research areas:

2.1.1 Cognitive enhancement

Performance optimization is often considered to involve the application of technologies and techniques aimed to help individuals and teams maintain peak performance in the face of environmental or task-related perturbations. This conceptualization of performance optimization is adopted from the system

and network engineering literature, which seeks to optimize system throughput and reduce performance degradation under conditions of high demand, interference, and unpredictability. Cognitive performance optimization strategies can accomplish those same goals through precise control, combination, and application over the short- and long term. For instance, providing real-time location updates for difficult to perceive targets could help military personnel optimize marksmanship performance by sustaining accuracy and efficiency under conditions of stress, workload, and uncertainty. In contrast, performance enhancement involves accelerating or amplifying individual and team performance beyond existing peak capabilities, in effect altering a performance distribution through a rightward shift, increased kurtosis, and/or modified skew. This conceptualization is consistent with the definition proposed by researchers and scientists, who defined cognitive enhancement as "the amplification or extension of core capacities of the mind through improvement or augmentation of internal or external information processing systems". Any new performance levels achieved with cognitive enhancement become an individuals' new personal best, raising the standard of future performance. Importantly, both optimization and enhancement realize performance benefits for individuals, but only in the latter case do benefits transcend existing human capability. Research in the cognitive enhancement domain will primarily focus on the design and development of HCI-enabled portable devices to quantify/handle cognitive impairments. In addition, it will also focus on the development of applications for yoga and other Indian knowledge system practices for improving mental health or cognition and the development of applications via wearable devices and/or 3D immersive apps for human posture improvements.

Representative projects:

- ❖ Development of applications for yoga and other Indian knowledge system practices for improving mental health or cognition.
- ❖ Development of HCI-enabled portable devices to quantify/handle cognitive impairments.
- ❖ Development of software for a virtual surgery training system, make corresponding plans for the actual surgery and practice before the surgery. The system may make more accurate pre-measurements and estimates and predict the complexity of the operation.
- ❖ Development of applications via wearable devices and/or 3D immersive apps for human posture improvements.
- ❖ Development of wearable devices for mental health monitoring or cognitive enhancement.

2.1.2 EEG/BCI-based interactive technologies and neurofeedback

While BCI applications have been well explored for applications involving attention monitoring, motor imagery, emotion recognition, some niches in brain decoding have only begun to be investigated recently. For instance, there is much scope of research and development in perceptual brain decoding, reconstructing images, text, and speech from brain signals, applications involving brain stimulation. Such systems can have applications in neuroscience, rehabilitation, forensics, defense, etc. With collaboration with organizations focusing on brain research, iHub will develop such advanced BCI systems. Also, as a next level, with such advanced BCI and stimulation systems iHub plans to work in brain-to-brain

communication. This will also be one of the Grand problems of the iHub. In a related domain, we note that there are several training simulators available in the market. These training simulators don't consider the emotional state or fatigue/attention level of the user. iHub would work to develop an adaptable training simulator that will consider the user's emotional, mental, and behavioral states. This simulator will adapt itself to an easy or hard level based upon the feedback from the user's state. This will also be one of the Grand problems of the iHub. iHub will also explore building products that would track the alertness of users in simulated environments and enhance attentiveness using tDCS and EEG neurofeedback.

Representative projects:

- Development of EEG-based neurofeedback applications for improvements to mental health, restorative rehabilitation including Indian knowledge system-based interventions
- Development of applications for de-addiction by using BCI technologies /tDCS/ yoga/other art forms.
- Development of methods/tools to identify mental issues (anxiety, depression, etc.).
- Development of personalized prosthetics, rehabilitation, teleoperation, and exoskeletons. Mobility solutions for aging/ailing population.
- Human stroke classification and prevention techniques.
- Development of education technology solutions incorporating neurofeedback.

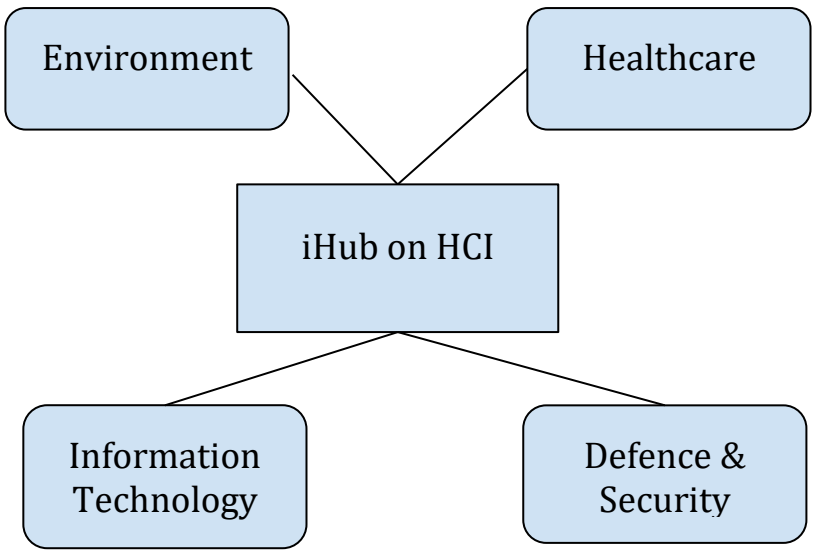


Figure 2. The iHub on HCI will focus on HCI-related projects under the Environment, Healthcare, Information Technology, and Defence & Security domains

2.1.3 HCI in Multi-sensory applications

The primary purpose of an 3D immersive system can be described as transporting its users to a virtual environment (VE) by offering coherent perceptual feedback corresponding to the actions that are taking place within that VE, leading the users to develop a psychological feeling of being there. This sense is usually referred to as presence. Researchers divided “presence” into two types of illusions: place illusion (PI) and plausibility illusion (Psi). PI refers to the specific feeling of "being there", and this illusion can occur in static scenes allowing the user to look around and explore the VE. PI is determined by the immersive system: the extent to which the equipment allows the user to explore the scene through natural sensorimotor contingencies (walk, look around, look under, look over, crouch, try to touch objects and feel them, etc.). Psi, on the other hand, is more difficult to achieve. It refers to the feeling that events occurring in the virtual world are truly happening despite the sure knowledge that they are not real. These events should match our expectations of how objects and people would react in the depicted situation. Additionally, they should refer to and be correlated with our actions in the VE. While the evolution and affordability of immersive 3D technologies have led to more widespread usage, the majority of these systems heavily depend on the stimulation of only vision and auditory. This dependence on only two senses can be a constraint, as our everyday experiences have a multisensory nature.

Most immersive experience devices currently focus on three of the five senses - audio, visual, and tactile. The two remaining senses - taste and smell are not yet tackled effectively. iHub will work in the integration of the five senses, i.e., listening (audio), seeing (visual), touch (tactile), smell (olfactory), and taste (gustatory), into an immersive 3D environment. Some preliminary work is done in odor and taste individually but integrating all five senses is not yet explored. iHub will incorporate all five senses into a single immersive 3D environment as one of its Grand problems.

In addition, immersive 3D environment has received much attention due to the advance in head-mounted display (HMD) technology, which have stepped up from expensive, high-end equipment to available, consumer-ready, and even mobile devices with potential mass adoption. In contrast to traditional ways of providing visual stimuli, (head-mounted) hardware offers immersive ways of experiencing virtual environments. Immersive 3D environment has been shown to complement or even substitute traditional therapy. Through the integration of biofeedback (a technique through which you can learn to control your bodily functions, such as heart rate and sensorimotor response), immersive 3D environment can potentially be a very effective and efficient intervention for a wide range of cognitive wellness and other conditions.

To begin with, immersive 3D environment are customizable that prevents the user from being rattled by the feedback. The Attention Restoration Theory (ART) asserts that spending time in as well as looking at environments with restorative qualities (e.g., nature settings) allows the brain to replenish its voluntary attention capacity, thereby improving concentration and relieving mental fatigue and stress. In line with ART, immersive 3D environment have been shown to lower stress levels and enhance productivity even when simulated. Besides adding a restorative effect, a fundamental mechanism biofeedback training is

useful is in operant conditioning through positive reinforcement. iHub also intends to evaluate the efficacy of integrating biofeedback into the immersive 3D environment system being developed and then deploy them as applications in different domains.

Representative projects:

- ❖ Digital Nose- Development of sensors, hardware, software, AI/ML to detect, identify, and classify smells.
- ❖ Digital Smell - Development of sensors, hardware, software, AI/ML to recreate smells from their digital patterns.
- ❖ Digital Tongue - Development of sensors, hardware, software, AI/ML to detect, identify, and classify taste.
- ❖ Digital Taste- Development of sensors, hardware, software, AI/ML to recreate taste from their digital patterns.
- ❖ Heart Rate Variability monitors - Development of wearable sensors, hardware, software, AI/ML to monitor heart rate variability with applications in Indian knowledge system and modern medicine.
- ❖ Biosensors and applications for detecting and monitoring diseases like diabetes.

2.1.4 Conversational AI-based social robotics

Social robots are robots that interact with humans and each other in a socially acceptable fashion, conveying intention in a human-perceptible way, and are empowered to resolve goals with fellow agents, be they humans or robots. A number of social robots have been developed (e.g., Furhat, Misty, Otto, Ohbot, Picoh, etc.), which can be utilized for developing applications for education and mental health improvement. For example, the Furhat robot is one kind of social robot, which has a face, a voice, and expressions. It can detect from which direction speech is coming. Since Furhat also moves its head and its eyes independently, it is capable of maintaining user interaction continuously. These things combined make Furhat especially well-suited to multiple use cases like developing learning skills (Math and English) for college students and cognitive behavioral therapy skills for improving depression, stress, and anxiety among poor and underprivileged Himachali youth and women. Similarly, other robots like Otto can be programmed to perform certain skills, which can help people destress. In this theme, iHub proposes to use social robots, including cost-effective ones, to educate youth and women as well as provide effective interventions for stress, anxiety, depression, and medical assistance.

Representative projects:

- ❖ Developing learning skills (Math and English) for college students.
- ❖ Cognitive behavioral therapy skills for improving depression, stress, and anxiety
- ❖ Medical assistants' robot in the hospital for a high level of patient care
- ❖ Yoga Instructors/meditation robot
- ❖ Customer-centric robots

While the grand-challenges would delve in some of the core HCI and BCI technologies, we also notice several other domains wherein a broader perspective of HCI in terms of developing systems involving user-friendly interfaces, visualizations, UI-UX etc. with a backend of AI-ML based algorithms. Table 2 details a list of some of these problems that the iHub would take up with its own faculty and its spokes over the next 5-years under different domains and subdomains (this table includes the environment and healthcare domains that form the major application areas). Under the environment domain, the iHub will address HCI issues and design efficient, reliable, and cost-effective HCI-based solutions in different sub-domains like agriculture, landslide monitoring, and air pollution monitoring. The HCI-based solutions under these sub-domains will focus on developing indigenous interfaces for disseminating agricultural advisories for different crops; development of interfaces for visualization of satellite/field-based data for landslide monitoring; and interfaces for air pollution monitoring, warning, and prediction. Under the healthcare domain, the iHub will endeavor towards addressing issues in different sub-domains like digital pathology, neuroradiology, and body area networks. The HCI-based solutions under these sub-domains will focus on the development of indigenous interfaces for triaging, screening, and labelling large volumes of whole-slide images, interfaces for visualization and processing of MRI/DTI/HDFT images, and interfaces for real-time monitoring of physiological variables like heart rate, temperature, blood pressure etc. In addition, the iHub will also focus on developing HCI-based solutions for telecom networks, cybersecurity, cognitive enhancement, and vehicle identification, among others. The potential users under different problems as well as their impact have also been listed in the table. Most of these problems are those where IIT Mandi has in-house expertise. Thus, around 40%-50% of these problems may go as research and development projects to the IIT Mandi faculty. The remaining percentage may go as projects to external research institutions as well as industry. Every project will participate competitively for funding with a call for proposal, proposal submissions, proposal review, presentation of shortlisted proposals to experts, and financing of the recommended projects. It is to be mentioned that the first call for proposals under the iHub has already been launched on 18th February 2021, and it covers HCI applications in Healthcare, Environment, and Information Technology. Also, the iHub foresees incubation of startups on several problems beyond those listed in Table 2 under the four domains of environment, healthcare, IT, and Defence & security.

Table 2. List of problems under different domains and subdomains, potential users, and impact

Domain	Sub-domain	Problems	Potential Users	Impact
Environment	Agriculture	Indigenous interface development and evaluation for disseminating agricultural advisories for different crops, diseases, economic variables via mobile	Local, state, and central govt. Insurance companies Academic research Farmers	State and national levels (covering large farming communities in different states in India)

		applications to rural farmers.		
	Landslides	Development and evaluation of an interface for visualization of satellite and field-based data for landslide monitoring, warning, and prediction	Local, state, and central govt. Insurance companies Academic research Citizens	State and national levels (covering the Himalayas and western ghats)
	Air pollution	Development and evaluation of an interface for air-pollution monitoring, warning, and prediction	Local, state, and central govt. Insurance companies Academic research Citizens	State and national levels (covering major non-attainment townships for real-time pollution monitoring)
Healthcare	CAD for Digital Pathology	Development of interfaces for efficient triaging, screening, labelling large volumes of whole-slide images	Pathologists Pathology Labs Hospital patient data management	All healthcare domains involving pathology support. (e.g., Biopsies Cytology)
	Body Area Networks	Development and evaluation of body area network interfaces for real-time monitoring and warning of physiological variables like heart rate, temperature, blood pressure, and others	Hospitals Medical practitioners Patients	Local, regional, state, and national across several healthcare centers and hospitals

	CAD for Neuroradiology	Development of interface for interactive processing and visualization for High-density fibre tracking (HDFT) for Diffusion-MRI imaging Software interface for analysis of structural and functional networks for MR based neuroimaging.	Radiologists Hospital management systems	All healthcare domains involving brain surgery and brain disorders requiring DTI and fMRI, and cognitive science labs
Information Technology	Telecom Networks	Interfaces for visualization of descriptive and predictive analytics for network management in the telecom sector.	Telecom companies Govt. agencies Network management companies	National level (a large number of telecom operators as well as network management companies)
	Behavioral cybersecurity	Game-theoretic interfaces in cybersecurity involving deception and intrusion-detection systems	Govt. IT industry Pen testers Researchers	National level (across several government and non-government organizations with online presence/operations)
Defence and Security	Cognitive Technologies	Development of an interface for Human Performance (individual/team) visualization and forecasting involving Transcranial Direct Current Stimulation (tDCS), VR/AR/MR and machine learning methods.	Military/Defence Hospitals Sports Education sector	State and national levels (among defence personnel as well as in education and sports industry)

	Multimedia Forensics	Interfaces for management, labelling, editing, low-resolution person and vehicle id from surveillance feeds, and ego-centric cameras. Interfaces for semi-automated audio analysis in local languages Software for audio-video-image authentication	Police Depts. Forensic Labs Other Govt. investigation agencies	Indigenous tools are required to be developed in India. Currently, most forensic labs purchase expensive tools or use low-end free software

The project descriptions under different domains mentioned above have been put as Annexure - 2 in the DPR at the end. These projects include some of those from IIT Mandi. Several other projects may be submitted by institutes (spokes) beyond IIT Mandi across different domains. Also, there was a list of problems shared by Department of Science and Technology (DST), out of which problems listed in Table 3 are the one which falls under the expertise of iHub at IIT Mandi.

Table 3. Problems identified from the Line of Ministries

Sr. No.	Name of the Ministry	Contact Person	Problem
1	Department of School Education and Literacy, Ministry of Education, Government of India	Smt. Anita Karwal, IAS, Secretary, 124-C, Shastri Bhawan, New Delhi, +91-11-23382587/23381104(Office) Email: secy.sel@nic.in	The technologies required to explore the learners to the world of digital platforms has been well considered, which includes Digital Learning/Contents, AI/ML employment, Chatbots, Visual/Audio-based interactive learning, simulations have been in place. Reference to NDEAR, new user experience technologies such as “conversation engines” (e.g., chatbots), “AR/ VR/ 3D/ Gamification”, maker experiences such as robotics, IoT devices, etc. should be explored as reusable core services that can be used across various functional blocks, and further coordination will be made through IIT Mandi.
2	Ministry of Skill Development & Entrepreneurship	Abhishek Meena, Deputy Director	Making available Augmented Reality (AR) based content that can be used on cheap smart devices expands the coverage of blended learning. This is important

		Ministry of Skill Development & Entrepreneurship Govt. of India, Shram Shakti Bhawan, Rafi Marg New Delhi - 110001	because most of the consumers of skilling are poor and can access at most cheap smartphones. For Augmented Reality/ Virtual Reality (AR/ VR) based solutions in training for job roles requiring high practical exposure, the cost of creating and delivering a complete course in digital medium with the latest technology functionalities remains prohibitive, including the equipment needed for the candidate. A novel centralized technology platform, models, and equipment, which can make quality vocational training in the online mode more affordable and accessible, is needed.

* *The people mentioned above in the line ministries have been contacted by iHub.*

3. Aims and Objectives

The long-term objectives of the proposed iHub would be the following (ranks are given in numbers from 1 to N, where 1 is the highest-ranked and N is the lowest-ranked):

1. Organize webinars, events, workshops, grand challenges, hackathons, and online courses directly relevant to the Grand and other problems via HCI-based solutions in various application domains.
2. Network with a global network of leading labs in grand and other problems areas under CPS.
3. Facilitate incubation, nurturing, guidance to startups in grand and other problems under CPS through an existing incubator.
4. Make most activities in Grand and other problems achieve a self-sustaining level by addressing knowledge, development, translation, and commercialization approach.

The deliverables coming out of the iHub will include the following:

3.1 Technology Deliverables

Using current strengths to develop technology interfaces across several ICPS problems (including those in the mountain region) concerning the different environment, healthcare, IT, and defense & security domains.

Table 3 shows some of the problems identified under different domains and subdomains and their deliverables. As seen in Table 3, various problems have been identified under different domains, with the potential deliverables from these problems. Some of these problems and deliverables may be taken up

by the IIT Mandi faculty directly. However, some of these and newer problems under the different domains may be tackled in projects given out to other Institutions and industrial partners.

Table 3: Problems identified under different domains and subdomains and their deliverables.

Domain	Sub-domain	Problems	Product (Deliverables)
Environment	Agriculture	Indigenous interface development and evaluation for disseminating agricultural advisories for different crops, diseases, economic variables via mobile applications to rural farmers.	A web- and mobile-interface for the dissemination of agricultural advisories
	Landslides	Development and evaluation of an interface for visualization of satellite and field-based data for regular or continuous landslide monitoring, warning, and prediction	A web- and mobile-interface combining satellite and field data for visualization and advisory
	Air pollution	Development and evaluation of an interface for air-pollution monitoring, warning, and prediction	A web- and mobile-interface for visualization air pollution values at different geographical locations
Healthcare	CAD for Digital Pathology	Development of interfaces for efficient triaging, screening, labelling large volumes of whole-slide images	A desktop/tablet-based software for efficient slide management and navigation Cloud-based and device-based ML/DL backend algorithms Semi-automated labelling, tagging, reporting tools based on Images, Text,

			speech, eye-tracking
	Healthcare analytics	Development and evaluation of interfaces for the following applications: 1. Healthcare analytics of healthcare cost and socio-economic variables over time 2. Machine learning-based models for blood glucose prediction	Web-based interface for visualizing and predicting patient-related healthcare expenditures. Web-based interface for visualizing and predicting blood glucose levels in the human body
	Body Area Networks	Development and evaluation of body area network interfaces for real-time monitoring and warning of physiological variables like heart rate, temperature, blood pressure, and others	Web-based interfaces for human body monitoring and warning
	CAD for Neuroradiology	Development of interface for interactive processing and visualization for High-density fiber tracking (HDFT) for Diffusion-MRI imaging Interface for analysis of structural and functional networks	Desktop, tablet, and VR based. A visualization system for HDFT fiber tracks Interface for analyzing and visualizing structural and functional brain networks. Algorithms on diffusion MR images and computation of fiber tracks Algorithms for brain connectivity Semi-automated

			tagging and reporting
Information Technology	Telecom Networks	Interfaces for visualization of descriptive and predictive analytics for network management in the telecom sector.	Web-based interfaces for visualization of performance variables in telecom networks
	Behavioral cybersecurity	Game-theoretic interfaces in cybersecurity involving deception and intrusion-detection systems	Web-based interfaces for testing cybersecurity scenarios involving deception and intrusion detection systems
Defence and Security	Cognitive Technologies	Development of an interface for Human Performance (individual/team) visualization and forecasting involving Transcranial Direct Current Stimulation (tDCS), VR/AR/MR and machine learning methods	Desktop-based and VR-based interface for visualizing and forecasting cognitive enhancement.
	Multimedia Forensics	Software for audio-video-image authentication Interfaces for management, labelling, editing, low-resolution person and vehicle id from surveillance feeds, and ego-centric cameras. Interfaces for semi-automated audio analysis in local languages, geo-mapped textures in the speech that characterizes region-specific soundscapes	Desktop and tablet-based software ML / DL algorithms running on the device or on the cloud

3.2 Deliverables concerning Grand Problems:

The iHub intends to address HCI issues and design effective interfaces to solve the Grand problems in the following research domains:

- Cognitive enhancement
- EEG/BCI-based interactive technologies and biofeedback
- Multisensory applications
- Conversational AI-based social robotics

3.2.1 Deliverables in the cognitive enhancement domain

- ➔ Development of applications for yoga and other Indian knowledge system practices for improving mental health or cognition.
- ➔ Development of HCI-enabled portable devices to quantify/handle cognitive impairments.
- ➔ Development of software for a virtual surgery training system, make corresponding plans for the actual surgery and practice before the surgery. The system may make more accurate pre-measurements and estimates and predict the complexity of the operation.
- ➔ Development of applications via wearable devices and/or immersive 3D environment apps for human posture improvements.
- ➔ Development of wearable devices for mental health monitoring or cognitive enhancement.
- ➔ Effect of Yoga in the Stress Reduction and in the Management of Anxiety and Somatic symptom disorders
- ➔ Effect of Covid-19 Pandemic on Social Fear Learning and Extinction
- ➔ Pupillometry using Smartphones
- ➔ Smart Glove for Sign Language Interpretation in the native language
- ➔ Detecting Textual Entities with Representational mining on Big Temporal Knowledge Graphs of Ancient Literature and Social Media Data
- ➔ Developing AI based cognitive function enhancement app by applying Artificial intelligence and biomarker profiling
- ➔ Interactive Virtual Surgery Training Agent
- ➔ Development of a new integrated, multimethod, dimensional approach for early detection of Mild Cognitive Impairment (MCI) using AI/ML techniques

3.2.2 Deliverables in the EEG/BCI-based interactive technologies and biofeedback

- ➔ Development of EEG-based neurofeedback applications for improvements to mental health, restorative rehabilitation including Indian knowledge system-based interventions
- ➔ Development of applications for de-addiction by using BCI technologies /tDCS/ yoga/other art forms.
- ➔ Development of methods/tools to identify mental issues (anxiety, depression, etc.).
- ➔ Development of personalized prosthetics, rehabilitation, teleoperation, and exoskeletons. Mobility solutions for aging/ailing population.
- ➔ Human stroke classification and prevention techniques.

- ➔ Development of education technology solutions incorporating neurofeedback.
- ➔ Design and Development of Brain Controlled Wheelchair Considering User's Intention to Move Through EEG Signal and Eye Tracking
- ➔ Adaptive Neurofeedback System Tracking Confidence Level of Decision-Making during Motor Imagery
- ➔ Neural Markers of Subclinical Anxiety during Young Adulthood
- ➔ Development of Artificial Intelligence based Depression Identification using Electroencephalogram Signals
- ➔ EEG based Smart Bed System for Bedridden Patients
- ➔ Multi scenario lie detection with EEG
- ➔ Design of tiny ML support Deep learning-based computation model for elderly person walking rehabilitation and diagnosis of fall recovery using wearable sensors
- ➔ EEG Source Localization assisted Ayurvedic Intervention in Brain Disorder Management
- ➔ Generation of Hindi-English Code-Mixed Computational Lexicon and Chatbot Counselling Application for Depression Disorder
- ➔ A Neural Feedback based Intelligent Software Application for Autism Spectrum Disorder (ASD) in Children, based on NLP Techniques
- ➔ Development of an FPGA based model predictive controller for tDCS using portable neuroimaging (fNIRS-EEG) data streams
- ➔ Design and Development of 3-dof Lower Limb Exoskeleton

3.2.3 Multisensory applications

- ➔ Digital Nose- Development of sensors, hardware, software, AI/ML to detect, identify, and classify smells.
- ➔ Digital Smell - Development of sensors, hardware, software, AI/ML to recreate smells from their digital patterns.
- ➔ Digital Tongue - Development of sensors, hardware, software, AI/ML to detect, identify, and classify taste.
- ➔ Digital Taste- Development of sensors, hardware, software, AI/ML to recreate taste from their digital patterns.
- ➔ Heart Rate Variability monitors - Development of wearable sensors, hardware, software, AI/ML to monitor heart rate variability with applications in Indian knowledge system and modern medicine.
- ➔ Biosensors and applications for detecting monitoring diseases like diabetes.
- ➔ Designing advanced, efficient, compact, highly reliable sensors and biomarkers-based systems to combat Alzheimer's disease, heart attacks and early-stage cancers
- ➔ Digital nose for healthcare: Diagnosing diabetes and heart diseases via a low-cost digital nose

- ➔ Glucose oxidase nanomaterial-based tattoo ink composite as biosensor to monitor the blood glucose level for diabetic detection

3.2.4 Conversational AI-based social robotics

- ➔ Social robots with learning skills (Math and English) for college students.
- ➔ Social robots with cognitive behavioral therapy skills for improving depression, stress, and anxiety
- ➔ Medical assistants' robot in the hospital for a high level of patient care
- ➔ Yoga Instructors/meditation robots
- ➔ Customer-centric robots

3.3 HRD & Skill Deliverables

Includes training and generating skilled manpower in the HCI area of ICPS at graduate, post-graduate, doctoral, post-doctoral, faculty (also, via workshops etc., with industry partners). The deliverables will include high-quality personnel training via physical (short-term; 1-week) and online (longer-term; 6-months) workshops. The physical workshops will take place on campus. In contrast, the online workshops will take place in the format of an online executive program with classes in the evenings (Annexure 2 details the curriculum for the online executive program). These workshops will train almost 1000+ personnel across areas concerning HCI and machine learning. There are also around 50 workshops (i.e., one with each of the 25 projects) planned. Each of these 50 workshops is likely to have about 100 participants, and these workshops will be organized by institutions that get projects from the iHub. The skill development activities will also train 50 MS, 50 PhD, and 40 postdocs across different projects and problems (15 out of 40 postdocs may be sponsored as institute postdocs working at IIT Mandi). The iHub will also offer three junior faculty fellowships and three chair professorships. It is also planned to impart 300 1-year fellowships to bright B. Tech. Students from India. These B. Tech. Students will attach themselves across different iHub projects (i.e., 12 B. Tech. per project across 25 projects and outside) and get trained on the best set of HCI technologies. A certain number of B. Tech. could be from IIT Mandi, who pursue their 3rd or final year projects on the iHub-sponsored and industry-sponsored projects. Certification program UI/UX design

3.4 International Collaborations

The iHub will make use of its existing and new international collaborations for getting project ideas. The iHub will leverage existing partnerships with TU9, CMU, NTNU, London Met, Unity 3D, ITRA, and RxData Science. These collaborations will enable the iHub to get relevant HCI problems from industry and academia to work upon. Also, these collaborations will help organize workshop events as part of the iHub and help review the project proposals submitted to the iHub. The iHub will also try to connect with new and existing Indian companies in the HCI area (Annexure 1 details a list of such companies). In fact, among industries, at an early stage, the iHub has already set up collaborations with HCI related companies like

Peepal Design, Think Design, Lemon Design, TCS, Elixar Systems, and American Express. These collaborations will help the iHub in entrepreneurship and startup activities. Annexure - 1 in this report lists some of the Indian companies that the iHub will contact for collaborations and iHub has signed MoUs with Rubiscape, ITRA, and Unity 3D.

3.5 Entrepreneurship and Startups Deliverables

It is planned to follow the Knowledge-Development-Translation-Commercialization approach to create a startup ecosystem with IIT Mandi Catalyst, the first TBI housed on the IIT Mandi campus and set up in Himachal Pradesh state. As part of this objective, 140 startups will be incubated, 21 entrepreneurs will be groomed into entrepreneurial careers, 20 startups will be accelerated, and five grand challenge activities will be held.

4 Strategy

Several strategies may be adopted to accomplish the objectives outlined above. Based upon discussion with the host institute, it is planned to follow a strategy that makes the iHub self-sufficient in the next 5-years. The pillars of this strategy rely upon industrial and academic collaborations, the involvement of existing experts from industry and academia, and following the Knowledge-Development-Translation-Commercialization steps in each project undertaken under the iHub. Some of the ongoing initiatives include small projects from Indian Central and State Governments and industry to develop prototypical interface-based solutions to several problems concerning the significant application areas of environment and healthcare and other application areas like IT, and Defence & security. However, these small projects would have either created lab-based solutions or solutions that have only been tested at the district or local levels. All prototypes are planned at NASA's TRL level 6 or above. Thus, there is tremendous potential to improve these prototypes to finished industry (translational) products and scale them up at the regional, state, and national levels. Below, strategy is mentioned that to be adopted against each deliverable.

4.1 Technology Deliverables

For the technology deliverables, stakeholders from different governments, industries, and societies will be identified where the development and evaluation of interfaces will benefit the industry and community. This identification will be made across all application areas, including the environment, healthcare, IT, and Defence & security. The project may be done in different modes: consulting or sponsored research. Thus, it is envisioned that problems will come from stakeholders or society who will directly benefit from a solution.

Next, the problem will be outsourced in-house or external iHub spokes and industry/academic partners. These projects will share the IPR and costs, which may likely benefit the iHub once some of the technologies from projects are commercialized. For projects taken up on industrial problems, some finances may come from the respective industry. Once the industry commercializes the project and some

threshold numbers of systems are sold, a small percentage of revenue would be given back to the iHub by the industry.

Also, different stakeholders may make use of the various services, infrastructure, and facilities present within the iHub to use for a defined fee. These earnings via project via a fee for use will enable the iHub to earn money and sustain itself.

In addition, the iHub may connect faculty and industry experts affiliated with it to relevant stakeholders for technology interface development and evaluation. It is proposed to have a fee set aside for the iHub for connecting the faculty and industry experts with relevant stakeholders.

Furthermore, the user-interface-based technologies developed in the iHub would be commercialized via IIT Mandi's technology incubator, IIT Mandi Catalyst. Thus, the iHub will get a share in the startup ventures and earnings from patents resulting from grants from iHub. This share will enable the iHub to sustain itself beyond 5-years of DST support.

There may likely be certain book writing grants given from the iHub. These book writing grants will be for undergraduates and postgraduates in HCI and AI/ML areas. The selling of the textbooks may bring a small percentage of earnings back to the iHub.

Furthermore, the HCI and computing infrastructure created as part of the iHub will enable the iHub to earn from leasing these infrastructures for a fee. There will be different rental models for the physical HCI infrastructure, and the computing infrastructure offered as a service.

4.2 HRD & Skill Deliverables

The iHub will start several training programs (on-campus and online) in the HCI area in collaboration with its partners or in-house expertise. The material for these training programs will be posted online, and it could be downloaded for a fee. The iHub will also conduct workshops regularly. The participation in these workshops will be based upon payment from attendees. In particular, the online executive programs are likely to engage many executives in the industry who cannot devote full time to the on-campus workshops. In addition, it is expected that graduate, postgraduate, doctoral, post-doctoral, and faculty at IIT Mandi will do research in the iHub. These research activities will bring non-monetary rewards in terms of publications and monetary rewards in terms of patents.

4.3 International Collaborations

The iHub will make use of its new international collaborations for getting project ideas. The iHub will leverage partnerships with international collaborators to enable the iHub to get relevant HCI problems from industry and academia. Also, these collaborations will help organize workshop events as part of the iHub and help review the project proposals submitted to the iHub. The iHub will also try to connect with Indian companies in the HCI area (Annexure 1 details a list of such companies). In fact, among industries,

at an early stage, the iHub has already set up collaborations with some HCI related companies. These collaborations will help the iHub in entrepreneurship and startup activities.

4.4 Entrepreneurship and Startups Deliverables

The iHub will follow a Knowledge-Development-Translation-Commercialization approach to creating a startup ecosystem with IIT Mandi Catalyst, the first TBI housed on the IIT Mandi campus and set up in the Himachal Pradesh state. Thus, iHub supported projects that develop software- or interface-based prototypes using the knowledge and development will be assisted in translation and commercialization stages via IIT Mandi Catalyst and via patenting of the product. The entrepreneurship and startup activities will involve a particular percentage share for the iHub with adequate compensation for IIT Mandi Catalyst. Thus, entrepreneurship and startup activities will enable iHub to sustain itself. In addition, the entrepreneur in residence program will likely allow a certain number of these individuals to startup companies, where the iHub could get a percentage share based upon investment and a certain percentage of revenue from products sold by these startups.

5 Target Beneficiaries

The target beneficiaries will include the common population, academia, industry, district, state, and central governments (the different stakeholders and impact under various problems listed under Table 1. The iHub will provide both products and services concerning the HCI area to its different beneficiaries across its offering, covering the following problems/applications: natural hazards (landslides) and environmental issues like air pollution; agricultural advisories via mobile applications; game-theoretic and cognitive simulations/interface development and evaluation for cybersecurity involving deception and intrusion-detection systems; ML-based network management and visualization in telecom sector; EEG and 3D immersive interface-based training for Indian Defence forces in the mountainous terrain; and, HCI and ML support for low-cost and PoC diagnostic systems. Also, for HCI-BCI area iHub can provide services to the healthcare in terms of tobacco and alcohol de-addiction. Also, for the justice department in form of lie detection system which will enhance the efficiency of the system.

Given its section-8 orientation, the iHub will work on a beneficiary model where benefits and costs to beneficiaries balance out. Ideally, products sold to beneficiaries will be charged an amount (to be decided for different product offerings). Also, services offered by the iHub in terms of research equipment time and computation time will be charged daily. The exact user charges for these equipment and computational resource time will be worked out (some assumptions and benefits have been detailed in this report).

Given the nature of projects and their outcomes, the impact on society and people is likely positive.

6 Legal Framework

The iHub is a section-8 company that is registered under the Companies Act, 2013. Separate MoUs regarding the involvement of iHub in its sponsored projects and earnings through patenting and

commercialization has been made. Also, an agreement has been made for using the services of iHub and the policy of reimbursements in case of damages to the equipment. Furthermore, legal contracts will be made with startup companies set up with support from the iHub. Moreover, MoUs will be signed with all iHub spokes and partners, and roles and responsibilities towards the collaboration will be outlined as part of these MoUs. IIT Mandi will purchase the equipment for HCI research, and it will be housed on IIT Mandi's campus. The section-8 company will allow translational activities for access to this equipment. There will be a MoA signed between the section-8 company and IIT Mandi for this purpose.

7 Environmental Impact

The environmental impacts are likely to be minimal and positive. For example, projects concerning natural hazards (landslides), environmental problems like air pollution, and agricultural advisories can create positive outcomes for people and society. As adequate space will be provided on the IIT Mandi campus to this HCI iHub, there will not be any adverse impacts like clearing space for setting up this iHub.

8 Technology

The choice of projects under different application domains have been made based upon the gap in the literature in HCI in these areas, the potential of future research in the corresponding area, the needs of India to emerge as a leader in HCI research in India, and the current strengths present at IIT Mandi. As India is still a developing economy with a sizeable socioeconomic disparity, most technologies focus on low-cost solutions. Thus, mostly the projects are expected to develop and evaluate interface-based technologies using open-source or non-commercial software. When commercial technology is used to provide a solution, care would be taken that the cost of retail technology is low. For example, for landslide and air-pollution monitoring, the iHub would encourage the use of low-cost MEMS-based sensors, which are available as components off the shelf.

Similarly, for agricultural advisories, the project plans to use low-cost mobile-based applications and low-cost sensors for measuring weather and soil parameters. Furthermore, developing environments, cybersecurity, and CAD tools for digital pathology and forensics will use open-source technologies like Unity, Python, PHP, MySQL, and MongoDB. The iHub will mainly fund the development of indigenous systems for the Indian setting.

9 Management

The iHub is headed by three Directors, the Directors of the section-8 company. Director IIT Mandi, Dean (Sponsored Research and Industrial Consultancy & International Relations), IIT Mandi, and a Senior Faculty from the host institute will serve as the directors of the section-8 company. Senior faculty or senior industry persons may join later as additional Directors. The yearly organization structure of the iHub has been shown in Figure 3 to Figure 7. The figures show that it may take up to 8-months to hire a Chief Executive Officer (CEO) in the iHub. This evaluation is based upon prior experience with section-8 companies incubated on the IIT Mandi campus, where it was challenging to hire a CEO. In addition to the CEO, faculty-in-charges will play an active role in managing the iHub in the first two years of its existence.

As shown in Figure 3-7, the IIT Mandi faculty will play a significant role to make the iHub a success across all 5-years.

There will also be a part-time senior advisor who would advise the overall faculty in charge in the first two years. The yellow boxes in the Figures indicate that only one of these two boxes may exist when the CEO gets hired. Over time, more autonomy is given to the CEO and the iHub staff to make it self-reliant in its management, where the faculty start playing an advisory role. In addition, the iHub will have a Hub Governing Body (HGB), which will include a minimum of 12 members: the three Directors of the section-8 company, three personnel from industry, three personnel from academia, the CEO, the faculty-in-charge, and the DST project director. There would be an overall faculty-in-charge of the iHub under the Directors and the HGB. The CEO and other faculty-in-charges (one for each for technology development, incubation, skill development, and operations) will work under the overall faculty-in-charge. There would be an outreach, PR, and operations vertical to manage the outreach, PR, finance, HR, and marketing activities of the iHub. This vertical will also take care of the international collaborations.

Similarly, there would be one vertical for each technology development, skill development, and incubation activity and a faculty-in-charge for each vertical. The incubation vertical will be handled by IIT Mandi's existing technology business incubator, IIT Mandi Catalyst. Each vertical will be staffed with program manager(s), associates, office assistants, and office attendants. There would be 12 staff hired in the first year, and 08 more staff would be employed in the second year. The CEO would likely be hired by the 8th month of the project. There would be eight staff working under IIT Mandi Catalyst for the iHub related incubation activities after two years (one senior manager, two managers, two senior associates, and three associates). Three of these eight incubator staff would be hired in the first year.

In the iHub, in the first year, beyond the CEO and senior advisor, four managers, five associates, and one office attendant would be hired. The remaining staff would be employed in the 2nd year. These staff would stay constant during the remaining 3-4 years. In addition, there would be several students (undergraduate, graduate, post-graduate), project/research staff, postdocs, and faculty across all IIT Mandi projects from the iHub. The stipend/salary for these students would come from projects sanctioned under the iHub. As also shown in Figures with ovals, there would be four domains with their own subject expert Faculty in-charges under the faculty in-charge, Research & Product Development.

Figure 3: Organization structure chart for Year 1

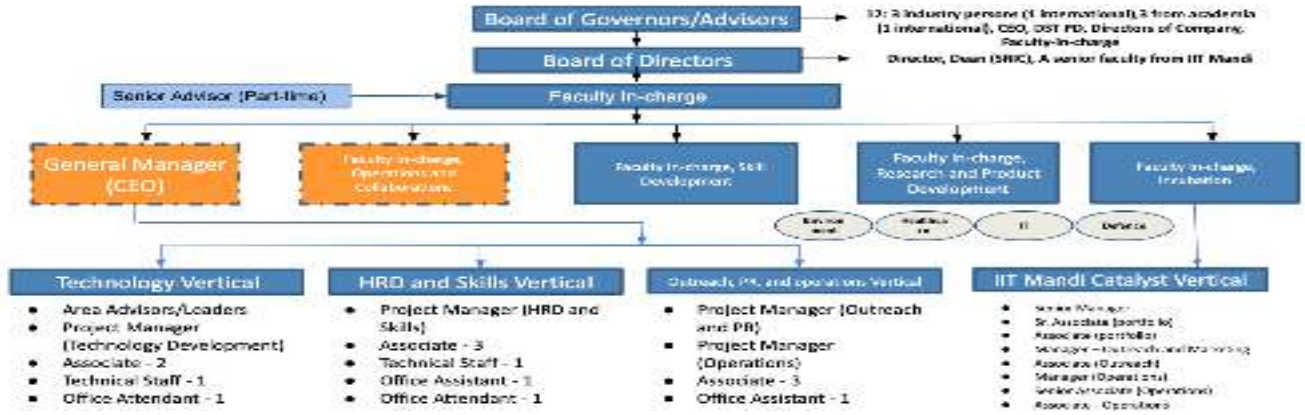


Figure 4: Organization structure chart for Year 2

Figure 5: Organization structure chart for Year 3

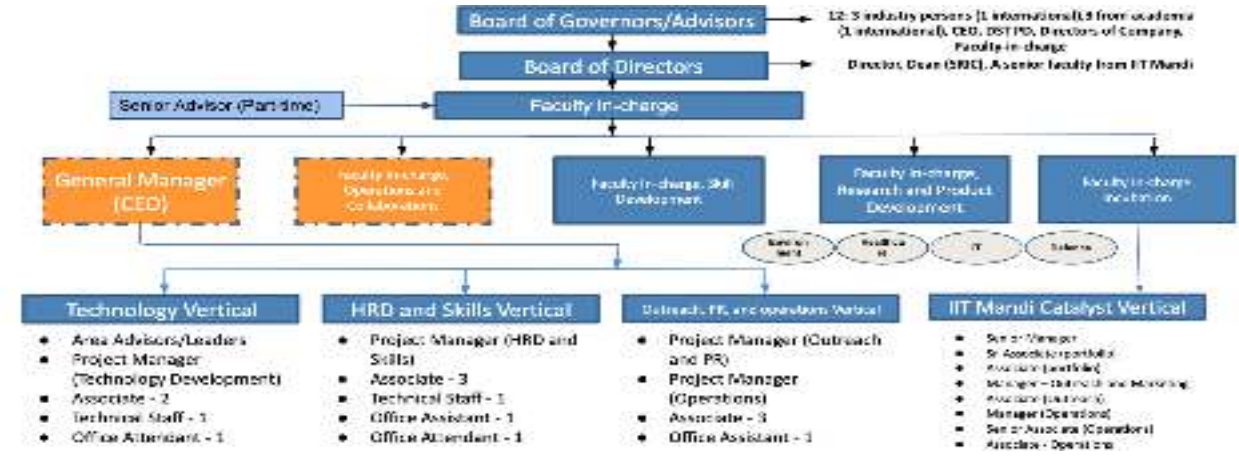


Figure 6: Organization structure chart for Year 4

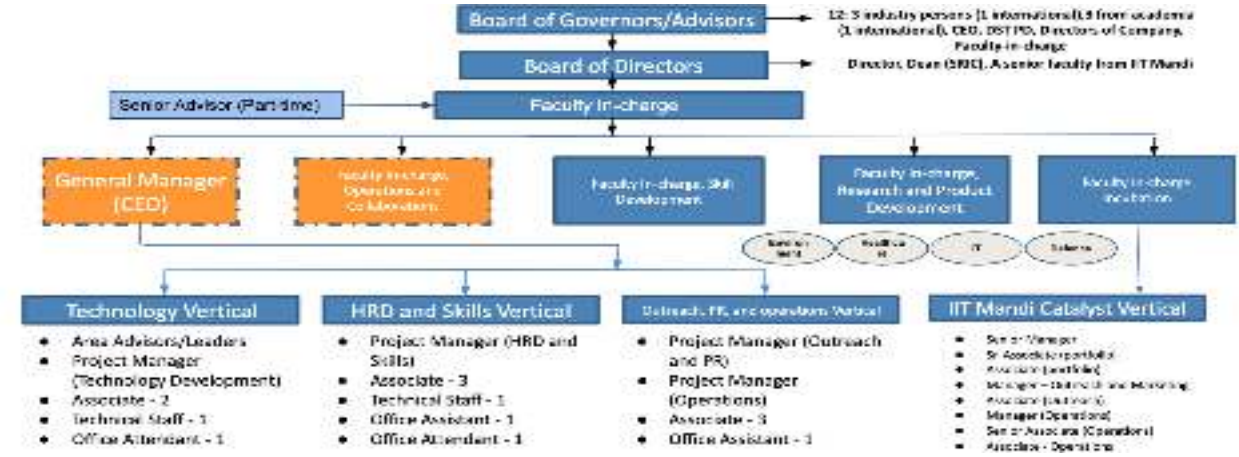


Figure 7: Organization structure chart for Year 5

10 Finance

Table 4 shows the break-up of different components of the entire year-wise budget of the iHub. The amounts have been segregated into recurring and non-recurring components. The total budget requested is INR 110 crores.

Table 4. Year-wise recurring and non-recurring costs over five years

Budget head / Year	Year 1 (in Crores)	Year 2 (in Crores)	Year 3 (in Crores)	Year 4 (in Crores)	Year 5 (in Crores)	Total (in Crores)
Recurring	9.15	9.06	2.31	1.99	1.05	48.25

Non-recurring	9.10	33.75	15.30	14.33	13.95	61.75
Total Rs in Crores	**18.25**	**42.81**	**17.61**	**16.32**	**15.00**	**110.00**

Table 5 shows the break-up of the budget into different components. In Table 5, the amounts have been segregated into manpower, travel, technology development, HRD and skill development, Innovation, entrepreneurship and startup ecosystem, international collaborations, equipment, honorarium, contingency, CAPEX, and miscellaneous expenses.

Table 5. Project budget over 5-years under different cost components.

Head	1st Year (in crores)	2nd Year (in crores)	3rd Year (in crores)	4th Year (in crores)	5th Year (in crores)	Total (in crores)
Recurring						
Manpower	0.88	0.12	1.34	1.46	1.60	5.41
Travel	0.23	0.00	0.32	0.32	0.51	1.37
Technology Development*	0.24	0.00	0.40	0.76	0.36	1.76
HRD and Skill development	2.70	2.72	5.02	5.11	2.82	18.37
Innovation, Entrepreneurship, and startup ecosystem	4.60	6.14	7.64	6.25	8.43	33.05
International Collaboration	0.05	0.05	0.05	0.05	0.05	0.25
Expenses for honorarium	0.04	0.04	0.04	0.04	0.04	0.19
Miscellaneous	0.37	0.00	0.50	0.35	0.15	1.37
Non-recurring						
Equipment	8.85	33.35	1.91	1.75	0.81	46.67
Capex	0.30	0.40	0.40	0.24	0.24	1.58
Grand Total	**18.25**	**42.81**	**17.62**	**16.32**	**15.00**	**110.00**

Note – The expenditures on Project Proposals under CFP are put in recurring as this would be an ongoing and repeat process spread over the years.

As shown in Table 5, the total budget for the iHub is INR 110 crores over five years. A certain amount will be spent on paying salaries to its manpower (20 personnel hired over the first two years; the CEO is hired by the 8th month). In addition, some amounts have been set aside for the travel for iHub promotions, reviews, and iHub-related work. Also, this travel amount will be used to support the travel experts to the iHub for different kinds of evaluations related to project selections and reviews, startup selection and review, and deliver skill development workshops. A certain amount has also been set aside for technology development. It will be given out in projects as a technology development component, which project PIs could use to buy some equipment towards technology development (about 25 projects will be funded from the iHub over five years, which will develop 25 products or more). Some amount has been set aside for skills development activities, including B. Tech., M.S., PhD, postdoc, and faculty fellowships. A small amount is also set aside to give travel support to about 25 graduate students (5 graduate students/year) for presenting at top international conferences. A part of the total amount has been set aside for startup activities (this amount will support the following activities: 140 startups incubated, 20 startups accelerated, 21 entrepreneurs in residence, and five grand challenges).

Furthermore, a certain amount has been set aside for developing international collaborations. Also, some amount has been set aside to pay an honorarium to experts who visit the Institute to review projects, startups, and skill development workshops. Also, the honorarium amount in the First Year will be paid to the faculty affiliated with or who serve the iHub. This honorarium is to be given to the professional development fund of the faculty.

A part of the total amount has been set aside for buying equipment given out in projects housed on the IIT Mandi campus. Annexure 4 shows the list of equipment and their costs which are to be purchased by the iHub across five years. The equipment purchased on the IIT Mandi campus will be offered to people for a specific fee, and it may create certain monetary benefits for the iHub. Also, this equipment will provide computational and experimental help to different projects funded from the iHub (see Table 1 and Grand problems) and aid with conducting short- and long-term workshops planned as part of the iHub. Specifically, purchasing these equipment allows the iHub to save equipment cost in funds given out as projects. In particular, the iHub proposes to set up two supercomputing machines. Each of these two machines contains multiple GPUs, and together they will help provide several GPUs for use at a single time. These multiple GPUs will support around 160 users across projects and startup activities in the iHub (about 40 users from startups and 120 users from projects). The supercomputing machines will also be provided to IIT Mandi, which would help in teaching and research activities at the host institute (priority will be given to the iHub-related activities over IIT Mandi-related activities for this purpose). Certain expenses have been considered miscellaneous expenses for paying for internet, telephone, and electricity over five years.

In addition, some amount has been set aside for capital expenditure for buying desktops, laptops, and furniture for the staff recruited at iHub. Table 6 shows the targets spread over five years as per the tripartite agreement (see Annexure 7). The targets are divided into four different areas: 1. Technology Development, 2. Entrepreneurship Development, 3. Human Resource Development, 4. International Collaboration (see Table 6). Under these areas, there are different sub-areas in which other targets are set for the five years. For example, in international collaborations, the target defined is one international collaboration per Year. So, there will be five international collaborations at the end of five years.

Table 6. Targets spread over five years

S. No.	Target Area	Targets					
		1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
1	**Technology Development**						
(a)	No of Technologies (IP, Licensing, Patents etc.)	6	10	9	0	0	25
(b)	Technology Products	0	4	5	7	9	25
(c)	Publications, IPR and other Intellectual activities	3	9	8	12	18	50
(d)	Increase in CPS Research Base	30	60	90	120	150	450
2	**Entrepreneurship Development**						
(a)	Technology Business Incubator (TBI)	1	-	-	-	-	1
(b)	Start-ups & Spin-off companies	7	7	7	7	7	35
(c)	GCC - Grand Challenges & Competitions	1	1	1	1	1	5
(d)	Promotion and Acceleration of Young and Aspiring technology entrepreneurs (PRAYAS)	1	-	-	-	-	1
(e)	CPS-Entrepreneur in Residence (EIR)	3	4	4	5	5	21
(f)	Dedicated Innovation Accelerator (DIAL)	1	-	-	-	-	1
(g)	CPS-Seed Support System (CPS- SSS)	1	-	-	-	-	1
(h)	Job Creation	100	1000	1650	2000	4000	8750
3	**Human Resource Development**						
(a)	Graduate Fellowships	25	45	60	80	90	300
(b)	Post Graduate Fellowships	12	20	18	0	0	50
(c)	Doctoral Fellowships	12	20	18	0	0	50
(d)	Faculty Fellowships	1	0	1	0	1	3
(e)	Chair Professors	0	1	0	1	1	3
(f)	Skill Development	200	200	200	200	200	1000
4	**International Collaboration**						
	International Collaboration	1	1	1	1	1	5

Table 7 provides the break-up of costs towards meeting different iHub goals over five years and the break-up of other expenses under different heads in the iHub. The total budget estimate of the iHub is likely to be INR 110 crores.

Table 7. Break-up of costs towards meeting different goals over five years

Sr. No.	Heads	Quantity	Per Unit Cost (in INR Crores)	Total (in INR Crores)
1. Technology Development = INR 1.76 Crores				
1(a)	No of Technologies (IP, Licensing, Patents etc.)	25	0.009	0.249
1(b)	Technology Products	25	0.04	1.011
1(c)	Publications, IPR, and other intellectual activities	50	0.01	0.5
2. HRD and Skill Development = INR 18.37 Crores				
2(a)	High-end skill development (Workshops)	1000 personnel	0.01	0.01
2(b)	Graduate Fellowships (Bright B. Tech. students)	300	0.0015	0.41
2(c)	Postgraduate Fellowships	50	0.04464 (Salary of 12,400/month for three years)	2.232
2(d)	Doctoral Fellowships	50	0.1380 (Salary of 35,000/month for the first two years and 45,000/month for the Third Year)	6.9
2(e)	Postdoctoral Fellowships	40	0.204 (Salary of 85,000/month for two years)	7.80
2(f)	Faculty Fellowships	3	0.2 (Salary 1,50,000/month	0.6

			for 12 months + 2,00,000 one-time contingency grant)	
2(g)	Chair Professors	1	0.40 (Salary of 2,50,000/month + 10,00,000 one-time contingency grant)	0.41
3. Entrepreneurship and Start-ups = INR 33.05 Crores				
3(a)	CPS-GCC Grand challenges and competitions	5	INR 0.05 crores/year over first 3-years; INR 0.06 crores/year in 4th-year; INR 0.09 crores/year in 5th Year	0.30
3(b)	CPS-Entrepreneur in Residence	21	INR 35,000/month for EIRs from Year 1 to Year 3, INR 40,000/month on Year 4 and Year 5	0.97
3(c)	CPS-Startups and Spin-Off Companies (Exploration + Incubation)	140	INR 0.0125 crores/startup for 100 startups for 3 months; INR 0.25 crores/startup for 25% of incubated startups from Phase 1	24.68
3(d)	Recurring expenses	1	Includes hiring of manpower, mentoring, consulting, and compliances. (See Annexure 6 for more details)	6.5
3(e)	Non-recurring expenses	1	Includes office furniture, fittings, and office equipment	0.6
4. International Collaborations = INR 25 Lakh				
4(a)	International Collaborations	5	INR 0.05 crores/collaboration for	0.25

			travel and logistics of the to-and-fro visits	
5. Equipment = INR 46.67 Crores				
5(a)	Equipment	1	Details of the equipment are given Annexure 4 and INR 27 lakh for each of the 25 projects in technology development	46.67
6. Travel expenses = INR 1.37 Crore				
6(a)	Travel concerning iHub personnel	225	Travel concerning iHub (3 travels/year for 5 years for 10 iHub affiliated people.	0.75
6(b)	Travel as part of the projects given through iHub	25	INR 0.005 crores/project/year over 3 years	0.375
6(c)	Travel grants for students	20	For a maximum of INR 0.02 crores/travel request	0.24
7. Salaries of people recruited at iHub = INR 5.41 Crore				
7(a)	CEO (hired by the 8th month)	1	INR 1.506 crores/person	1.506
7(b)	Senior Advisor (Contractual/Part-time) @ 1 lakh per month for the 1st two years (hired by 6th month)	1	INR 0.18 crores/person	0.24
7(c)	Project Manager @ 0.7 lakh per month (hired by 6th month)	2	INR 0.49 crores/person	0.98
7(d)	Associate @ 0.5 lakh per month (hired in the 13th month)	3	INR 0.286 Crore/person	1.14

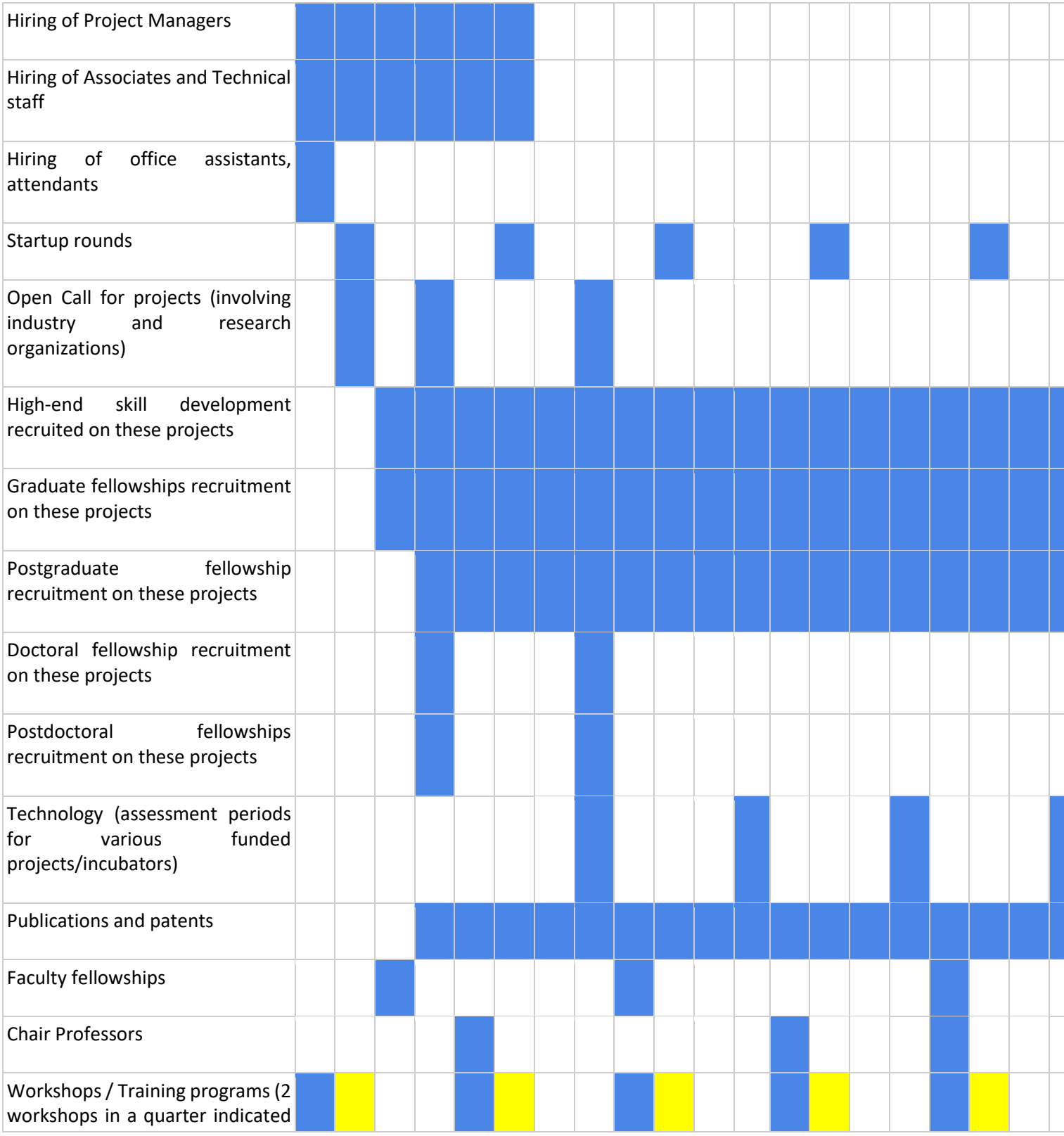
7(e)	Associate @ 0.5 lakh per month (hired in the 4th month)	3	INR 0.36 Crore/person	1.08
7(f)	Technical Staff @ 0.25 lakh per month (hired by 13th month)	1	INR 0.14 crores/person	0.14
7(g)	Office Assistant @ 0.2 lakh per month (hired by 13th month)	1	INR 0.114 crores/person	0.114
9(i)	Office Attendant @ 0.15 lakh per month (hired by 13th month)	1	INR 0.086 crores/person	0.096
9(j)	Office Attendant @0.15 lakh per month (hired by 3rd month)	1	INR 0.109 crores/person	0.114
10. Expenses for honorarium, stay, and mementos = INR 0.19 Crores				
10(a)	Expenses for honorarium, stay, and memento	75 experts/visits	Guest Visit and Faculty Honorarium	0.19
11. Miscellaneous expenses = INR 1.37 Crores				
11(a)	Miscellaneous	1	1.37	1.37
12. Capex = 1.58 Crores				
12	Capex	1	1.58	1.58
Total = 110 Crores				

11 Time Frame

Figure 8 shows the timeline of different activities concerning the iHub. The first and future quarters would be utilized to prepare the DPR, register the section-8 company, form the hub governing board (HGB), and hire the CEO and other company staff. The hiring schedule is the following: 1 office attendant will likely be employed by the 3rd month; four project managers are likely to join by the 6th month; one senior advisor will be hired by 6th month; five associates will join by 4th month; and, three associates, two technical staff, two office assistants, and one office attendant will be hired by the 13th month. The CEO will likely get hired by the 8th month. The hiring of the CEO will relieve a faculty in charge of the operation activities, where the faculty can focus on iHub-related research and development. Also, it will bring other faculty in-charges into an advisory role. The second, fourth, and eighth quarters will be focused on an open call for projects from the iHub. It is targeted to give out six projects in the first round, 10 in the second round, and 9 in the third round. Each of these 25 projects will span three years, and likely, 50% of these projects may go to the host institute as per DST norms. The workshops/training programs will span five years, where there will be one physical workshop and one online executive program per year. These workshops are in addition to the project-related workshops organized by respective project PIs. The projects will require the hiring of skilled manpower throughout different quarters over a period of 5-years. In several instances, doctoral students and postdocs may be hired because of projects given out to different institutions.

The iHub will also incubate companies as well as have the EIRs over five years. There would be regular yearly assessment periods of projects given out by the iHub. It is expected that the publications and patents will follow throughout the 5-years from the iHub. The iHub will also invite three faculty fellows for a duration of 1-year each to participate in research and the different iHub-related activities. Also, the iHub will ask three chair professors for a period of 1-year each to participate in research and the various iHub-related activities. The iHub will also organize a five grand challenge competition over five years (i.e., 1 per year). The iHub will undergo internal evaluations every three quarters and external evaluations every four quarters of its activities.

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q 10	Q 11	Q 12	Q 13	Q 14	Q 15	Q 16	Q 17	Q 18	Q 19	Q 2
Writing DPR, registering a section-8 company, creation of HGB																				
Hiring of CEO																				
Hiring Senior Advisor																				


Hiring of Project Managers
Hiring of Associates and Technical staff
Hiring of office assistants, attendants
Startup rounds
Open Call for projects (involving industry and research organizations)
High-end skill development recruited on these projects
Graduate fellowships recruitment on these projects
Postgraduate fellowship recruitment on these projects
Doctoral fellowship recruitment on these projects
Postdoctoral fellowships recruitment on these projects
Technology (assessment periods for various funded projects/incubators)
Publications and patents
Faculty fellowships
Chair Professors
Workshops / Training programs (2 workshops in a quarter indicated

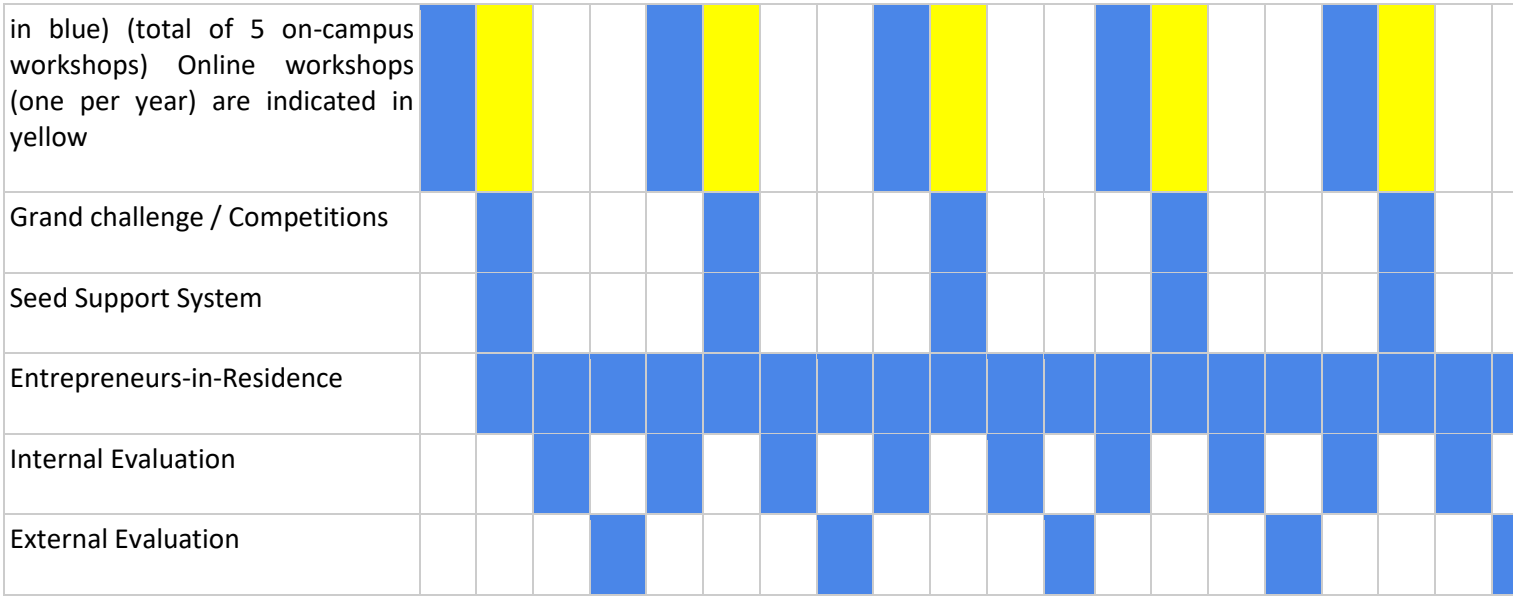


Figure 8. The timeline of different activities in the iHub for 5-years

Table 8 shows the year-to-year plan of activities under the iHub. As can be seen, the iHub will start slowly in year one and accelerate towards its different targets in year 2. In year 3, the iHub will achieve efficiency in its operations, which will continue to mature in years 4 and 5.

Table 8: Year-to-year plan of the activities and the goals reached

Activities	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Manpower	12/20	20/20	20/20	20/20	20/20
Research and Technology Development					
Projects* Products Patents Publications	6/25 0/25 0/25 3/50	16/25 4/25 0/25 12/50	25/25 9/25 5/25 20/50	25/25 16/25 13/25 32/50	25/25 25/25 25/25 50/50
Skill Development					

Workshops B. Tech fellowships Master's fellowships Doctoral Fellowships Postdoctoral Fellows Faculty Fellowships Chair Professors	5/60 25/300 12/50 12/50 13/40 1/3 0/3	12/60 70/300 32/50 32/50 23/40 1/3 1/3	30/60 130/300 50/50 50/50 40/40 2/3 1/3	40/60 210/300 50/50 50/50 40/40 2/3 2/3	60/60 300/300 50/50 50/50 40/40 3/3 3/3
Startups Incubated					
Incubation Phase 1 Incubation Phase 2 EIRs Grand Challenges Accelerator	28/140 7/35 3/21 1/5 2/20	56/140 14/35 7/21 2/5 5/20	84/140 21/35 11/21 3/5 10/20	112/140 28/35 16/21 4/5 15/20	140/140 35/35 21/21 5/5 20/20
International Collaborations	1/5	2/5	3/5	4/5	5/5

Notes. * It is expected that 25 projects will lead to 25 products for 5-years. X/Y means that X amount achieved out of the Y goal.

12 Cost-Benefit Analysis

Table 9 shows the inflows from different components of the iHub over five years. As explained in the finance section (see Tables 4 and 5), the iHub will use the funds obtained from DST in such a manner that it becomes sustainable over five years. **The numbers assumed in Table 9 are conservative, and the earnings are likely to be more than those listed in the table.** There will be potential earnings from workshops of around INR 7.4 crores over five years. This amount assumes the following: an INR 8000 registration fee per participant for five 1-week long on-campus workshops (one per year with 50 participants in each); 1.89 crores per workshop earnings from online executive programs (one per year, 6-months long, and 150 executives from the industry with INR 85,000 from each executive); and, 10% earnings from 50 workshops of 75-participants each conducted by institutions who get projects from the iHub (one 1-week long workshop per project @ INR 8000 per participant), where IIT Mandi faculty and iHub-affiliated personnel and students may also participate. The assumption of 130 participants per online executive program assumes about 6-7 people per company, where around 20 companies, including those listed in Annexure 1, will likely be involving their personnel for such workshops. It is also assumed that INR 0.3 crores will be generated from the district or state government contributions over five years. It is believed that around 20% of the incubated companies and 30% of the accelerated companies will be successful, with a 4% share going to the iHub. A 3-year gap in these earnings from incubation (most benefits in 6-10 years).

Companies are incubated with a worth of 10 Crores and accelerated worth 50 Crores. Thus, only a small part of INR 6.68 crores will come by years 4 and 5 and most of the remaining INR 17.52 crores will come between years 6 and 8. It is assumed that 10% of the patents will be successful and generate a lump sum amount of INR 0.5 crores. Thus, leading to a benefit of INR 0.5 crores at the end of 5 years. It is assumed that 30 people use 10 equipment with a daily rental charge of INR 500 for 60 days per year for 4.5 years. Thus, leading to a benefit of INR 4.1 Crores at the end of 5 years. It is assumed that for academia, 30 people use the computation facilities for 16 hours a day for 75 days at $2/hour and for industry, 30 people use the computation facilities for 16 hours a day for 75 days at $5/hour. Thus, leading to a benefit of 8.505 Crores at the end of 5 years. Furthermore, it was also expected that the five workshop course materials will be downloaded around 2000 times each with a cost of INR 400 per download. Thus, leading to a benefit of 0.4 Crores at the end of 5 years. If around 4 companies will use the workspace on IIT Mandi campus over a 5-year period (i.e., one company each in years 2, 3, 4, and 5), the iHub stands to gain a benefit of 0.3 crores (with a monthly rental of INR 25,000 in return for space and access to IIT Mandi campus faculty, lab, and library facilities). It is also assumed that after operations are established, the iHub will approach different external agencies (including industry via CSR) for generating these INR 5.0 crores grants over a 5-year period. These earnings will be obtained from the 3rd year onwards. It is assumed that around 4 projects will come from industry with 50% contribution. These projects will lead to an overall inflow of INR 2 crores over a 5-year period. **Overall, the total benefits are likely to be INR 32.63 Crores (6.53 Crores/year) at the end of 5-years**. **Also, the total benefits are likely to be INR 10.68 Crores (2.14 Crores/year) between the 6th year and 8th year**.

Table 9. Inflows from different components of the iHub over five years

Sr. No.	Benefits description	Inflows (In Crores)	Explanation
1	Earning from workshop registrations	7.4	INR 8000/participant for on-campus workshops, 1.89 Crores from online programs (130 per workshop), and 10% from project workshops
2	Earning from district/state government contributions	0.3	Assuming a contribution of INR 6 Lakh/year

3	Earnings from startups	4.12 (10.68) *	If around 20% of the incubated companies and 30% of the accelerated companies will be successful, with a 4% share going to the iHub. A 3-year gap in these earnings from incubation (most benefits in 6-10 years). Success: Incubated worth 10 Crores and accelerated worth 50 Crores.
4	Earning from patents	0.5	Assuming 20% of the patents will be successful and generate a lump sum of INR 0.5 crores.
5	Earnings from equipment	4.1	Assuming 30 people use ten equipment with a daily rental charge of INR 500 for 60 days per year for 4.5 years
6	Earning from the utilization of computation as a service	8.505	For academia: Assuming 30 people use the computation facilities for 16 hours a day for 75 days at $2/hour For industry: Taking 30 people to use the computation facilities for 16 hours a day for 75 days at $5/hour
7	Download of workshop material	0.40	Assuming five workshop materials downloaded by 2000 people for INR 400/download
8	Revenue from space for companies in iHub	0.30	Assuming rental charges for four companies (assumed) of INR 25000/month

9	Grants from external agencies and industry	5.00	Assuming that after operations are established, the iHub will approach different external agencies (including industry via CSR) for generating these grants. Around 40 lac per year on average from 3rd year onwards.
10	Total industry contributions in terms of projects to iHub	2.00	Assuming four projects from the industry with 50% contribution.
Total (at the end of 5th year) = 32.63 Crores (6.53 Crores/year) **Total (between 6th and 10th years) = 10.68 Crores (2.14 Crores/year)**			

* The value in the brackets shows the inflow in the 6–8-year time.

Table 10 shows the different inflows over time. Most of the earnings will be non-uniform, and inflows are expected to come towards five years.

Table 10: Details of the inflows per year

S. No.	Benefits	Year 1 (In INR crores)	Year 2 (In INR crores)	Year 3 (In INR crores)	Year 4 (In INR crores)	Year 5 (In INR crores)	Total (In INR Crores)
1	Earning from workshop registrations	1.48	1.48	1.48	1.48	1.48	7.4
2	Earning from district/state government contributions	0.00	0.00	0.05	0.125	0.125	0.3

4	Earnings from startups	0	0	0	1.5	2.62	4.12 (10.68 in next 3 years)
5	Earning from patents	0	0	0	0.2	0.3	0.5
6	Earnings from equipment	0.2	0.98	0.98	0.98	0.98	4.1
7	Earnings from computation as a service	1.00	1.88	1.88	1.88	1.88	8.51
8	The download of workshop material	0.08	0.08	0.08	0.08	0.08	0.40
9	Revenue from space for companies in iHub	0	0.075	0.075	0.075	0.075	0.30
10	Grant from external agencies and industry	0	0	0.5	1	3.5	5
11	Industry contribution	0	0.2	0.3	0.5	1	2
	Total (at the end of 5th year)	**2.76**	**4.69**	**5.35**	**7.82**	**12.04**	**32.63**

	Total (between 6th and 10th year)						**10.68**

In addition, there are likely to be several non-monetary benefits from the iHub in terms of papers published, products developed, skills imparted, and companies incubated. These non-monetary benefits have been detailed in Table 11 below. As shown in Table 11, this Hub will create 8750 jobs across all activities, including research and technology development, skill development, entrepreneurship and startups, and collaboration.

Table 11: Non-monetary benefits from the iHub

S. No.	Benefits description	Quantity
1	Number of technology products generated	25 (some with partial funding from industry)
2	Number of publications	50
3	Number of IPRs generated	25
4	Number of PhDs + Postdocs trained	50+40
5	Number of master's students trained	50
6	Number of B. Tech fellowships	300
7	Number of Faculty Fellowships	3
8	Number of Chair Professors	3

9	Number of people trained from workshops (physical/online)	1000+
10	Number of travel grants given to students for international exposure	25
11	Number of companies incubated + accelerated	140 (35 with major funding) + 20
12	Number of course materials downloaded	2000 downloads of 5-course materials each
13	Number of EIRs	21
14	Job Creation	8750

13 Risk Analysis

Table 12 lists the different risks and their mitigation strategies. The primary risks have been constructed under the following headings: Legal/contractual risks, environmental risks, revenue risks, project management risks, and regulatory risks.

Table 12. Different risks and their mitigation strategies

Risk Type	Risk	Mitigation strategy
Legal/contractual risks	The company directors leave	Ex-officio members who hold positions in IIT Mandi.
	The startup company does not give a share of the profits to iHub after incubation	Before committing funds to a startup company credentials of the company and its directors will be checked. Also, legal agreements on stamp papers will be executed, prosecuting in

		an Indian court of law.
	The project's intellectual property is not shared with the iHub	Intellectual property generated from each project will be submitted to the iHub for approval before patenting, and other formalities are executed. Also, the iHub will be made a partner in the patent application.
Environmental risks	The advisory information provided via mobile, or web interfaces is misinterpreted	Different stakeholders using the interfaces will be trained on the meaning of information and its interpretation.
	The advisory information provided via mobile, or web interfaces has false positives and false negatives	Different stakeholders using the interfaces will be educated that information may contain false positives and false negatives.
Revenue risks	The iHub does not receive funds from DST in time	The iHub will contact the mission director at DST and seek assistance from IIT Mandi to overcome any financial difficulty in the short term.
	The iHub is unable to generate revenues from its startup companies	The success of the startup companies and the product will be carefully assessed while deciding to incubate companies - a proven market for the product will be an essential criterion.
	The iHub is unable to generate revenues from workshops and its services	Active marketing of services and facilities available in the iHub will be done via online methods. Workshops will be popularized

		among the relevant stakeholders.
	The iHub is unable to generate revenues from industry contributions	Industry partners will be actively approached for funding and contributions. Funding via industry CSR may be tapped.
Project management risks	The project gets delayed in meeting its objectives	A regular periodic review of the iHub and its activities and outcomes will be done for detailed purposes.
	The project manpower leaves	The work and code of the projects will be maintained via a version control system, and faculty and existing staff involved will provide continuity in case new members need to be brought up to speed.
	The CEO is not hired in time.	The faculty-in-charges will guide to ensure the success of the iHub over five years.
	The faculty in-charges are changed	New faculty in-charges will be assigned to take over the responsibilities of different components of the iHub.
Regulatory Risk	The interest rate on corpus funds changes.	A sensitivity analysis with different assumptions of interest rates will be performed. Also, adequate money will be kept in the corpus to account for a reduction in interest rates.

14 Outcomes

Measurable terms will be used to evaluate the outcomes of projects undertaken. Some of these measurable terms include the number of events/workshops of different participants, number of projects given, number of patents filed, number of peer-reviewed publications, number of equipment usages received, number of stakeholders benefited. In addition, the IHUB will use revenue generation for each project as an indicator and the ratio of revenue per number of X, where X could be events/workshops, projects, patents, equipment usage requests, stakeholders. In general, the measurements would be done based upon the goals set in Table 13 below, where the numbers mentioned against different items would be realized over the five years. **Please note that in some instances, the goals specified in Table 13 are different from those given by DST, where certain goals have been scaled based upon the capabilities of the host institute, IIT Mandi.** Beyond the five years, new goals will be set based upon the cost-benefit analyses of the technologies undertaken.

Table 13. Different IHUB components and respective goals

Description	Goal to be realized
Technology Development	
No of Technologies (Patents, IPs)	25
Technology Products	25
Publications	50
Increase in CPS Research Base	450
HRD and Skill Development	
High-end Skill Development (internships and workshops)	1000
Graduate Fellowships	300
Postgraduate fellowships	50

Doctoral Fellowships	50
Post-doctoral fellowships	40
Faculty Fellowships	03
Chair Professors	03
Entrepreneurship and Start-ups	
CPS-GCC Grand Challenges and Competitions	05
CPS - Promotion and acceleration of young and aspiring technology entrepreneurs*	01
CPS - Entrepreneur in Residence	21
CPS-Startups and Spin-Off Companies	140
CPS-Technology and Business Incubator	01 with 140 companies incubated (35 with significant funding)
CPS-Seed support system	01
CPS-Dedicated Innovation Accelerator	01 with 20 companies incubated
International Collaborations	05
Job Creation	8750

14.1 Deliverables with respect to grand problems

The iHub intends to address HCI issues and design effective interfaces to solve the Grand problems in the following research domains:

- Cognitive enhancement
- EEG/BCI-based interactive technologies and biofeedback
- Multisensory
- Conversational AI-based social robotics

14.1.1 Deliverables in the cognitive enhancement domain

- ➔ Development of applications for yoga and other Indian knowledge system practices for improving mental health or cognition.
- ➔ Development of HCI-enabled portable devices to quantify/handle cognitive impairments.
- ➔ Development of software for a virtual surgery training system, make corresponding plans for the actual surgery and practice before the surgery. The system may make more accurate pre-measurements and estimates and predict the complexity of the operation.
- ➔ Development of applications via wearable devices and/or 3D immersive experience apps for human posture improvements.
- ➔ Development of wearable devices for mental health monitoring or cognitive enhancement.
- ➔ Effect of Yoga in the Stress Reduction and in the Management of Anxiety and Somatic symptom disorders
- ➔ Effect of Covid-19 Pandemic on Social Fear Learning and Extinction
- ➔ Pupillometry using Smartphones
- ➔ Smart Glove for Sign Language Interpretation in the native language
- ➔ Detecting Textual Entities with Representational mining on Big Temporal Knowledge Graphs of Ancient Literature and Social Media Data
- ➔ Developing AI based cognitive function enhancement app by applying Artificial intelligence and biomarker profiling
- ➔ Interactive Virtual Surgery Training Agent
- ➔ Development of a new integrated, multimethod, dimensional approach for early detection of Mild Cognitive Impairment (MCI) using AI/ML techniques

14.1.2 Deliverables in the EEG/BCI-based interactive technologies and biofeedback

- ➔ Development of EEG-based neurofeedback applications for improvements to mental health, restorative rehabilitation including Indian knowledge system-based interventions
- ➔ Development of applications for de-addiction by using BCI technologies /tDCS/ yoga/other art forms.

- ➔ Development of methods/tools to identify mental issues (anxiety, depression, etc.).
- ➔ Development of personalized prosthetics, rehabilitation, teleoperation, and exoskeletons. Mobility solutions for aging/ailing population.
- ➔ Human stroke classification and prevention techniques.
- ➔ Development of device and tool for BCI/EEG based lie detector.
- ➔ Development of education technology solutions incorporating neurofeedback.
- ➔ Design and Development of Brain Controlled Wheelchair Considering User's Intention to Move Through EEG Signal and Eye Tracking
- ➔ Adaptive Neurofeedback System Tracking Confidence Level of Decision Making during Motor Imagery
- ➔ Neural Markers of Subclinical Anxiety during Young Adulthood
- ➔ Development of Artificial Intelligence based Depression Identification using Electroencephalogram Signals
- ➔ EEG based Smart Bed System for Bedridden Patients
- ➔ Multi scenario lie detection with EEG
- ➔ Design of tiny ML support Deep learning-based computation model for elderly person walking rehabilitation and diagnosis of fall recovery using wearable sensors
- ➔ EEG Source Localization assisted Ayurvedic Intervention in Brain Disorder Management
- ➔ Generation of Hindi-English Code-Mixed Computational Lexicon and Chatbot Counselling Application for Depression Disorder
- ➔ A Neural Feedback based Intelligent Software Application for Autism Spectrum Disorder (ASD) in Children, based on NLP Techniques
- ➔ Development of an FPGA based model predictive controller for tDCS using portable neuroimaging (fNIRS-EEG) data streams
- ➔ Design and Development of 3-dof Lower Limb Exoskeleton

14.1.3 Deliverable in the multisensory domain

- ➔ Digital Nose- Development of sensors, hardware, software, AI/ML to detect, identify, and classify smells.
- ➔ Digital Smell - Development of sensors, hardware, software, AI/ML to recreate smells from their digital patterns.
- ➔ Digital Tongue - Development of sensors, hardware, software, AI/ML to detect, identify, and classify taste.
- ➔ Digital Taste- Development of sensors, hardware, software, AI/ML to recreate taste from their digital patterns.

- ➔ Heart Rate Variability monitors - Development of wearable sensors, hardware, software, AI/ML to monitor heart rate variability with applications in Indian knowledge system and modern medicine.
- ➔ Biosensors and applications for detecting monitoring diseases like diabetes.
- ➔ Designing advanced, efficient, compact, highly reliable sensors and biomarkers-based systems to combat Alzheimer's disease, heart attacks and early-stage cancers
- ➔ Digital nose for healthcare: Diagnosing diabetes and heart diseases via a low-cost digital nose
- ➔ Glucose oxidase nanomaterial-based tattoo ink composite as biosensor to monitor the blood glucose level for diabetic detection

14.1.4 Deliverable in the Conversational AI-based social robotics

- ➔ Social robots with learning skills (Math and English) for college students.
- ➔ Social robots with cognitive behavioral therapy skills for improving depression, stress, and anxiety
- ➔ Medical assistants' robot in the hospital for a high level of patient care
- ➔ Yoga Instructors/meditation robots
- ➔ Customer-centric robots

The iHub will also focus on creating low-cost mobile-based applications and robust IoT systems to monitor crop health for development and evaluation to disseminate agricultural advisories for different crops, diseases, and economic variables to rural farmers. This application would create a farmer-friendly interface, and it would help to enhance crop management practices. Also, low-cost MEMS-based sensors and interfaces for visualization of satellite and field-based data for regular or continuous landslide monitoring and associated machine learning algorithms will be developed. These deliverables will help detect the triggering of landslides at an early stage.

Furthermore, looking at the trends of air quality data monitoring across the country, it is pretty evident that air pollution has become a severe problem in India. Along with other steps required to reduce air pollution, setting up modern air-quality sensing systems and warning systems is especially important and urgent. These systems would monitor air quality and send cautions and warnings to the people of an area where the pollution levels breach pre-defined thresholds. The low-cost air-quality monitoring prediction and warning system would warn people in real-time via SMSs and other interfaces if the air quality deteriorates in an area.

In healthcare domains like CAD for digital pathology, the iHub will introduce a digital pathology database management system and create reporting tools based on images, text, speech, and eye-tracking. These tools would be supported by cloud-based and device-based ML/DL backend algorithms. Also, the iHub plans to provide remote diagnostic tools. These tools will help medical emergencies, especially when the users are in remote places or are not in healthy moveable conditions. The iHub plans to introduce body

area network technologies to provide helpful healthcare monitoring of vital body parameters such as EEG, ECG, EMG, blood pressure, glucose level, etc. Table 14 lists the concrete deliverables across Grand and other problems.

Table 14. Deliverables with respect to other problems

Domain	Sub-domain	Problems	(Deliverables/outcomes)
Environment (Grand Problem)	Agriculture	Indigenous interface development and evaluation for disseminating agricultural advisories for different crops, diseases, economic variables via mobile applications to rural farmers.	Develop low-cost and robust IoT systems to monitor crop health and develop and deliver mobile app-based advisories to farmers using a farmer-friendly interface.
	Landslides	Development and evaluation of an interface for visualization of satellite and field-based data for regular or continuous landslide monitoring, warning, and prediction	Develop low-cost MEMS-based sensors for visualization of satellite and field-based data for regular or continuous landslide monitoring.
	Air pollution	Development and evaluation of an interface for air-pollution monitoring, warning, and prediction	Develop a low-cost air-quality monitoring prediction and warning system that would warn people via SMSes if the air quality deteriorates based on (AQMPWS) technology.
Healthcare (Grand Problem)	CAD for Digital Pathology	Development of interfaces for efficient triaging, screening, labelling large volumes of whole-slide images	A desktop/tablet-based software for efficient slide management and navigation Cloud-based and device-based ML/DL backend algorithms Semi-automated labelling, tagging,

			reporting tools based on Images, Text, speech, eye-tracking
	Healthcare analytics	Development and evaluation of interfaces for the following applications: 1. Healthcare analytics of healthcare cost and socio-economic variables over time 2. Machine learning-based models for blood glucose prediction	Web-based interface for visualizing and predicting patient-related healthcare expenditures. Web-based interface for visualizing and predicting blood glucose levels in the human body
	Body Area Networks	Development and evaluation of body area network interfaces for real-time monitoring and warning of physiological variables like heart rate, temperature, blood pressure, and others	Web-based interfaces for human body monitoring and warning
	CAD for Neuroradiology	Development of interface for interactive processing and visualization for High-density fiber tracking (HDFT) for Diffusion-MRI imaging Interface for analysis of structural and functional networks	Desktop, tablet, and VR based. A visualization system for HDFT fiber tracks Interface for analyzing and visualizing structural and functional brain networks Algorithms on diffusion MR images and computation of fiber tracks Algorithms for brain connectivity Semi-automated tagging and reporting
Information Technology	Telecom Networks	Interfaces for visualization of descriptive and predictive analytics for network management in the telecom sector.	Web-based interfaces for visualization of performance variables in telecom networks and Dashboard, which assists

			network administrators in decision making, based on descriptive analytics and inferences drawn from machine learning (ML) models.
	Behavioral cybersecurity	Game-theoretic interfaces in cybersecurity involving deception and intrusion-detection systems	Game-theoretic simulation tools enable participants to perform as penetration testers against factors like team size, network size, the proportion of honeypots, and the accuracy of an intrusion detection system.
Defence and Security	Cognitive Technologies	Development of an interface for Human Performance (individual/team) visualization and forecasting involving Transcranial Direct Current Stimulation (tDCS), VR/AR/MR and machine learning methods	Desktop-based and VR-based interface for visualizing and Machine-learning models and algorithms predicting the extent of performance enhancement pertaining to complex decision-making given multivariate variables evaluated before and after tDCS intervention.
	Multimedia Forensics	Software for audio-video-image authentication Interfaces for management, labelling, editing, low-resolution person and vehicle id from surveillance feeds, and ego-centric cameras Interfaces for semi-automated audio analysis in local languages, geo-mapped textures in the speech that characterizes region-specific soundscapes	Desktop and tablet-based software ML / DL algorithms running on the device or on the cloud Development of deep learning-based multimedia forensic interactive software package including functionality for Image, video and speech

			authentication, and forgery analysis

14.2 Evaluation

Evaluation will form an essential part of iHub's portfolio. Every half-year, an internal assessment will involve both HGB and iHub's partners and stakeholders. In addition, every two years, a third-party evaluation of the iHub will be done. The evaluations will require an audit of the finances of iHub as well as its output on different measurable terms. Any activity where the iHub was non-performing well will be identified, and measures will be discussed and implemented to improve the non-performing activities.

Annexure - 1: Indian companies to be contacted by the iHub for collaborations

S. No	Name of the Company	Link
1	Microsoft Research India, Bengaluru	https://www.microsoft.com/en-us/research/lab/microsoft-research-india/
2	Google Research India, Bengaluru	https://about.google/
3	Tata Consultancy Services (TCS) Innovation and Research, Bengaluru, New Delhi	https://www.tcs.com/tcs-research
4	Wipro, Bengaluru	https://www.wipro.com/en-IN/
5	Cognizant Technology Solutions, Bengaluru	https://www.cognizant.com/india
6	Webstaff India (ITRA Japan)	http://www.webstaff.in/
7	NetBramha UI/UX Studio, Bengaluru	https://netbramha.com/
8	Think Design Collaborative, New Delhi	https://think.design/
9	Pinktech Design, New Delhi	http://www.pinktechdesign.com/
10	Thence, Bengaluru	https://www.thence.co/
11	Peepal Design, Bengaluru	https://www.peepaldesign.com/
12	Lemon Design Pvt. Ltd., Pune	https://www.linkedin.com/company/lemon-design-pvt.-ltd.?trk=similar-pages_result-card_full-click
13	Threye, New Delhi	http://www.threye.com/
14	Lollypop UX/UI Studio	https://www.lollypop.design/
15	TouchMagix Studios, Pune	http://www.touchmagix.com/
16	Elixar Systems, Pilani, Rajasthan	https://www.elixarsystems.com/
17	Rxdata Sciecnce	https://www.rxdatascience.com/
18	Syneos Health	https://www.syneoshealth.com/
19	Dattendriya	https://www.dattendriya.com/

20	Emotiv	https://www.emotiv.com/
21	Rubiscape	https://www.rubiscape.io/
23	Unity3D	https://unity.com/

Annexure - 2: Project descriptions under different domains

Project descriptions under different domains are given below.

Domain: Environment

Subdomain: Agriculture

Introduction and challenges:

Given the locational challenges of rapidly varying terrain, 80% of mid-Himalayan farmers generally tend to have small landholdings and depend on rainfed irrigation. The uncertain climatic conditions have created an urgent need to develop constantly evolving agriculture practices that can deliver reliable returns to the farmers. Foremost among these are dynamic advisories at the last mile, which enable the farmers to apply the right agricultural inputs at the appropriate time, harvest at the appropriate time and plan the appropriate crop rotation cycle. Such advisories enable the farmer to minimize input costs while maximizing their outputs. The main challenge towards enabling such a system is adapting the appropriate technology for mountainous terrain and the acceptance of the same by the farmers.

SOTA works: Current work related to precision agriculture [1-3] and advisories usually have been demonstrated in indoor conditions such as greenhouses or in large farm holdings using mobile aerial vehicles. There is a dearth of a comprehensive advisory system suitable for small farm holders in hilly terrains.

Data resources: Currently block-level weather data are available from IMD and Satellite image data from ISRO. However, one of the aims of this project is to generate high-resolution weather and image data at the farm level.

Deliverables: Develop low-cost and robust IoT systems to monitor crop health; To analyze data from IoT systems to develop advisories for farmers to enhance the crop management practices; to develop and deliver mobile app-based advisories to farmers using a farmer-friendly interface.

References:

[1] E. Finkel, “With ‘phenomics,’ plant scientists hope to shift breeding into overdrive,” Science 2009, 325(5939):380-381.

[2] X. Zhang et al., “High-throughput phenotyping and QTL mapping reveals the genetic architecture of maize plant growth,” Plant Physiology 2017, 173(3):1554-1564.

[3] B. Valle et al., “PYM: a new, affordable, image-based method using a Raspberry Pi to phenotype plant leaf area in a wide diversity of environments,” Plant Methods 2017, 13(1):98.

Subdomain: Landslides

Development and evaluation of an interface for visualization of satellite and field-based data for landslide monitoring**,** warning, and prediction

Introduction and challenges: Satellite data is useful to monitor the vulnerability of larger areas in terms of their landslide risk potential while ground sensors can give exact information of landslide parameters for a smaller area. Recently, various countries have adopted the combination of satellite data along with the ground sensors for monitoring and prediction of landslide events. Thus, there is evidence that the integration of satellite data with the ground deployed sensors network would be appropriate for landslide monitoring and early warning.

SOTA work: Some contemporary research efforts (1) (2) (3) have been reported in literature where researchers developed and used similar kinds of monitoring systems in other parts of the world. However, these systems are currently not available for landslide monitoring in India.

Data resources: Satellite data (Sentinel-1A, TRMM/GPM) and deployed ground sensors development of algorithms.

Deliverable: Develop integrated satellite and ground sensors-based landslide monitoring system with associated machine learning algorithms to detect triggering of landslide at an early stage. Interfaces for management, labeling, editing, low-resolution person and vehicle id from surveillance feeds, and ego-centric cameras Interfaces for management, labeling, editing, low-resolution person and vehicle id from surveillance feeds, and ego-centric cameras

References:

(1) J. A. Smethurst, A. Smith, S. Uhlemann, C. Wooff, J. Chambers, P. Hughes, … D. Hughes (2017). Current and future role of instrumentation and monitoring in the performance of transport infrastructure slopes. **Quarterly Journal of Engineering Geology and Hydrogeology**, 50(3), 271–286.

(2) Kahmen H., Eichhorn A., Haberler-Weber M. (2007) A Multi-Scale Monitoring Concept for Landslide Disaster Mitigation. In: Tregoning P., Rizos C. (eds) **Dynamic Planet**. International Association of Geodesy Symposia, vol 130. Springer, Berlin, Heidelberg.

(3) L. Zan, G. Latini, E. Piscina, G. Polloni and P. Baldelli, "Landslides early warning monitoring system," **IEEE International Geoscience and Remote Sensing Symposium**, Toronto, Ontario, Canada, 2002, pp. 188-190 vol.1.

Sub-domain: Air pollution

Introduction and challenges: Air pollution in India is at its worst currently (Vox, 2018) (1). Pollutants such as particulate matter with an aerodynamic diameter smaller than 2.5 µm ($PM_{2.5}$), nitrogen oxides (NOx), and tropospheric ozone (O_3) continue to be a cause of cancer, respiratory and cardiovascular disease, and premature death (EEA, 2016) (2). Poor air quality is detrimental to human health, with several studies finding short-term and long-term pulmonary and cardiovascular health effects of PM10 and PM2.5 (Rückerl, Schneider, Breitner, Cyrys, & Peters, 2011) (3). Air pollution also incurs major economic costs on the order of billions of Euros a year (EEA, 2016). The air-quality problem is severe in India. Recent evidence shows that due to forest fires, weather patterns, and tailpipe and industrial emissions, the air-quality problem is becoming severe in several townships in India. To address this problem, there is an urgent need to set up air-quality sensing and warning systems, which could monitor air-quality and warn people in case pollution levels to breach pre-defined thresholds.

SOTA work: Reference (4) proposed an indoor air-quality monitoring system for monitoring of temperature, humidity, PM2.5, PM10, total VOCs, SO_2, CO, illuminance, and sound levels. However, sensors were limited to indoors and there were no benchmarks used. Prior research proposed an air-quality monitoring system for urban areas in Italy where measurements were limited to CO, NO_2, O_3, temperature, and humidity values. Also, sensors used costly proprietary nodes and comparison with benchmarks was limited (7). Reference (6) proposed an air-quality system where the measurements were restricted to CO, SO_2, O_3, temperature, and humidity values with a limited comparison to benchmarks. In this research, a system is proposed that monitors seven pollutants (PM1.0, PM2.5, PM10, Carbon Monoxide, Nitrogen Dioxide, Ozone and Sulphur Dioxide) and five weather variables (Temperature, Pressure, Relative humidity, Wind speed, and wind direction) and we benchmark the values measured against hand-held meters or other real-time air-quality devices.

Deliverable: Development of low-cost air-quality monitoring prediction and warning system (AQMPWS) technology, which could be deployed at several townships in India for 24x7 monitoring of air pollution. The technology would warn people via SMSes in case the air-quality deteriorates at the deployed location.

References:

(1) Irfan, U. (2018, June 9). Why India's air pollution is so horrendous. Retrieved from https://www.vox.com

(2) European Environment Agency: Air Quality in Europe (2016).

(3) Rückerl, R., Schneider, A., Breitner, S., Cyrys, J., & Peters, A. (2011). Health effects of particulate air pollution: a review of epidemiological evidence. Inhalation toxicology, 23(10), 555-592.

(4) Tiele, A., et al.: Design and Development of a Low-Cost, Portable Monitoring Device for Indoor Environment Quality, Article 5353816 (2018).

(5) Brienza, S. et al.: A Low-Cost Sensing System for Cooperative Air Quality Monitoring in Urban Areas (2015).

(6) Ikram, J., et al.: View: implementing low-cost air quality monitoring solution for urban areas. Environmental Systems Research (2012).

(7) Goodfellow, I., Bengio, Y, and Courville, A.: Deep Learning. 2nd edn. MIT Press (2016).

Domain: Healthcare

Sub-domain: CAD for digital pathology

Introduction and challenges: In the digital pathology domain, even with the availability of fast slide scanners which can digitize microscopy slides, one of the primary bottlenecks are to assess such large whole slide images (WSI) each of which is of the order of hundred million pixels, especially considering that the abnormal regions are localized to smaller regions in the WSI. Thus, for a large number of cases, efficient algorithms with very high specificity and sensitivity are required for practical systems, which work with weak labeling. Moreover, considering the pathologists in the loop systems, such systems should learn interactively and progressively via a user-friendly online learning and relevance feedback frameworks

SOTA work: Approaches considering weak labeling is only recently being reported (1,2). Moreover, none of these approaches follow an online learning method. Some user interactive systems also exist (3). However, these systems also involve user corrections, which is not fed back into the system for progressive improvements.

Data resources: To initiate work, one can use some public datasets such as (). However, our more realistic and larger amounts of data would be available from our industry and hospital partners (e.g., Aindra Systems Pvt. Ltd, AIMS, PGIMER)

Deliverables: (i) A desktop / tablet-based software for efficient slide management and navigation based on online learning and relevance feedback systems to prioritize diagnosis for scenarios involving many cases. (ii) Semi-automated labeling, tagging, reporting tools based on Images, Text, speech, eye-tracking (iii) Digital pathology database management system (iv) Cloud-based and/or device-based ML/DL backend algorithms

References:

(1) P. Courtiol et. al., “Classification and Disease Localization in Histopathology using only Global Labels: A Weakly-Supervised Approach” arXiv:1802.00212, 2020.

(2) D. Tellez et. al., “Neural Image Compression for Gigapixel Histopathology Image Analysis” arXiv:1811.02840, 2020.

(3) https://metasystems-international.com/in/

Sub-domain: Body Area Networks

Introduction and challenges: It's very vital for the healthcare system to provide remote diagnostics, especially when users are either located in remote places or they are nor in healthy moveable conditions. BAN-communication is one such mechanism which can easily facilitate remote monitoring and

diagnostics. BAN or Body Area Networks refers to communication between sensor networks that are embedded on and off the human body and provide useful health care monitoring of vital body signatures such as EEG, ECG, EMG, blood pressure, and glucose level, etc. (1 - 3). Under the framework of BAN an interface/circuit can be developed which collects data (vital signatures) form on-body sensors and through off-body wireless communication this data is transmitted to remote health care-unit for necessary diagnostics/analysis. This may lead to more efficient patient management in hospitals especially during mass-casualty disasters by automatically monitoring the vital signs of many patients simultaneously and shortening patient's wait-times. iHub - HCI can play a major role to facilitate the widespread utilization of BAN technology through interface/circuits development and generating a startup-ecosystem to accelerate the work on BAN systems.

Deliverable: BAN based interface of remote diagnostics.

References:

1) Huan-Bang Li; Takizawa, K.; Kohno, R., "Trends and standardization of body area network (BAN) for medical healthcare," European Conference on Wireless Technology, EuWiT 2008.

2) J. Ko, et Al., "MEDiSN: Medical Emergency Detection in Sensor Networks", ACM Trans. on Embedded Computing Systems, 2009.

3) C Chakarborty et al, "A Review on Telemedicine-Based WBAN Framework for Patient Monitoring", Telemedicine Journal and E Health, 2013 Aug; 19(8): 619–626.

Sub-domain: CAD for neuroradiology and associated domains

Doctors aid for analyzing brain connectivity for diagnostics and surgical planning

Introduction and challenges: Diffusion MRI based fiber tracts estimates can help doctors to characterize brain disorders causing structural changes and can assist them in surgical planning. High-Definition Fiber Tractography (HDFT) is a popular pipeline used for traumatic brain injury (TBI) to identify which brain connections are damaged. However, robust fiber tracking as HDFT needs more brain volumes i.e., more scanning time, and hence less feasible in clinical settings, especially in India. Reduction in scanning time can help in increasing diagnosis throughput. Furthermore, brain connectivity computed from both structural and functional perspectives has recently been shown to be important in various neurological conditions. However, tools which radiologists can employ to analyze complex brain connectivity are yet to be developed.

SOTA works: Few efforts have been reported (1,2,3) to reduce the overall scanning time. However, still, they are struggling with performance and better generalization. Furthermore, some recent work has highlighted an integrated approach employing both structural and functional connectivity (4,5).

Data resources: Majorly, data from the Human connectomics project is available for assessment of different existing approaches. In addition, MRI machines from partner hospitals will be used to acquire more domain specific data.

Deliverable: (i) Desktop, tablet and VR based Visualization system for HDFT fiber tracks

(ii) An interactive software system powered by deep learning algorithms on diffusion MR images which can enable the use of fewer volumes to yield robust fiber tracts. (iii) Interface for analyzing and visualizing structural and functional brain networks. (iv) Algorithms for brain connectivity (v) Semi-automated tagging and reporting.

References:

(1) Benou, Itay, et.al, "Deeptract: A probabilistic deep learning framework for white matter fiber tractography," MICCAI, 2019.

(2) RR Jha, A Nigam, A Bhavsar et al., “Multi-Shell D-MRI Reconstruction via Residual Learning utilizing Encoder-Decoder Network with Attention (MSR-Net),” EMBC, 2020

(3) Kratika Gupta et.al, “Bayesian dictionary learning and under-sampled multishell Hardi reconstruction,” Int. Conf. on Information Proc. in Medical Imaging, IPMI, 2017.

(4) A Iraji et. al., “Connectome-scale assessment of structural and functional connectivity in mild traumatic brain injury at the acute stage,” Neuroimage, 2016.

(5) S. Surampudi et. al., “Multiple Kernel Learning Model for Relating Structural and Functional Connectivity in the Brain,” Scientific Reports, Nature, 2018.

Low-cost early-stage screening for neurological diseases

Introduction and challenges: Early-stage identification of mental diseases is essentially important for doctors but challenging without any secondary and explicit manifestation of symptoms. Recently, compact setups such as EEG, MEG, fNIRS have been utilized in the classification and grading of several brain disorders like Alzheimer's, Stroke, and Epilepsy. Thus, there is evidence that monitoring electrical activity in the brain using EEG and other methods can reveal neurological illness.

SOTA work: Some contemporary research efforts (1) (2) (3) have been reported to characterize and classify brain disorders. However, these methods are usually not generalizable because state-of-the-art works tend to get over-fitted on a particular dataset, and do not perform well on other testing datasets. Thus, real-life commercial technology needs to be considering much larger data and exhaustive validation.

Data resources: Most For pilot development of algorithms, some public datasets can be used. Our plan to collaborate with PGI Chandigarh for larger patient data and acquire healthy person data indigenously using in-house devices.

Deliverable: Develop unimodal and multimodal device interfaces with associated softwares to detect brain diseases at an early stage.

References:

(1) Li, Fenglian et.al, "Multi-Feature Fusion Method Based on EEG Signal and its Application in Stroke Classification" Journal of Medical Systems, 2020.

(2) Cicalese, Pietro A. et.al, "An EEG-fNIRS hybridization technique in the four-class classification of Alzheimer's disease." Journal of Neuroscience Methods, 2020. (3) Fiscon, Giulia et.al, "Combining EEG signal processing with supervised methods for Alzheimer's patients' classification." BMC med. Info. and decision making, 2018.

A tool for doctor's aid for enhanced CT diagnostics (HDCT)

Introduction and challenges: Computed tomography (CT) plays an integral role in diagnosing Acute Pancreatitis (a phenomenon of death of cells in Pancreas) but involving radiation exposure. Low radiation CT yields noisy images as compared to high dose CT. Repeated CT scans might be necessary for accurate assessment leading to a substantial risk of radiation exposure.

SOTA works: Existing works like (1), (2), (3) on reducing low-dose CT noise show decent performance on PSNR and SSIM metrics. However, work on unpaired data is still unexplored. Real-time data available in hospitals are usually unpaired.

Data resources: We are currently collaborating with PGI Chandigarh hospital for some work for CT for Pancreas, which will extend to some other organs in near future. Also, public CT Scan data for different regions (Lung, Thorax, etc,.) is available at https://public.cancerimagingarchive.net/ncia/

Deliverable: Design a user interface and an algorithm to denoise and enhance a low dosage (70 KVP) CT Scan such that it resembles a high dosage (100 KVP) CT Scan, to enhance the diagnostic ease of Pancreatic Necrosis. Learning low to high dose transformation from without paired data is a huge challenge.

References:

(1) Qingsong Yang et, al "Low-Dose CT Image Denoising Using a Generative Adversarial Network with Wasserstein Distance and Perceptual Loss." IEEE Transactions on Medical Imaging (Volume: 37, Issue: 6, June 2018)

(2) Hongming Shan et, al "3-D Convolutional Encoder-Decoder Network for Low-Dose CT via Transfer Learning From a 2-D Trained Network" IEEE Transactions on Medical Imaging (Volume: 37, Issue: 6, June 2018)

(3) Maryam Gholizadeh-Ansari·Javad Alirezaie·Paul Babyn "Deep Learning for Low-Dose CT Denoising Using Perceptual Loss and Edge Detection Layer." Journal of Digital Imaging, 2019.

Domain: Information Technology

Sub-domain: Telecom networks

Introduction and challenges: Telecom network monitoring for service assurance (fault and performance) is becoming more and more challenging not only because of network growth and introduction of new technology platforms but also due to the expectation of quality of service. Today's telecom networks have 100s of millions of customers and millions of managed objects. The traditional network monitoring approaches are having their limitations as the amount of data to be monitored reaches big-data scale. Hence, this requires a revisit of the software architecture used for such data-analytic approaches. The challenge is to develop a service assurance tool that enables the service provider to view the status and predict the future status of the network (both optical and mobile) in real-time. This envisages sophisticated data analytics and data mining that would advise the operator on efficient fault management, service provisioning, and network planning for networks serving 100s of millions of subscribers. The interface development for this would require research in

1. Highly scalable and fault-tolerant software architecture based on cloud computing paradigms.
2. Application of machine learning techniques and advanced visualizations for processing and understanding Big-Data gathered from the operational networks.

SOTA works: NMSWorks Software Pvt. Ltd. (NMSWorks) has its CygNet [1] suite of products/solutions for telecom network monitoring for service assurance addressing optical transport network (OTN) and Internet protocol/multi-protocol label switching (IP/MPLS) technology domains [2,3]. This operation support system (OSS) addresses both terrestrial and submarine cable systems. This OSS space requires improved service assurance solutions with improvement in problem detection and possibly problem prediction and proactive healing. This would require new methodologies from descriptive and predictive data analytics to be applied.

Data resources: The broad network data retrieved from CygNet OSS that was managing a Tier-1 telecom service provider network having a total of 75000 network elements of multiple technologies. This involves one-year data from Jan 2018 to Jan 2019. The data contain approximately 20 key performance indicators (KPIs) per network element recorded at every 15-minute polling interval. This also contains fault data collected primarily through traps/notifications and from polling.

Deliverables:

Main deliverable: Dashboard which assists network administrators in decision making, based on descriptive analytics and inferences drawn from machine learning (ML) models.

Other deliverables on the support to the dashboard:

1. Scalable architecture for analytics of telecom data using a distributed streaming platform

2. Statistical analysis of faults/alarms and performance measures of different devices of a telecom network

3. Machine learning (ML) models for future prediction of the performance of network devices and future prediction of alarms/faults in network devices.

References:

[1] T A Gonsalves, A. JhunJhunwala, Hema A Murthy, et al., "CygNet: An Integrated Management for Modern Telecom Networks", in Proc. of National Conference on Communication (NCC-2000), IIT-Delhi, Jan. 2000.

[2] R. Madanagopal, N. Usha Rani, T.A. Gonsalves, "Path Computation Algorithms for Dynamic Service Provisioning with Protection and Inverse Multiplexing in SDH/SONET Networks", in IEEE/ACM Transaction on Networking, vol. 18, no. 5, pp. 1492-1504, October 2010.

[3] C. Jagadish and T. A. Gonsalves, "Distributed Event Flood Control in a Large Telecom Network", in International Journal of Network Management, vol. 20, no. 2, pp. 57–70, Mar/Apr. 2010.

Sub-domain: Cybersecurity

Introduction and challenges:

Our research will focus on human factors of cybersecurity where it will be investigated, how the accuracy of intrusion detection systems and deception via honeypots influence the decisions of hackers attacking computer networks. The main challenges are in creating simulation environments that allow researchers to create different cyberattack scenarios that vary in the proportion of honeypots and hosts. Once such simulations are created, another challenge is to find qualified people who could perform as penetration testers in studies where cybersecurity factors as well as human factors are varied. In this research, we plan to vary factors like team size, size of the network, the proportion of honeypots, and the accuracy of intrusion detection systems.

Background/ SOTA work:

Researchers have tried to make use of gaming technology to increase cybersecurity awareness [1][2]. We are also working on deception games via honeypots, through which we investigate the influence of various parameters in hacker's decisions using simulated environments [4][5]. Recently, researchers have tried to make use of augmented reality (AR) to increase cybersecurity awareness [3].

Data Resources:

Participants of the study will be graduate students from the Indian Institute of Technology, Mandi, with computer science as their background. Also, the participants must possess some basic knowledge of computer networks and cybersecurity.

Deliverables:

Game-theoretic simulation tools that enable the decisions of participants performing as penetration testers against factors like team size, size of the network, the proportion of honeypots, and the accuracy of intrusion detection systems.

References:

1. Salazar, M. & Puerta, José & Laorden, Carlos & Bringas, Pablo. (2013). Enhancing cybersecurity learning through an augmented reality-based serious game. IEEE Global Engineering Education Conference, EDUCON. 602-607.

2. Alotaibi, Faisal & Furnell, Steven & Stengel, Ingo & Papadaki, Maria. (2016). A Review of Using Gaming Technology for Cyber-Security Awareness. International Journal for Information Security Research.

3. Alqahtani, Hamed & Kavakli-Thorne, Manolya. (2020). Design and Evaluation of an Augmented Reality Game for Cybersecurity Awareness (CybAR). Information. 11. 121. 10.3390/info11020121.

4. Aggarwal, Palvi & Gonzalez, Cleotilde & Dutt, Varun. (2016). Cyber-security: Role of Deception in Cyber-Attack Detection.

5. Aggarwal, Palvi & Gonzalez, Cleotilde & Dutt, Varun. (2018). HackIt: A Real-Time Simulation Tool for Studying Real-World Cyber-Attacks in the Laboratory.

Domain: Defence and Security

Sub-domain: Cognitive Technologies

Human Performance Enhancement via Transcranial Direct Current Stimulation (tDCS) and Virtual Reality (VR) and its performance forecasting via machine learning methods

Introduction and challenges: In military forces, various operations such as remotely piloted and manned aircraft operations require a human operator to monitor and respond to multiple events simultaneously over a long period of time. With the monotonous nature of these tasks, the operator's performance may decline shortly because of stress and cognitive workload. For achieving short-term cognitive enhancement, the utility of non-invasive brain stimulation techniques like Transcranial Direct Current Stimulation (tDCS) has been examined by several researchers and has been found to offer significant benefits among a host of other traditional techniques. Furthermore, since the past few years, virtual reality (VR) has been used as a means of training and assessing individuals in complex and dynamic tasks. Though there is some literature addressing the application of tDCS for cognitive rehabilitation in clinical / rehabilitation population [like depression, schizophrenia, OCD] in the Indian context, there is very little research done on how tDCS can be used as an intervention for achieving cognitive enhancement among the civilian and the military population.

SOTA work: Research has shown a wide range of cognitive effects of tDCS, mainly dependent on the site and polarity of stimulation (the montage), and duration and pattern of current flow (the protocol) (Davis & Smith, 2019). tDCS is believed to work by inducing polarity-dependent stimulation to the outer cortical layers, exerting hyperpolarizing or depolarizing effects on the membrane potential of the axon. Although tDCS has been widely applied in the fields of learning and memory, comparatively little research has been conducted on the effects of tDCS on complex decision-making processes (Coffman et al., 2014). For evaluating, monitoring, and predicting cognitive performance, we propose a multivariate method invoking behavioral, cognitive/demographic/neuro- physiological (EEG, fNIRS) parameters. EEG and fNIRS measure different physiological responses to mental state changes. EEG measures the electrical potentials caused by neurons firing during brain activity (Hirshfield et al., 2009). fNIRS measures blood volume and oxygenation changes, reflecting hemodynamic responses to brain activity (Aghajani et al., 2017). Overall, combining EEG and fNIRS can provide information about both the neural activations and the subsequent oxygenation and blood flow changes in the brain (Subhani et al., 2017). This combination will give the user valuable information on the participant's mental workload, stress, and engagement levels. Furthermore, several state-of-the-art machine learning techniques (like SVM, CNNs, and MLPs) can be used to accurately classify these changes in the mental states over time once human data for training algorithms is collected across several experiments.

Data resources: We intend to collect our own data from the civilian population for the validation of our hypothesis. After the validation, we intend to collect data from the military population through our liaison at INMAS, DRDO.

Deliverable:

1) Virtual reality-based stimuli/context-specific battery for evaluating and enhancing complex decision-making

2) A tDCS framework for cognitive enhancement of military personnel that considers the duration, amount of current stimulation, and number of sessions of current stimulation.

3) Machine-learning models and algorithms predicting the extent of performance enhancement pertaining to complex decision-making given multivariate variables evaluated before and after tDCS intervention.

References:

1) Davis, S. E., & Smith, G. A. (2019). Transcranial Direct Current Stimulation Use in Warfighting: Benefits, Risks, and Future Prospects. Frontiers in human neuroscience, 13.

2) Coffman, B. A., Trumbo, M. C., Flores, R. A., Garcia, C. M., Van Der Merwe, A. J., Wassermann, E. M., ... & Clark, V. P. (2012). Impact of tDCS on performance and learning of target detection: interaction with stimulus characteristics and experimental design. Neuropsychologia, 50(7), 1594-1602.

3) Hirshfield, L. M., Chauncey, K., Gulotta, R., Girouard, A., Solovey, E. T., Jacob, R. J., ... & Fantini, S. (2009, July). Combining electroencephalography and functional near infrared spectroscopy to explore users' mental workload. In International Conference on Foundations of Augmented Cognition (pp. 239-247). Springer, Berlin, Heidelberg.

4) Aghajani, H., Garbey, M., & Omurtag, A. (2017). Measuring mental workload with EEG+ fNIRS. Frontiers in human neuroscience, 11, 359.

5) Subhani, A. R., Mumtaz, W., Saad, M. N. B. M., Kamel, N., & Malik, A. S. (2017). Machine learning framework for the detection of mental stress at multiple levels. IEEE Access, 5, 13545-13556.

Sub-domain: Multimedia and Forensics

Identification and Diagnostics for surveillance and ego-centric scenarios

Introduction and challenges: The low-resolution person identification task is an increasing concern for surveillance-based scenarios as images are captured from a large distance at very low-resolution. It is applicability in image tagging too, where multiple people are captured in the frame, and each of these entities is of small resolution. It is useful for the identification of suspicious subjects during the forensic investigation when user cooperation is very limited. However, the key challenges are limited information content (8x8 and 16x16) with blur, pose, and illumination. Given the popularity and availability of go-pro cameras, egocentric videos are used for various computer vision tasks. Moreover, many fields like gaming, robotic motion, and exoskeleton motion rely on first-person movements. However, while there is a lot of scopes, such technologies have not been well explored for biometric applications where a major challenge is the non-visibility of the person in egocentric videos.

SOTA works: GAN based methods can achieve about 93% rank-1 recognition accuracy (1) and a dual branch CNN method has shown 5% improvement over existing methods in recognition accuracy (2). But these recent methods are validated over a limited dataset, which is not enough for a real practical system. Existing algorithms for ego-centric video analysis can extract the pose (6) with a 17% error rate and gait (7) with a 76% accuracy from the egocentric videos. But their utility as to creating an artificial personalized motion is not yet examined.

Data resources: Some surveillance datasets along with few large scales unconstrained face datasets are publicly available for training and testing LRFR systems such as Mega Face Challenge 2 LR subset (3), SCface (4) and UCCS (5). Our plan is to generate a huge Indian LRFR dataset captured using mobile and other surveillance cameras. 2 major ego-centric datasets are present, FPSI (8) and Epic Kitchen (9) datasets having ego-centric data of 6 and 32 subjects each. Gait, pose, and attribute data acquisition of almost 100 subjects can be achieved by using go-pro cameras, Kinect, and third-person cameras.

Deliverable: Interfaces for management, labeling, editing, low-resolution person and vehicle id from surveillance feeds, and ego-centric cameras, which will also involve algorithms to identify a person and extracting face and gait attributes from surveillance and egocentric videos.

References:

(1) Li, P., Prieto, L., Mery, D., & Flynn, P. J. (2019). On low-resolution face recognition in the wild: Comparisons and new techniques. *IEEE Transactions on Information Forensics and Security*, *14*(8), pages: 2000-2012.

(2) Zangeneh, E., Rahmati, M., & Mohsenzadeh, Y. (2020). Low-resolution face recognition using a two-branch deep convolutional neural network architecture. *Expert Systems with Applications*, *139*, 112854.

(3) A. Nech and I. Kemelmacher-Shlizerman. The level playing field for million scale face recognition. arXiv preprint arXiv:1705.00393, 2017.

(4) M. Grgic, K. Delac, and S. Grgic. Scface–surveillance cameras face database. Multimedia Tools and Applications, 51(3):863–879, 2011.

(5) Archana Sapkota et.al, large scale unconstrained open set face database. In IEEE International Conference on Biometrics: Theory, Applications, and Systems, pages 1–8, 2013.

(6) Jiang, Hao, and Kristen Grauman. "Seeing invisible poses: Estimating 3d body pose from Egocentric video." IEEE CVPR, 2017.

(7) Hoshen, Yedid, and Shmuel Peleg. "An egocentric look at video photographer identity." IEEE CVPR, 2016.

(8) A. Fathi, et al. “Social Interactions: A First-Person Perspective”, IEEE CVPR, 2012.

(9) D. Damen, et al. "Scaling egocentric vision: The epic-kitchens dataset." ECCV, 2018.

Indigenous software solutions for speech-based and image-based multimedia forensics

Introduction and Challenges: The problems in multimedia forensics are becoming increasingly challenging with advances in new methods of multimedia data forgery and easy availability of forgery tools, and large-scale low-cost deployment of surveillance systems which suffer from poor image/signal quality. Thus, forensic experts require interactive, user-friendly, and interpretable systems that can address contemporary problems in digital forensics such as forgery analysis and efficient surveillance data mining.

SOTA works: While there have been existing software tools for image forgery detection methods (1), they can only address traditional approaches for forgery and not contemporary methods such as deep fakes. The algorithms for identifying deep fakes are only recently being reported, and there is much scope of improvement [3,4]. To our knowledge, audio authentication is still largely unexplored, at least in terms of system development.

Data resources: To initiate development we can consider the Deep-Fakes data sets and low-resolution face datasets. We will also collect a large amount of data collaborating with our partner Regional Forensic Science Lab Mandi.

Deliverables: A multimedia forensic interactive software package including functionality for Image, video and speech authentication, and forgery analysis.

References:

(1) https://photo-detective-pro-ios.soft112.com/

(2) A. Kumar, A. Bhavsar, R. Verma. "Detecting deepfakes with metric learning." International Workshop on Biometrics and Forensics (IWBF) 2020.

(3) A. Kumar, A. Bhavsar, R. Verma. "Syn2Real: Forgery classification via unsupervised domain adaptation." Winter (ii) Low-resolution contextual face and gait-based biometrics and reidentification (iii) Low-resolution number plate identification (iv) Single-view metrology (v) Labeling Conference on Application of Computer Vision (WACV), DeepPAB Workshop 2020.

Continuous mobile phone authentication using SIGToon (SIGToon):

Introduction and challenges: Due to the fast internet, the utility of online banking in smartphones (UPI) poses a high-security concern. However, strict security measures hinder the ease of usability of such systems. Continuous authentication can bridge the gap between security and ease of banking in mobile phones. Here, a major challenge is retrieving the behavior of a person from touch screen usage robustly and dealing with intra-class variation.

SOTA works: Signature verification systems like (1,2) which use the temporal data extracted from signature tablets have achieved good performance (97%, 96%). But they analyze the signature, not the underlying human behavior. Recent networks like transformers (3) can provide an efficient understanding of temporal data.

Data resources: There are many signature datasets that are publicly available, but to analyze the touch behavior of a person, we will create our own data using Wacom tablets and mobile phones.

Deliverables: To use the person's mobile phone touch screen usage behavior to create a continuous authentication system by analyzing how a person draws any pattern (SIGToon) on the phone, using just the temporal touch data. It can also be used for automatic signature identification useful for the banking industry.

References:

(1) E. Alajrami, et al. "Handwritten Signature Verification using Deep Learning." **IJAMR (2020)**.

(2) R. Tolosana, et al. "DeepSign: Deep On-Line Signature Verification." ***arXiv (*2020)**.

(3) A. Vaswani, et al. "Attention is all you need." **Advances in NIPS. 2017**.

Biometric Cancellation for mobile devices (BCAN)

Introduction and challenges: Privacy is a growing concern in today's technocrat world, owing to an outrageous growth in biometric-based digital authentication due to the deployment of large biometric systems like Aadhar (India), Mykad (Malaysia) and recent lockdown conditions. Thus, it is essential to ensure the security of biometric templates to gain public confidence and trust, which is possible using a cancelable biometric system if the biometric data is lost or compromised. The major challenge is to maintain a trade-off between security and accuracy (1).

SOTA works: Existing systems can work well on small datasets captured well in constrained environments. Current state-of-the-art on ear biometrics achieves 12.52% EER (2) and on the iris, biometrics achieves 0.16% EER (3) on NIR data and 15% EER on VIS data.

Data resources: Major iris datasets in the cancelable domain are: CASIA-V3 Interval (249 subjects), IITD (224 subjects) (2), ear dataset: AWE dataset (100 subjects) (3). Data can be captured via hand-held biometric sensors and mobiles.

Deliverables: To develop a cancelable authentication system based on traits like iris, knuckle, gait or ear in such a way that if a biometric data got compromised, it can be canceled, and new transformation can be issued.

References:

(1) Harkeerat Kaur et al. "Random Distance Method for Generating Unimodal and Multimodal Cancelable Biometric Features", IEEE, TIFS, 2019

(2) Kiran B. Raja et al. “Morton Filters for Iris Template Protection - An Incremental and Superior Approach Over Bloom Filters.”, IEEE, BTAS-2019

(3) Harsh et al. “Upgrading security and protection in-ear biometrics”, IET Biometrics, 19

Annexure - 3: Details of the Online Executive Program

- **IEP - Core Program Committee:** Arnav, Dileep, Aditya, Kalpesh, Satyajit, Anil, Padmanabhan, Varun.
- **Total Strength:** At least 150 students, almost 300 per year.
- **Time duration:** 9 months of distance learning online course. Two semesters of 4 months each with a break of 1 month.

  1 July to 31 October **(Semester 1)**

  1 November to 30 November **(Break)** Project work with the mentor

  1 December to 31 March **(Semester 2)**
- **Eligibility:** B.Tech/M.Tech in any stream of engineering with a good programming background.

  (Open to the whole world. We can try to get students from Nepal, Bhutan, Bangladesh)
- **Campus Stay:** During the break period of one month, they need to plan a one week visit to IIT Mandi to discuss his project with his mentor. (Maybe relaxed for international candidates)
- **Lecturing mode:** Online live lecturing starting in the evening from 6:30 PM to 9:30 PM, 3 Hrs., during weekdays, and longer classes during weekends starting from the morning.
- **Selection process:** First come first serve. Interview, if more than 300 candidates apply.
- **Fee structure:** 3000 INR (**) per credit, 4 credit requires 42 lectures hours. Hence (18+6+18 = 42) 42*3000 = 1,26,000 INR for full 9-month course (i.e., INR 84,000 for a 6-months course per professional). (Fee for professionals)

  (**) (Variable fee structure for students (1K/credit), faculty (1.5K/credit), and professions (3K/credit). A different fee structure for international students (e.g., 6K/credit for the USA) depends on the country and its development status)
- **Minimum revenue generated per year:** 1,26,000 INR * 150 = 1,89,00,000 **(1 cr and 89 lakhs)**.
- **The Course running cost:**
  - **Faculty remuneration:**
    - Per 1 hr lecture 5K INR as an honorarium.

- Hence teaching a 4-credit course attracts an honorarium of 42*5 = 2,10,000 INR.
- Total teaching cost: credit 42*(42/4 hrs.) * 5 INR = 22,05,000. (Adding 3 lakhs as misc.) **(Total 25 Lakhs)**
  - **Staff remuneration:** 5 Staff managing the courses and other managerial and academic stuff. (10K each for 9 months * 5 = 4,50,000 lakhs) (adding 0.5 lakhs as misc.) **(5 Lakhs)**
  - **Institute overhead:** 20 % of the total earning (Providing infrastructure and human resources) (0.2* 1.89 cr) **(37,80,000 Lakhs)**
  - **Publicity cost:** **(5 Lakhs)**
  - **Initial invest (one time):** Teaching equipment (2-3 laptops and iPad along with useful apps) and high speed and reliable internet: **(10 Lakhs)**
  - **Total of spent = 82,80,000 INR**

- **Finally, revenue generated for iHub in a year (1,06,20,000) INR**

Part A (Course work): IEP total course work is of 36 credits divided into the two, 4 months semesters with 18 credits per semester. **(36 credits)**

(All courses are compulsory)

Semester-01		
Name/Credit	Content	Faculty
Mobile VR and AI in Unity (3 Credits)	Module A: Introduction to Unity, Unity Editor, moving a Cube, Lights, Particle Systems, Applying Physics, and Unity Asset Store, C# Coding Introduction, Variables, Methods, If Blocks, Loops, Hello Mammoth, User Interaction in Unity, Inputs Introduction Preview, Key Presses, Moving a Player, Jumping, Moving Forward, Cycling Cameras, Prefabs Introduction, What are Prefabs? Instantiating Objects, Random Angles, Destroying Objects, Explosion Effects, Module B: Developing a Pathfinding Game, How to Set Up a Project, Node, String Map, A* Algorithm Setup, A* Algorithm Loop, Auxiliary Methods, Finishing the Algorithm, importing 2D	Varun

	Assets, Building a Level, From Console to Visual, Adding Tanks, Identifying Nodes, Moving the Tank, Visually Moving Tank, Smooth Movement, Smooth Rotation, Ordering Tank to Move, Speeding up Player, Spawning Logic, Crate Visuals, Adding Crates to Valid Positions, Collecting Crates, Score Counting, Game Interface, Starting the Game, Game Over Screen, Scoring, Module C: VR Introduction - Unity, Activating VR, building a Castle, Camera Changing Position, Lowering Castle Doors, Triggering Events Interface, Blender, Download and Install Blender, Introduction & Customizing Settings, Controlling Blender Camera, Emulate Numpad Camera, Manipulating Objects, Common Tools, Mirroring 1 Side of Object. Case Study: Flappy bird Unity game, First person shooter game, Kart Unity game. Module D: Introduction to Unity-ML, Why Machine Learning, different kinds of learnings, Neural Networks (NNs), Training a NN, Optimizer, Convolutional layers, Transfer learning, Imitation learning in Unity, Training the kart in kart game via IL, Testing the drive. Module E: Introduction to Reinforcement Learning in Unity-ML, Reinforcement Learning, Initial state, training a policy, The PPO algorithm, Evolutionary Strategies, Reward, Training a kart in the kart game with RL, Tensor board analysis, Testing results	
Linear Algebra (2 credits)	Module A: Background and review: Linear system of equations, and their solutions, Linear transformation, Matrices, Determinant, Rank, Linear Vector spaces, Basis, Dimensions, Subspaces, Inner product and orthogonality, Range space and null space, Eigenvalues, and eigenvectors. Module B: Norms for vectors and matrices: Vector norms and their properties, Matrix norms, Error analysis in linear systems. Module C: Perturbation theory and Eigenvalue Problems: The condition of Eigenvalues, Condition numbers, and their application, location, and perturbation of Eigenvectors, Generalized Eigenvalue problems, Module D: Matrix factorization and least square problems:	Satyajit/Kalpesh

	Singular value decomposition, generalized pseudoinverses, QR factorization, PCA, least square problems. Module E: Types of matrices, their properties, and analysis: Graphs and matrices, Sparse matrices, Sparse eigenvalue, and singular value problems, Symmetric, Properties of positive definite matrices, Toeplitz and Circulant matrices.	
Probability and Random processes (3 credits)	Module A: Sigma field: Review of axiomatic probability, conditional probability, and independence. Module B: Recap of random variables – Discrete and continuous random variables, and functions of random variables. Module C: Probability generating function, moment generating function and characteristic function-properties and applications. Module D: Joint, marginal, and conditional distribution, Covariance, and correlation, Multinomial, Multivariate Normal, Conditional Expectations. Module E: Basics of Markov chains, classification of states and chains, stationary distribution and limit theorem, Poisson process. Application of Markov Chain in Page Rank. Module F: The convergence of random variables – basic results, inequalities (Markov and Chebyshev), the law of large numbers (weak and strong), central limit theorem. Module G: Concentration inequalities – Chernoff's bound, Hoeffding's inequality, and their applications. Module H: Introduction to Random vectors and covariance matrix. Random processes.	Satyajit/Arnav
Basic MLDL programming practicum (3 credits)	1. Python, TensorFlow, Pytorch 2. Other relevant libraries like Dlib, Scikit-learn, Keras 3. 12 Laboratory assignments, basics python and libraries, Time-series forecasting, Speech recognition, Speech synthesis,	Aditya/ Dileep/ Arnav/ Varun

	Medical imaging, Biometric applications, Video related applications, Prediction, classification, and regressions tasks.	
Machine Learning (3 credits)	Module A: Bayes Decision Theory: Minimum-error-rate classification Classifiers, Discriminant functions, Decision surfaces Normal density and discriminant functions Discrete features. Module B: Parameter Estimation Methods: Maximum-Likelihood estimation: Gaussian case Maximum a Posteriori estimation Bayesian estimation: Gaussian case Unsupervised learning and clustering — Criterion functions for clustering-Algorithms for clustering: K-Means, Hierarchical and other methods-Cluster validation Gaussian mixture models Expectation-Maximization method for parameter estimation Maximum entropy estimation. Module C: Sequential Pattern Recognition: Discrete-Time Warping (DTW) Hidden Markov Models (HMMs) — Discrete HMMs — Continuous HMMs. Module D: Dimensionality reduction: Principal component analysis – its relationship to eigen analysis Fisher discriminant analysis – Generalized eigen analysis, Eigenvectors/Singular vectors as dictionaries. Module E: Linear discriminant functions: Gradient descent procedures Perceptron, Support vector machines.	Dileep
Deep Learning-I (4 credits)	Module A: Basics of Neural Networks: Perceptron algorithm and its convergence, multilayer perceptron, Activations and loss functions, Optimizers, and backpropagation (Gradient flow), guided backdrop. Module B: Convolutional Neural Networks: Convolutional/pooling layers, a case study of ImageNet winning CNN's, Regularizations (weights/dropout/batch norm), Network initializations, Visualization of convolutional filter (Data backpropagation), Dilated convolution, Deconvolution, Small memory networks. Atrous Convolutions. Module C: Object Detection Networks: Object detection via.	Aditya/ Arnav

	Regression and Classification, over feat Network, RCNN Family (RCNN, Fast RCNN, and Faster RCNN), YOLO and SSD, Comprehensive object detection survey. Module D: Deep Metric Learning: Siamese network, Contrastive loss, Triplet loss, n-array loss, Centre loss. Module E: Autoencoder and its applications: Basic autoencoder, Deconv/upsampling layers, Denoising AE, Image Segmentation using Unet/SegNet, Function/ transformation learning, Sparse AE, Regularized AE. Module F: Recurrent Neural Networks and its applications: Cons of CNN, Introduction to RNN, BPTT/TBPTT, Cons of RNN, Gated RNNs (LSTM/GRU) and their backpropagation, Word2vec and glove embedding, seq2seq for neural machine translation, other examples in NLP and time series prediction.	
Semester-02		
Foundation for MLDL (3 credits)	Vector Calculus: Differentiation of univariate function, Partial differentiation, and gradients, gradients of vector and matrices, Automatic differentiation, Linearization, and Multivariate Taylor series. Module B: Continuous Optimization: Optimization using gradient descent, Constraint optimization and Lagrange multiplier, convex optimization. Module C: Information theory: Information, Mutual information, Entropy, Cross entropy, Various distributions, and their properties such as Bernoulli and Gaussian distribution, Distribution learning using KL-Divergence and Jenson Shannon Div (JSD), Channel coding and compression, Variational inference and Total variation, Independence and conditional independence testing, Information bottleneck.	Satyajit/Arnav
Contemporary Computer Vision (4 credits)	Module A: Vision, the Challenge, Images, and Imaging Operations, Image Filtering and Morphology, The Role of Thresholding, Edge Detection. Module B: Corner, Interest Point, and Invariant Feature	Arnav

	Detection, Texture Analysis. Module C: Binary Shape Analysis, Boundary Pattern Analysis, Line, Circle, and Ellipse Detection, The Generalized Hough Transform. Module D: Object Segmentation and Shape Models, The Three-Dimensional World, Tackling the Perspective n-point Problem, instance, and Semantic segmentation. Module E: Invariants and perspective, Image transformations and camera calibration, Motion. Module F: Face Detection and Recognition: The Impact of Deep Learning, Surveillance, Identification, and reidentification. Module G: In-Vehicle Vision Systems.	
Basics of Image processing (4 credits)	Module A: Introduction to digital image processing: What is image processing, Different types of images, Visual perception, Image sensing, and Acquisition, Quantization, Sampling, color image processing, Module B: Intensity transformation, filtering in spatial and Frequency domain: Image negatives, Log transformations, Histogram processing, Spatial filter: smoothing and Sharpening, Discrete Fourier transform, properties of 2-D DFT, Image smoothing and sharpening in Fourier domain. Module C: Image transforms: Two-dimensional orthogonal and Unitary transforms, Optimum transform, Properties of Unitary transforms, 2D DFT, Cosine transforms, Hadamard transforms, KL transforms, Comparison of image transforms. Module D: Edge detection: Gradient and Laplacian based edge detection, Diffusion based edge detection: Isotropic and anisotropic diffusion. Module E: Wavelet transforms for Image Processing: Multiresolution expansion, Wavelet functions, Wavelet Series expansion, Continuous and Discrete Wavelet Transform, Wavelet transforms for two-dimensional signals (images), Applications of wavelet transforms for edge extraction, noise	Anil/Arnav

	suppression. Module F: Image segmentation: Thresholding, region-based Morphological Watersheds, Bayesian-based image segmentation. Module G: Image restoration and reconstruction: Models of image degradation, noise models, Spatial and Frequency domain-based approaches for image restoration, Inverse filtering, Wiener Filtering, Bayesian denoising. Module H: Image Compression: Spatial and Temporal redundancy, Basic image compression models, compression standards, basic compression methods: Huffman coding, Run-length coding, Block transform coding, Predictive coding Module I: Color Image Processing: Color Fundamentals, Color Models, Color transformation, smoothing, sharpening and edge detection in color images.	
Natural Language processing (3 credits)	Module A: Introduction to NLP and Word Vectors, Word 2 Vectors, Glove and Word Senses, Word Window Classification. Matrix Calculus, and Backpropagation, Linguistic Structure: Dependency Parsing Module B: The probability of a sentence? Recurrent Neural Networks and Language Models, Vanishing Gradients and Fancy RNNs Module C: Machine Translation, Seq2Seq and Attention, Question Answering, and an introduction to Transformer architectures Module D: ConvNets for NLP, Information from parts of words (Subword Models), Contextual Word Representations: Embedding from language models (ELMO), BERT, Retransformed, Megatron, GPT2 Module E: Contextual Representations, and Pre-Training, Natural Language Generation, Analysis, and Interpretability of Neural NLP	Aditya/Varun

Deep Learning-II (4 credits)	Module A - Generative Models: PixelRNN, Variational AE and its basic intuition and working, detailed mathematical understanding of VAE and its loss function, Introduction to GANs and their intuition along with its mathematical convergence proof, detailed recent case studies of DCGAN, ConditionalGAN, Pix2Pix, CycleGAN, SRGAN, TextureGAN, SAGAN, Speech2face GAN. Module B - Advanced Topics: Attention and Self-attention techniques, Explainable AI, Teacher-student network, Network Pruning by redundant filter removal, filter ranking and filter attention learning, GraphCNN, CapsuleNet, Multi-task learning, Domain adaptation via. SelectionGAN, Latest object detection such as EfficientDet, Transformers, and Video Transformers, few shot Incremental learning, Novel loss functions such as focal loss, content loss, distribution-based losses, distillation loss, total variation loss, Deep Fooling and Mathematics of Deep Learning.	Aditya

Part B (Project): M.Tech Project (6 credit) to be done in one month break. **(6 credits)**

Total of 42 credits in nine months and 2 semesters and a one-month break period.

Annexure - 4: List of equipment planned to be purchased for HCI research at the iHub

Sl. No	Equipment	Quantity	Total Cost (in INR Crore)
1	DGX A100 (Supercomputer)	1	2
2	Oculus Rift S + VR-enabled state-of-the-art laptop	1	0.03
3	A network of Egocentric Vision + 360-degree vision cameras + Depth and motion cameras + Android mobile devices for HCI application creation + Apple devices like iPad, iPhone, and pencil for HCI application creation	1	0.05
4	ANT-Neuro 256-Channel EEG + Biofeedback acquisition system (one 256-channel, two 128-channel, 4 64-channel systems and 2 64 channel dry electrodes)	1	2.6
5	High performance design and data analysis workstations	8	1.55
6	16-Channel Transcranial Direct Current Stimulation/Transcranial Alternating Current Stimulation/Transcranial Random Noise Stimulation system	1	0.87
7	State-of-the-art TMS System	1	0.9
8	3T fMRI Scanner	1	30.05
9	24-channel fNIRS system (integration-compatible with tDCS system mentioned above)	1	0.65

10	HTC Vive Pro Eye + Peripherals (Haptic Guns + Vests) + VR-enabled state-of-the-art laptop for data acquisition	1	0.15
11	Augmented Reality Platforms (Microsoft Hololens)		0.15
12	Tobii Pro research-grade Eye Tracker	1	0.8
13	Tobii EyeX/4C gaming/consumer-grade eye tracker	1	0.04
14	Data Acquisition Centers (iMacs/Macbook)	1	0.15
IoT Devices			
15	Tactile Sensors (arm, feet, body, hands)		0.064
16	Feel Real Olfactory Masks for HTC Vive/Pro + Store downloads		0.06
17	KatVR Locomotion Treadmills		0.16
18	OpenBCI - Consumer-end 16-channel headsets		0.092
19	LX6 Polygraph System by Lafayette Instrument Company (lafayettepolygraph.com)	1	0.05
		Total	**40.416**

Annexure - 5: Cost break-up for HRD and skill development

*All cost in INR Crores

Details	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Physical workshops	0.03	0.03	0.03	0.03	0.03	0.15
Online workshops	0.82	0.82	0.82	0.82	0.82	4.1
B. Tech fellowships	_	0.067	0.09	0.12	0.14	0.412
Post-graduate fellowships	0.179	0.476	0.744	0.565	0.268	2.232
Doctoral fellowships	0.504	1.344	2.244	1.836	0.972	6.9
Post-doctoral fellowships	0.97	2.346	2.754	1.734	0	7.80
Faculty fellowships	0.2	0	0.2	0	0.2	0.6
Chair Professors	0	0.4	0	0.4	0.4	1.2
Total	**2.70**	**5.483**	**6.878**	**5.505**	**2.83**	**23.48**

Annexure - 6: IIT Mandi Catalyst Expenses

Plan for Deliverables: Entrepreneurship and Start-ups

Deliverables	Target as mentioned in iHub Template	1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
CPS-GCC Grand Challenges and Competitions	**1**	1	1	1	1	1	**5**
CPS-Entrepreneur in Residence	**21**	3	4	4	5	5	**21**
Incubation Phase I		28	28	28	28	28	**140**
Incubation Phase II	**35**	7	7	7	7	7	**35**
Acceleration		2	3	5	5	5	**20**

Details of the budget for Entrepreneurship and Start-ups

Particulars	1st Year (in INR Crore)	2nd Year (in INR Crore)	3rd Year (in INR Crore)	4th Year (in INR Crore)	5th Year (in INR Crore)	Total
A. Support to EIR (Stipend for EIR Only)	0.13	0.17	0.19	0.24	0.24	0.97
B. Seed Fund (Exploration + Incubation + Acceleration)	3.58	4.32	5.42	5.68	5.68	24.68
C. Recurring Expenses	0.76	1.50	1.83	2.02	2.30	8.41
D. Non-recurring expenses	0.09	0.11	0.14	0.15	0.11	0.60
E. Grand Challenge	0.05	0.05	0.06	0.06	0.09	0.30
Total	**4.595**	**6.136**	**7.637**	**8.162**	**8.425**	**34.96**

Details of the budget

Details		Year 1	Year 2	Year 3	Year 4	Year 5	Total
EIR budget (in crores)		1260000	1680000	1920000	2400000	2400000	9660000
EIR Salary: INR 35,000/head/month in year 1 and year 2 and INR 40,000 /head/month thereafter							
Seed funding (in INR)							
Exploration fund		9520000	9520000	9520000	9520000	9520000	47600000
Incubation Fund		17500000	21000000	24500000	24500000	24500000	112000000
Accelerator Fund		7000000	10500000	17500000	20000000	20000000	75000000
Operational Expenses for Seed Fund		1764000	2135000	2672000	2821000	2821000	12213000
Total		**35784000**	**43155000**	**54192000**	**56841000**	**56841000**	**246813000**
Incubation Fund of INR 25,00,000/startup for 25% of the incubated startups in first year, INR 30,00,000/startup for year 2, INR 30,00,000/startup thereafter							
Recurring Expenses							
Manpower (in INR)							
Portfolio Management	Requirement	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Senior Manager	Delayed Hiring		1320000	1478400	1655808	1854505	6308713
Sr. Associate	Immediate	900000	1008000	1128960	1264435	1416167	5717563
Associate	Delayed		900000	900000	1008000	1128960	3936960

Manager - Outreach and marketing	Immediate	1200000	1344000	1505280	1685914	1888223	7623417
Associate	Delayed		873600	978432	1095844	1227345	4175221
Manager - Operations	Delayed Hiring		1200000	1344000	1505280	1685914	5735194
Sr. Associate - Operations	Delayed		1008000	1128960	1264435	1416167	4817563
Associate - Admin - Operations	Immediate	720000	806400	903168	1011548	1132934	4574050
Salary of senior manager (portfolio) - INR 110000/month with 12% increment yearly (Delayed hiring) Salary of manager (outreach and marketing) - INR 100000/month with 12% increment yearly Salary of associate admin - INR 60000/month with 12% increment yearly							
Mentoring, Compliances, and Consulting (in INR)							
Advisors and mentors for incubator		1440000	1612800	3360000	3763200	4214784	14390784
Mentor Honorarium (For startups in initial days at incubator, senior industry people for advice)		700000	700000	700000	700000	700000	3500000
Legal, Compliance and Consulting		600000	660000	960000	1056000	1161600	4437600
Advisory and mentoring for incubator - Budget of INR 1,20,000/month for first two years, and INR 250000 per month in later years, annual increment of 12% Mentor honorarium - INR 4000/hour, 5 hours/startup Legal, compliance and consulting - INR 50,000/month to start with, increased to 80000 per month in third year							
Operations Expenses							
Logistics (Travel and Stay expenses)			1100000	1100000	1200000	1875000	5275000
Administrative, Operational, IT (MIS, Printing, Stationary,		1000000	1120000	1254400	1404928	1573519	6352847

Meeting expenses, Collaboration resources Mementos)							
Outreach Expenses		500000	550000	605000	665500	732050	3052550
Renovation and Maintenance			200000	300000	300000	300000	1100000
Contingency		500000	550000	605000	665500	732050	3052550
Honorarium for speakers - INR 20,000/2-day workshop; 15 workshops/batch, 2 batches a year Logistics - INR 30,000/speaker/batch + 200000 for incubator team in the first year Outreach expenses - INR 500,000/year, increase at 10% per year							
Non-recurring expenses (in INR)							
IT Infrastructure, Network, Equipment		400000	500000	600000	800000	600000	2900000
Furniture, Furnishing, Fittings		500000	600000	800000	700000	500000	3100000
Computer systems, printers, other setups for new staff members 20 seating spaces, INR 25,000/seat in the first year							
1. Grand Challenge (in INR)							
Prize Money		200000	200000	300000	300000	500000	1500000
Operational Expenses, Outreach and Event Management		250000	275000	302500	332750	366025	1526275

Annexure - 7: Tripartite Agreement

भारत सरकार
विज्ञान और प्रौद्योगिकी मंत्रालय
विज्ञान और प्रौद्योगिकी विभाग
टेक्नोलॉजी भवन, नया महरौली मार्ग
नई दिल्ली-110 016

GOVERNMENT OF INDIA
MINISTRY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF SCIENCE AND TECHNOLOGY
TECHNOLOGY BHAWAN, NEW MEHRAULI ROAD
NEW DELHI-110 016

दूरभाष / Tel : 26562819, 26567373, 26562134, 26562122 (EPBAX)
फैक्स / Fax : 26569806, 26515637, 26863847, 26862418
वेबसाईट/website : www.dst.gov.in

National Mission on Interdisciplinary Cyber Physical Systems (NM-ICPS)

No.DST/NM-ICPS/Tripartite Agreement/2020 18.11.2020

Office Memorandum

Subject: Execution of Tripartite Agreement reg.

This is with reference to establishment of Technology Innovation Hub (TIH) under National Mission on Interdisciplinary Cyber Physical Systems (NM-ICPS) at your institute and subsequent release of funds.

2. The Tripartite Agreement is required to be executed on **Non-Judicial Stamp Paper** in three copies between Mission, Host Institute and Section-8 company and signed by Mission Director on behalf of NM-ICPS, Director of the Host Institute on behalf of HI and CEO/Authorised Signatory on behalf of Section-8 Company. A copy of Tripartite Agreement is enclosed herewith.

3. The Tripartite Agreement has been vetted by the Ministry of Legal Affairs and approved by the NM-ICPS Mission Governing Board (MGB) and Secretary, DST. As the Tripartite Agreement is vetted by the Ministry of Legal Affairs, there will be no further changes except the portions which needs to be filled up by the Host Institute. Any change required by the Host Institute needs to be approved by the Mission and also vetted by the Ministry of Legal Affairs.

4. Further release of funds from the Mission will happen directly to the Section-8 Company only after execution of Tripartite Agreement.

5. Registration of Section-8 company needs to be carried out in Darpan Portal.

6. Registration in PFMS system will be carried out at DST and Unique Code will be provided to the Section -8 Company for further augmentation of details

7. The Tripartite Agreement is required to be signed at the earliest possible time, latest by 20th December 2020 and balance budget will be released on **'First Come First Serve'** basis.

Encl: Tripartite Agreement

(K R Murali Mohan)
Mission Director, NM-ICPS

To

1. The Director, Indian Institute of Technology Madras, IIT P.O. Chennai, Chennai (Tamilnadu)-600036.

AGREEMENT

THIS Agreement is made and executed on this …… day of …….. 2020 (“Effective date”) at New Delhi

BY AND BETWEEN

The President of India acting through **Mission Director, Mission Office NM-ICPS**, Ministry of Science & Technology, Department of Science & Technology, Technology Bhavan, S J S Marg, New Delhi-110016 (hereinafter referred to as 'Mission' which expression shall, unless excluded by or repugnant to the context, be deemed to include its successors in the office and assignees) as the **FIRST PARTY**

AND

The Host Institute (HI), i.e., **Indian Institute of Technology, Mandi (IITMANDI)**, A statutory body constituted under the Institutes of Technology Act 1961, functioning at its premises at Parashar Road, Tehsil Sadar, Near Kataula, Kamand, Himachal Pradesh 175005 acting through The Director, IIT Mandi, (hereinafter referred to as ‘HI’ which expression shall where the context so admits includes its successors in interest and permitted assigns) as **SECOND PARTY.**

AND

Technology Innovation Hub (iHub), i.e., **IIT Mandi iHub and HCI Foundation,** A Section-8 Company Registered under Companies Act 2013 with **(CINU73100HP2020NPL008102)** having office at Indian Institute of Technology Mandi, Kamand, Mandi, Kataula, Mandi, Himachal Pradesh – 175005 represented by Chief Executive Officer (CEO), IIT Mandi iHub and HCI Foundation, (hereinafter referred to as ‘Hub’, which expression shall, unless repugnant to the context or meaning thereof, be deemed to mean and include its successors-in-interest, designates and permitted assigns) as **THIRD PARTY**.

“Mission”, “HI” and “Hub” shall be collectively referred to as “PARTIES” and individually as “PARTY”.

WHEREAS, HI, in response to the “Call for Proposals” issued by the Mission, has submitted a proposal to the Mission showing their willingness for establishment of a Hub i.e., Technology Innovation Hub (iHub) for implementation and realising the part of objectives of National Mission on interdisciplinary Cyber-Physical Systems (NM-ICPS).

AND WHEREAS, Mission has considered the proposal of the HI and based on its technical merit approved the proposal. Accordingly, the Mission agreed to support the Hub at HI with the Grant-In-Aid up to a maximum amount of Rs 110.00 crore to be released to the Hub over a period of 5 years subject to the fulfilment of all the terms and conditions enumerated in this **Agreement.** Mission has released a token grant of Rs 7.25 crore to HI as an initial grant through Science & Engineering Research Board (SERB) to initiate Hub registration and other administrative actions. The remaining amount will be released

periodically and directly to the Hub by the Mission, DST. The HI has now created the Hub to achieve the targets set by the Mission.

NOW, THEREFORE, in consideration of the premises and mutual covenants hereinafter contained, the parties hereto agree and understand the responsibilities and obligations of the Parties in the **Agreement** including terms and conditions, financial arrangements, intellectual property rights, monitoring mechanism etc.

2. ABOUT THE NM-ICPS

Cyber-Physical Systems (CPS) are new class of engineered systems that integrate computation and physical processes in a dynamic environment. CPS encompasses technology areas of Cybernetics, Mechatronics, Design and Embedded systems, Internet of Things (IoT), Big Data, Artificial Intelligence (AI) and many more. The CPS systems are intelligent, autonomous, and efficient and are expected to drive innovation in sectors as diverse as agriculture, water, energy, transportation, infrastructure, security, health and manufacturing. Thus, it is heralded as the next paradigm shift in technology that can exponentially spur growth and technology led economic development.

To harness the potential of this new wave of technology and make India a leading player in CPS, the Union Cabinet approved the National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) to be implemented by DST with a total outlay of Rs.3660 crore for a period of five years. The Mission aims to create a strong foundation and a seamless ecosystem for CPS technologies by coordinating and integrating nationwide efforts encompassing knowledge generation, translation research, technology and product development, human resource development, innovation &commercialization standards and international collaborations. The Mission is implemented through a network of 25 Technology Innovation Hubs (iHubs) established across the country. Each hub will follow a technology life cycle approach, addressing all stages viz. Knowledge-Development-Translation-Commercialization in their assigned Technology Vertical. The hubs will be equipped and supported to function independently as stand-alone entities. However, they would leverage each other's strengths and power of collaboration to produce synergistic outcomes. The NM-ICPS Detailed Project Report (DPR) shall be an overall guiding document for the Mission and Hubs. The 25 Technologies Verticals assigned to 25 HIs areas under:

S No	Host Institute	Technology Vertical
1.	IIT Kharagpur, Bengal	AI & Machine Learning
2.	IIT Bombay, Maharashtra	Technologies for IoT & IoE

3.	IIIT Hyderabad, Telangana	Data Banks, Data Services & Data Analysis
4.	IISc Bengaluru, Karnataka	Robotics & Autonomous Systems
5.	IIT Kanpur, U P	Cyber Security & CS for Physical Infrastructure
6.	IIT Jodhpur, Rajasthan	Computer Vision, Augmented & Virtual Reality
7.	IIT Roorkee, Uttarakhand	Device Technology & Materials
8.	IIT Patna, Bihar	Speech, Video & Text Analytics
9.	IIT Madras, Tamil Nadu	Sensors, Networking, Actuator & Controls
10.	IIT Hyderabad, Telangana	Autonomous Navigation & Data Acquisition systems
11.	IIT BHU, Varanasi, U P	Data Analytics & Predictive Technologies
12.	IIT Guwahati, Assam	Technologies for Underwater Exploration
13.	IIT Mandi, H P	Human Computer Interaction
14.	IIT Delhi	Cobotics
15.	IIT Ropar, Punjab	Technologies for Agriculture & Water
16.	IIT Dhanbad, Jharkhand	Technologies for Mining
17.	IIT Palakkad, Kerala	Intelligent Collaborative Systems

18.	IIIT Bengaluru, Karnataka	Advanced Communication System
19.	BITS Pilani, Rajasthan	Bio-CPS
20.	ISI Kolkata, Bengal	Data Science, Big Data Analytics & Data Curation
21.	IIT Indore, M P	System Simulation, Modelling & Visualization
22.	IIIT New Delhi	Cognitive Computing & Social Censing
23.	IISER Pune, Maharashtra	Quantum Technologies
24.	IIT Tirupati, A P	Positioning and Precision Technologies
25.	IIT Bhilai, Chhattisgarh	Technologies for Financial Sector (Fintech)

3. GENERALIZED ACTIVITIES OF HUBS

The Mission aims to create robustly productive and sustainable hubs with associated ecosystem. The Hub development mechanism adopts a bottom-up revenue model in which the initiation of the Hub is by government support, through NM-ICPS, for developing capabilities and gradual build-up of resource generation in the later years of the Mission period. For the purpose of clearly defining the objectives and the activities of the Mission, it has been divided into four major streams, namely -

(a) TECHNOLOGY DEVELOPMENT: Through expert-driven research, Consortium based Research through Cluster-Based Network Programs, directed research for the specific requirements of Industry, other Govt. verticals and International Collaborative Research Programs.

(b) HRD AND SKILL DEVELOPMENT: Through Fellowship Based UG/ PG, Ph.D., Post-Doctoral and Short-Term Training for Faculty.

(c) INNOVATION, ENTREPRENEURSHIP AND START-UP ECOSYSTEM: To enhance competencies, capacity building and training to nurture innovation and Start- up ecosystem.

(d) International Collaborations: To establish and strengthen the international collaborative research for cross-fertilization of ideas.

4. HUB INTERNAL FRAMEWORK

(a) Within the academic institution, the Hub would be a team mandated to focus on the domain area of research. Such an entity may bring together faculty/researchers/technologists from different disciplines, multiple institutes and provide shared facilities.

(b) The Hub will work in a distributed model in which all the stakeholders may not necessarily be physically located in the Hub but may contribute and avail services from their own location in a Hub and Spoke model.

(c) The Hub will laterally coordinate with other hubs for delivering integrated products, technology, and services.

(d) Each Hub would be headed by a CEO. CEO should have techno-management experience and vision to drive the Hub to foster creation of unicorns.

(e) Encourage faculty members with high quality publications and establish industry linkages. A hub is an outward looking entity wherein rapid collaborations with other Institutes is built rapidly and will work as an integrating platform with product delivery as a major motive.

(f) Nurture collaborators from other institutions.

(g) Develop International collaborators.

(h) Industry Partners with financial support in kind and cash.

5. Institutional Framework for Seamless Integration of Hubs

(a) The objectives are to carryout transnational research and establish world-class R&D in specific technological verticals of the Mission. These Hubs would support and encourage innovative technology-based start-ups, industries, Public Sector Undertakings (PSUs) that have an application and/or impact in the core sectors of the economy. Hubs would also provide the incubation centers for start-ups with necessary guidance, mentorship, tech support, infrastructure, access to investors, VCs connect, networking, and facilitating a host of other resources that may be required for the start-up to survive and scale.

(b) Government and industry/ industry associations will be encouraged to participate. It shall be joint collaborative mechanisms that Hubs shall manage, contributed, and monitored. Value addition and service provision shall be the driving force. The existing and successful models and best practices shall be adopted in each Hub.

(c) Under the Mission, each Hub to follow a technology life cycle approach, addressing all stages viz.

Knowledge-Development-Translation-Commercialization.

(d) As Hubs are part of technology life-cycle continuum in the Mission, these hubs will not have sharp boundaries of functions; overlapping of their operations will be encouraged to address the complete technology lifecycle if the delivery and commercialization of technology is promising. With this design, each such hub will, on one hand have forward and/or backward linkage with each other; on the other hand, they will work in tandem with experts/ institutions outside or with other initiatives of government and international institutions. In the highly networked mode as each Hub would be, they will be equipped sufficiently to function independently as stand-alone entity, however, they would leverage each other's strengths and the power of collaboration to produce synergistic outcomes. This would ensure that there is a dynamic functional model where technologies being focused are driven by market demands.

6. Public Private Model & Revenue Model

Hubs with a Public Private Partnership (PPP) model in place will be encouraged with additional support. This would ensure that research output have Industry buy in. However, it is difficult to attract private capital without Proof of Concepts (PoCs) in place, especially in a country like India, even for cutting edge areas of research such as CPS. Thus, initial phase would be driven by Govt. funding and in later years for Scale and growth phase, it is suggested to bring in 20- 30% capital from private pools, with majority of that capital coming in post 2 years, where enough output would be visible to attract private capital. The core area of output will be the following five revenue channels with a focus on creating a self-sustaining model.

(a) APPLIED TECHNOLOGIES & ENGINEERING - R&D sponsored by Industry, Govt. or Start-ups leading to outputs in forms of innovative product or services that can be leveraged.

(b) IP CREATION AND LICENSING (COULD ALSO LEAD TO NEW VENTURES) - Selecting ideas to co-create with Start-ups or Industries or Government with an aim to spinning it off into independent ventures. This could be done in a for profit setup supported by the Hubs with enough autonomy for execution. For this, close linkage be built with Industry, Accelerators and Venture Capital (VC) funding ecosystems.

(c) TRAINING AND CONSULTING - Helping Industries, Govt., and other stakeholders on how to innovate their processes and leverage CPS strategically in their efforts, while increasing the base of CPS engineers by offering open-source courses for faster adoption

(d) POLICY GUIDANCE AND HELP IN FORMULATION – Standards development and Policy creation for rapid and adoption of CPS across various stakeholders.

(e) DATABANK CREATION ACROSS STRATEGIC AREAS OF FOCUS - Aggregating Data banks across verticals from Govt., Industry for offering data as a service for bootstrapping CPS applications.

7. MISSION MANAGEMENT AND HUBS PERFORMANCE EVALUATION & MONITORING: The following are the empowered bodies for evaluation, monitoring and quantification of performance of each Hub.

(a) MISSION GOVERNING BOARD (MGB)

The MGB will be the Apex Authority to provide the guidelines for implementation and operating the Mission, including decisions on all Mission related matters. The MGB will approve and determine the level of support for each Hub and review their performance. MGB will also set overall directions, goals, vision, and targets for each of the Hub.

(b) SCIENTIFIC ADVISORY COMMITTEE (SAC) is a technical committee, will involve in scrutiny, evaluation and monitoring of Hub and activities.

(c) INTER-MINISTERIAL COORDINATION COMMITTEE (IMCC) will facilitate in connecting the Mission and Hubs to stakeholders. The requirements of stakeholders shall be taken up as Tech. Development projects under Hubs.

(d) COORDINATION COMMITTEE A Coordination Committee chaired by Secretary, DST and comprising members of all Heads of Hubs/HIs will be created to ensure better outcomes of the research activities and for development of collaborative solutions.

8. MANAGEMENT OF HUBS: Each Hub will be managed by a Hub Governing Body (HGB). A generic structure is as given below:

Director/ Vice-Chancellor of Host Institute	: Chairman
Academic representatives (not less than 2)	: Members
Industry Representatives (not less than 2)	: Members
Mission Director, Mission Office, DST	: Member
CEO/Project Director, Hub:	: Member-Secretary

(a) TERMS OF REFERENCE

(a) The HGB shall be the Apex body for overall supervision, control, directions, and mid-course correction in the implementation of Hub at Host Institutes.

(b) Will approve key guidelines for implementation of the Hub.

(c) Governing Body of each Hub will be the final authority to provide guidelines for implementation

and operating the Hub and all other matters related to them. HGBs will have full financial and administrative powers, including approvals to, re-appropriation of the budget within the ceiling of sanctioned budget, hire the appropriate manpower as per industry standards, sign Memorandum of Understanding (MoU) with International institutions and approve Collaboration foreign visits, partner with industry, receive/ support for projects in their domain areas to academic, R&D institutions, Industry, other funding agencies and linkages with existing TBIs or create a new TBI if there is no TBI in HI. Support for projects will be based on requirement, open call and with due scientific diligence and processes.

(d) HGBs could co-opt eminent people (India/ abroad) as members.

(e) The HGB would meet as often as required and at least once in six months.

(f) Can Constitute sub-committees from time-to-time for efficient implementation of Hubs at HIs.

9. OBLIGATIONS AND RESPONSIBILITIES OF THE PARTIES

Broad roles and responsibilities of the three Parties to this agreement are as under:

(1) OBLIGATIONS AND RESPONSIBILITIES OF MISSION

(a) Mission to support funds amounting to a maximum of Rs 110.00 crore over a period of five years subject to fulfilment of all the specified terms and conditions of the Hub sanction. To release Year-wise outlay of the funds to Hubs in the broad following heads to achieve set targets. However, based on performance, Mission can moderate, increase, or decrease or terminate funding support for the Hub.

Budget Head	**Budget in Rs Crores**					
	1st Year	**2nd Year**	**3rd Year**	**4th Year**	**5th Year**	**Total**
Recurring	11.25	15.00	19.82	18.55	15.62	80.24
Non-Recurring	7.00	8.00	10.18	3.45	1.13	29.76
Total	18.25	23.00	30.00	22.00	16.75	110.00

(b) Mission to review and steer the progress of the Hub, fulfilment of set targets and will hold meetings of SAC, IMCC, MGB and other Committees to review the Hub.

(c) TAX BENEFITS: With Mission support on Hub is getting created. Mission to provide required certificates, authorizations etc. and Hub to process with CBDT or GST Council or any other Authorities/Agencies to get such benefits like Income Tax, GST etc.

Mission to facilitate to get DSIR R&D recognition (SIRO) and FCRA clearance for Hub.

(2) OBLIGATIONS AND RESPONSIBILITY OF HOST INSTITUTE (HI)

(a) HI to constitute and notify Hub Governing Body (HGB) and will have full autonomy in devising their internal processes and procedures for achieving the targets/deliverables subject to the general directions of MGB. The HGB will have full financial and administrative powers, including re-appropriation of the budget within the ceiling of sanctioned budget; hiring of the appropriate manpower as per industry standards; sign Memorandum of Understanding (MoU) with national and international institutions and industry; approve Collaboration foreign visits; partner with industry; receive and give projects in the domain areas of Hubs to academia, R&D institutions, Industry, and other funding agencies. HGB will have power to link and support existing TBIs or to create a new TBI for incubation. HGB will also evolve specific targets for the Hubs in consonance with the MGB directions and monitor the progress to report to MGB.

(b) Provide the required space (minimum of 30,000 sq.ft. covered space preferably at a single location), infrastructure, and recruit staff for the Hub. The Hub to be managed by a dedicated full time Chief Executive Officer (CEO) with desired domain and management expertise and other core team/supporting staff for its successful operations within three months from the date of signing of this Agreement. A faculty could be designated as Project Director either full time or part-time and will act as an interface between Hub, HI, and researchers. The HGB to take a decision on appointment of a Project Director and to decide Roles, Responsibilities, Terms and Conditions of appointment.

(c) For the initial grant received through SERB, the leftover funds with HI, if any, to be transferred to Hub.

(d) HI to encourage/allow its faculty/researchers to bid projects in Hub. Student mentorship, guidance and supervision etc. are to be encouraged.

(e) Make available, provide access, and facilitate some of R&D infrastructure available with HI to Hub vice-versa is also be encouraged.

(f) Encourage and incentivize faculty to work with Hub in translating their research concepts, co-develop PoC, prototypes and associate with Hub till it reaches higher TRLs. IP, monetization, and patent facilitation through Hub is to be encouraged.

(g) HI to treat the Hub as their associated structure and as a facilitator to take their research to commercial domain i.e., Hub to be positioned and utilized as a research translation platform and research translation wing of HI.

(h) HI to provide supervisory / mentoring support and will award PG and Doctoral Degrees to the selected fellows. Fellowships amounts shall be disbursed by Hub as a sponsor.

(i) The HRD component will be executed jointly by Hub and HI.

(j) Conducive infrastructure and necessary mentoring are to be provided to the on boarded start-ups for performing seamlessly such as provisioning of co-working space, lab & infrastructure, workshop facilities, utilities, support services, pre-incubation services, networking, mentoring, financing through VC/Angel etc. Hub shall have overall responsibility in achieving set objectives, set targets, sustainability plan and overall success.

(k) HI to support in executing all the set targets enumerated in this Agreement. On accomplishment of which will make Hub to receive next instalments from Mission.

(l) HI to provide all HGB approved minutes timely to Mission. The views of MGB on minutes/activities is binding on HI.

(3) OBLIGATIONS AND RESPONSIBILITY OF HUB

The Hub will be responsible for delivery, on a best-efforts basis, of deliverables and targets mentioned below:

S No	Target Area	Targets					
		1st Yr	2nd Yr	3rd Yr	4th Yr	5th Yr	Total
1	**Technology Development**						
(a)	No of Technologies (IP, Licensing, Patents etc)	6	10	9	0	0	25
(b)	Technology Products	0	4	5	7	9	25
(c)	Publications, IPR and other Intellectual activities	3	9	8	12	18	50
(d)	Increase in CPS Research Base	30	60	90	120	150	450

2.	**Entrepreneurship Development**						
(a)	Technology Business Incubator (TBI)	1	-	-	-	-	1
(b)	Start-ups & Spin-off companies	7	7	7	7	7	35
(c)	GCC - Grand Challenges & Competitions	1	1	1	1	1	5
(d)	Promotion and Acceleration of Young and Aspiring technology entrepreneurs (PRAYAS)	1	-	-	-	-	1
(e)	CPS-Entrepreneur In Residence (EIR)	3	4	4	5	5	21
(f)	Dedicated Innovation Accelerator (DIAL)	1	-	-	-	-	1
(g)	CPS-Seed Support System (CPS- SSS)	1	-	-	-	-	1
(h)	Job Creation	100	1000	1650	2000	4000	8750
3.	**Human Resource Development**						
(a)	Graduate Fellowships	25	45	60	80	90	300
(b)	Post Graduate Fellowships	12	20	18	0	0	50
(c)	Doctoral Fellowships	12	20	18	0	0	50
(d)	Faculty Fellowships	1	0	1	0	1	3

(e)	Chair Professors	0	1	0	1	1	3
(f)	Skill Development	200	200	200	200	200	1000
4.	**International Collaboration**	1	1	1	1	1	5

(a) It will build linkages and collaborations with network of research institutes and labs across India and abroad. Hub to work in close collaboration with Industry to create symbiotic relationship and world class products development. Hub will emphasize on development of infrastructure tools for direct application of basic and applied research leading to Technology Development, including development of new areas of CPS applications/ platforms. Hub will provide the ecosystem for application-based technology development and deployment. Hub will also be responsible for delivering commercial technology and taking ideas / concepts or prototypes and turning them into marketable products by way of proactive coordination, communication and interfacing for technology transfer to the industry. These would work closely with Startup ecosystem, Corporate, Governments and Regulatory bodies. The Hub will specialize in a thematic domain and will connect with all institutes / groups / individuals who have expertise in that domain. It will co-ordinate across the country and will act as single point of contact for that domain. Hub will collaborate with industry for fabrication/ services, work with nanofabrication, material centers, other Centers and TBI's. International network – Hub would connect to a global network of leading labs and institutes and researchers that can enable close research collaborations.

(b) Hub will be the nodal centre spearheading the activities in a specific domain. With leading-edge knowledge, competency and facilities, the hub to attract talented individuals and harness expertise available nationwide, thus fostering research innovation, world class technology and product development. Hub to coordinate across the country and build linkages with research institutes and labs in India and abroad. Hub to work in close collaboration with industry to deliver commercial technology and products and build a vibrant innovation ecosystem by providing a reliable platform for technology-based start-ups and entrepreneurs.

(c) The Hub to establish a Technology Business Incubator (TBI) or connect with existing TBI, for development and translation of technologies into start-ups and Spin-off companies.

(d) Provide up to date data and information to the Mission Office to answer Parliament Questions, RTI, Public Grievances or other government requirements from time to time.

(e) Hub to follow open and transparent policy in their activities. HGB is the final authority in all decisions concerning the Hub. MGB will be the overall authority for the entire Mission.

(f) Hub can receive grants from Government and non-Government entities, trusts, foundations, CSR funds, financial institutions including Venture Capital institutions.

(g) Hub can bid international projects and receive funding support. Standards development is one of the core mandates of the Hub. Participation, contribution, ratification of standards and collaboration with international standards development Organizations/Agencies/Bodies/Nation and international standards development efforts.

(h) Hub can support projects in the domain area to academic, R&D institutions, PSU's, industry, and other Hubs. Support for projects must be based on requirement, open call and with due scientific diligence and processes with the approval of HGB. The Detailed Project Report (DPR) submitted by the HI and approved by the MGB shall be the guiding document for the Hub.

(i) Hub can provide support to student start-ups.

(j) Can initiate international collaborative projects on cost sharing basis between India and participating country/ International institutions. Collaborations should be based on existing international cooperation modalities and as per requirements of Hub.

(k) Real time update on all the activities of Hub to be made available on the web portal of the Hub and to be integrated with the portal of NM-ICPS Mission Office in DST.

(l) Hub to complete all registration process like DARPAN, PFMS, other registrations mandated time to time by GoI.

(m) Hub's funding would be prioritized with those having a Public Private Partnership (PPP) model in place. This would ensure that research output have Industry buy in. However, it is difficult to attract private capital without proof of pilot in place, especially in a country like India, even for cutting edge areas of research such as CPS. Thus, initial pilot phase would be driven by Govt. funding and in later years for Scale and growth phase, it is suggested to bring in 20- 30% capital from private pools, with majority of that capital coming in post 3 years, where enough output would be visible to attract private capital. The core area of output will be the five revenue channels as described in para 6 with a focus on creating a self-sustaining model post initial 5 years of investments.

(n) Hubs to provide scientific literature/ information on NM-ICPS to academicians, students, and scientists for awareness generation. For the above purposes of education and awareness generation, a series of conferences, workshops, brainstorming sessions and online platform & Web Portal and initiation of a dedicated Indian Journal of CPS are planned under Mission and hubs to facilitate the same.

(o) A portion of the (around 50%) funds provided for development of technology products to Hubs will be earmarked for technologies/ products developed by multiple Hubs having complementary goals to work together.

10. CONFIDENTIALITY

The Hub undertakes on its behalf and on behalf of its sub-contractors / employees to maintain strict confidentiality of the project including, but without limitation to, the R&D work and know-how generated and prevent disclosure thereof, for any purpose, other than in accordance with this Agreement. All Parties will also ensure confidentiality as required for the project except the disclosure is warranted by operation of law.

11. INTELLECTUAL PROPERTY RIGHTS (IPR)

The Hub to formulate and notify its IPR Policy well within the guidelines, Regulations and Rules of Govt of India.

a) All IP should be owned by Hub if the project is completely funded and executed by it.
b) IP generated by projects at HI or any other entity, funded jointly by Hub or other entities, will be jointly owned by entities and Hub, with revenue share of any benefits accrued from licensing or sale of such IP.
c) Based on the nature of IP and its translation into product or company, revenue share will be decided. Hub will have the exclusive right to commercialize (license, repackage or sell) the IP for the life of the IP right available.
d) Revenue sharing of the IP will be transparent and will be decided on a case-to-case basis by the IP committee and investment committee together with the mutual consent of the IP owners for maximizing returns for everyone.
e) Sponsored strategic research projects which fall into the roadmap decided by Hub by entities other than Hub will lead to joint ownership of IP. Hub will own exclusive rights to commercialize the IP. Participating entities can get non-exclusive rights to IP usage on a business model.
f) Hub can also decide based on funding amount to give exclusive rights for IP which is time-bound to the industry partners.
g) Hub will take responsibility for the entire life cycle of the IP generated by Hub funding covering the filing for protection via patents, copyrights or trademarks and finding suitable licensees.
h) In case of start up being formed out of the IP, License to IP and depending on the IP, there may be more than one starts up formed and hub shouldn't favour one start up over other in access to IP. This along with ownership will be transferred to start up in lieu of equity, revenue or data sharing or a combination thereof. In case Industry partners are significantly participating in IP creation, they can be given participation rights in the start-up being formed via AI studio or Hub Venture Fund.
i) If the start-up who is assigned IP gets closed before funding, IP ownership and IP rights goes back to Hub, which can further license it out again.
j) Hub can create special IP licensing policy for pre-existing start-ups in case they are collaborating in Hub projects in lieu of data sharing for innovation and research.

k) In case Hub contributes significantly to IP creation along with pre-existing startup, it can take equity in lieu of transferring IP in exclusive fashion for a period via AI studio. Existing/prior IP at HI, in areas of relevance to the Hub, can be licensed to Hub for further commercialization with a revenue-sharing agreement on a case-to-case basis on the exclusive model.
l) IP Policy will be updated each year by the IP committee with the approval of the Hub Governing Board.

IP relation between HI and Hub

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

IP relation in projects supported by Mission

- IPs generated from projects supported completely by the Hub with the funds provided by The Mission, all IP's will be owned by Hub for commercial exploitation if not an alternate arrangement is specifically agreed upon by the parties IP in other conditions.
- IPs generated under all conditions not covered by the above clauses will be covered by the IP Policy of Hub as per approvals of HGB and MGB.

12. FORCE MAJEURE

No Parties shall be held responsible for non-fulfilment of their respective obligations under this Agreement due to exigency of one or more of the force majeure events such as, but not limited to Acts of God, war, flood, earthquakes, strike, lockouts, epidemics, riots, civil commotion etc., provided on the occurrence and in cessation of any such event, the Party effected thereby shall give a notice in writing to the other Party immediately, after but not later than one month of such occurrence and cessation. The period between the occurrence and cessation of such event will be excluded while calculating the period during which the Party must perform his obligations under this Agreement. If the force majeure conditions continue beyond six months, the Parties may mutually decide about the future course of action.

13. TERMINATION OF THE AGREEMENT

Mission may decide for the termination of the funding to the Hub based on on account of following:

(a) The grant released is not properly utilized for intended purpose / activities or for the purpose for which it was released.

(b) Failure to achieve the envisaged targets and objectives of the Hub despite best efforts.

(c) Breach of Terms & Conditions of provision of this Agreement.

In the event of such eventuality, the HI and Hub shall return all balance unused funds to Mission.

14. AMENDMENTS

No amendments in this Agreement shall be effective unless it is in writing and signed by duly Authorized representatives of the Parties. The Agreement may be extended/modified/amended as may be required with mutual written consent of the Parties.

15. VALIDITY

This Agreement shall be deemed to have come into force from the date of signing of the Agreement and will remain valid for the duration of the Mission or 5 years, whichever is longer.

16. RESIDUARY MATTERS

Any matter not covered specifically in the Agreement may be settled by mutual agreement and with the approval of MGB.

17. REPRESENTATION AND WARRANTIES

For the purposes of this Agreement, the Parties make the following representations and warranties:

(a) The Parties holds all valid permissions, authorizations, approvals and consents, licenses, and registrations, which may be required under the laws prevalent from time to time, for the performance and delivery of the Services under this Agreement. The Parties shall ensure that all such permissions, authorizations, approvals and consents, licenses, and registrations, where required to be renewed, shall be kept valid and subsisting throughout the period of the Agreement.

(b) All information or data furnished by the other Party or obtained either Party or developed under this Agreement shall be treated as Confidential and protected by the respective Parties to prevent disclosure to any persons other than those authorized by the other Party.

(c) The Parties possesses the necessary expertise, know-how, technology, resources, and infrastructure along with enabling rights and will continue to possess all the Intellectual Property Rights (IPR) over its background Intellectual Property (IP), to enable the Parties to pursue the transactions contemplated under this Agreement.

18. CONFIDENTIAL INFORMATION

(a) Confidential Information means any information, technical data, or knowhow, including, but not limited to, that which relates to the Technology, product or service plans, know how, intellectual property, agreement terms, products, services, employees, suppliers, customers, technology, markets, software, know-how, developments, inventions, processes, designs, drawings, models, frameworks, systems, integrations, engineering, hardware configuration information, marketing, finances, notes, analyses or studies and all tangible and intangible embodiments thereof of any kind whatsoever concerning the Parties, whether or not labelled as "Confidential Information" and disclosed by the disclosing Party in connection with this Agreement to the recipient, irrespective of the medium in which such information or data is embedded. Confidential Information shall be deemed to include any notes, analyses, compilations, studies, interpretations, memoranda, other documents (regardless of the form thereof), Technology or other derivatives made or derived there from by the receiving Party or its representatives which contain, reflect, or are based upon, in whole or in part, any information furnished to the receiving Party or its representative pursuant hereto.

(b) All Confidential Information disclosed pursuant to this Agreement, shall be used exclusively for the purpose of this Agreement, and the receiving Party shall be permitted to use Confidential Information disclosed to it pursuant to this Agreement only for such sole purpose of this proposal and for no other purpose, unless otherwise expressly agreed to in writing by the disclosing Party; shall not be distributed, disclosed, or disseminated in any way or form by the Receiving Party to anyone except its own employees, who have a reasonable need to know the Confidential Information and who are bound to confidentiality by their employment agreements or otherwise with the Receiving Party; shall be treated by the Receiving Party with the same degree of care to avoid disclosure to any other party as is used with respect to the Receiving Party's own information of like importance which is to be kept confidential; shall remain the property of the disclosing Party; shall not be disclosed to any other Party by the Receiving Party without the prior written approval of the disclosing Party; shall not attempt to (I) reverse engineer (e.g., decompile, disassemble, reverse translate) any Confidential Information provided by or on behalf of the disclosing party, (2) discover the source code of or trade secrets in any such Confidential Information, or (3) circumvent any technological measure that controls access to such Confidential Information in any manner whatsoever.

(c) Confidential Information does not include information which (i) is already in receiving Party's possession at the time of disclosure; (ii) before or after it has been disclosed to receiving Party, becomes part of the public knowledge or literature, not as a result of any action or inaction of receiving Party; (iii) is approved for release by written authorization of the disclosing Party; (iv) is disclosed to receiving Party by a third Party not in violation of any obligation of confidentiality and without any confidentiality obligation; (v) is independently developed by receiving Party without reference to or use of Confidential Information; or (vi) is required to be disclosed by a valid order

by a court or other governmental body or applicable law. This exception shall not apply to any information or part thereof that has been published by IITMandi in academic or technical journals.

(d) The disclosing party is disclosing the Confidential Information on "as is" basis without any warranty or representation of any nature whatsoever. The disclosing party shall therefore not be liable to the Receiving Party for any direct, indirect, special, consequential, incidental, or punitive damages or loss, regardless of the form of action or theory of liability (including, without limitation, actions in contract, warranty, negligence, or products liability) resulting from any defect in or use of any Information by the Receiving Party, even if the Receiving Party has been advised of the possibility of such damages or losses.

(e) Following the completion or termination of Agreement, the Receiving Party promptly shall return to the disclosing party, or destroy, all Confidential Information of the disclosing party provided under or in connection with this Agreement, including all copies, portions and summaries thereof, except as provided under this Agreement.

(f) The obligation to maintain confidentiality will survive for 3 years from expiration/termination of the Agreement.

(g) If the receiving Party commits a breach of, or threatens to commit a breach of, any of the terms of conditions of this Agreement, the disclosing Party shall have the right to seek and obtain all judicial reliefs (including but not limited to injunctive reliefs, specific monetary damages, interest and attorneys' fees and expenses) as may be ordered or awarded by a court of competent jurisdiction.

(h) The provisions and obligations relating to Confidentiality under this Agreement shall survive the expiry or early termination of this Agreement.

19. USE OF NAMES AND TRADEMARKS

The Parties agree that they will not use the name of the other Party or its employees in any advertisement, press release or publicity with reference to this Agreement or any product or service resulting from this Agreement, without prior written approval of the other Parties.

20. PUBLICATION

HI faculty will share their research results, which emerge from a Hub funded project, with Hub's explicit consent before publicly disclosing their research results, with a timeout clause. In case Hub determines that IP protection is warranted for the research results, it will help with the entire process of IP protection, including paying for it. All other aspects of the publication policy of the Hub will be in concurrence in toto with the IP policy of the Hub.

21. TERM

The effective date of commencement of this Agreement is ---------- ("Effective Date") and shall continue until a period of 5 years.

22. NO ASSIGNMENT

It is understood by the Parties herein this Agreement is based on the professional competence and expertise of each Party and hence any Party shall transfer or assign the Technology or this Agreement, or rights or obligations arising hereunder, either wholly or in part, to any other Party without the prior written consent of the other.

23. DISPUTE RESOLUTION

Any disagreement/ difference of opinion/ dispute between the Parties regarding the interpretation of the provisions of this Agreement or otherwise arising from this Agreement and the activities undertaken under this Agreement shall be resolved by mutual consultation by the Parties under the leadership of the Chairman, MGB or his nominee. For any dispute unresolved for a period not exceeding thirty (30) days, reference shall be made under the provisions of the Arbitration and Conciliation Act, 1996 or any statutory modification / re-enactment thereof and rules made there under. The place/venue/seat of arbitration shall be New Delhi and the proceedings shall be conducted in English or Hindi language. The award of the arbitrator shall be binding on all Parties.

24. LIABILITY

Save as otherwise provided herein, in no event shall Parties be liable to the other, either for or under this contract, tort or any other legal theory, for any direct, indirect, incidental, special, consequential, reliance or cover damages, including, but not limited to, loss of profits, revenue, data or use, incurred by the other Party under this Agreement even if advise of the possibility of the same and arising out of either the performance or non-performance of its obligations under this Agreement.

25. GOVERNING LAW

This Agreement will be governed by and construed in accordance with the Laws of India and the Parties submit to the exclusive jurisdiction of the Courts of Delhi/India.

26. NOTICES

All notices, requests, demands and other communications under this Agreement or in connection herewith shall be given to or made upon the respective Parties as follows:

If to HI: Dean, Sponsored Research and Industrial Consultancy& International Relations, Indian Institute of Technology Mandi, Kamand Campus, VPO Kamand, District Mandi, Himachal Pradesh - 175075

If to Hub: CEO, IIT Mandi iHub and HCI Foundation: Indian Institute of Technology Mandi, Kamand, Mandi, Kataula, Mandi, Himachal Pradesh – 175005

If to Mission: Mission Director, Mission office NM-ICPS, Department of Science & Technology, S J Marg, New Delhi-110 016

27. SEVERABILITY

If any terms, conditions or provisions of this Agreement is held to be in violation of any applicable law, statute or regulation the same shall be deemed to be severable from the other provisions of this Agreement and this Agreement shall be construed as if such term, condition or provision had not been contained in this Agreement.

28. MODIFICATION

No term of this Agreement will be changed or modified unless the Parties mutually agree to such change or modification in writing.

29. ENTIRE AGREEMENT

This Agreement, including its Exhibits, constitutes the entire agreement between the Parties hereto in relation to its subject matter and will supersede all prior correspondence, arrangements or agreements, whether oral or written, entered into between the Parties hereto on the subject matter of this Agreement.

30. WAIVER

Any Party to this Agreement may (a) extend the time for performance of any of the obligations or other acts of any other Party, (b) waive any inaccuracies in the representations and warranties of the Parties contained herein or in any document delivered by the Parties pursuant hereto or (c) waive compliance with any of the terms or conditions of the Parties contained herein. Any such extension or waiver shall be valid only if set forth in an instrument in writing signed by the Party to be bound thereby. Waiver of any term or condition shall not be construed as a waiver of any subsequent breach or a subsequent waiver of the same term or condition, or a waiver of any other term or condition, of the Agreement. The failure of any Party to assert any of its rights hereunder shall not constitute a waiver of any such rights.

31. NON-EXCLUSIVITY

Unless otherwise agreed between the parties, the relationship of the Parties under this Agreement shall be nonexclusive and Parties, including their affiliates, subsidiaries, and divisions, are free to pursue other agreements or collaborations of any kind.

32. AUTHORITY

Each signatory to this Agreement represents and warrants that he/she is duly authorized by the Party for and on whose behalf he/she is signing this Agreement to execute the same in a manner binding upon said Party and that all corporate approvals and procedures necessary for vesting such authority in him/her have been duly complied with.

33. SURVIVAL

The other clauses of this Agreement, which by their very nature ought to survive termination / expiration of this Agreement, shall so survive.

34. SEAL OF PARTIES

IN WITNESS WHEREOF THE PARTIES HERETO HAVE SIGNED THIS AGREEMENT ON THE DAY, MONTH AND YEAR RESPECTIVELY SHOWN AGAINST THEIR SIGNATURES:

1	2	3
For and on behalf of the President of India Signature: Name: Designation: Date:	**For and on behalf of IIT Mandi** Signature: Name: Designation: Date:	**For and on behalf of IIT Mandi iHub and HCI Foundation** Signature: Name: Designation: Date:
IN THE PRESENCE OF WITNESSES		
Signature: Name: Designation: Date:	Signature: Name: Designation: Date:	Signature: Name: Designation: Date: