Detailed Project Report

for

Technology Innovation Hub

on

Positioning and Precision Technologies

Under the

National Mission on Interdisciplinary Cyber-Physical Systems

DST Sanction No. **DST/NM-ICPS/MGB/2018**

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Submitted by

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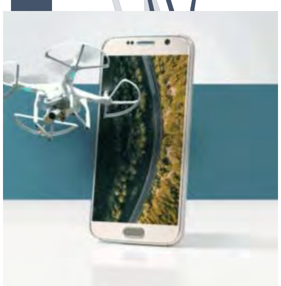

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1. Executive Summary

Positioning and Precision Technologies (PPTs) are indispensable tools for monitoring, integrating, and analyzing spatially and temporally distributed resources to aid in effective decision-making across multiple domains. These technologies include remote sensing (non-invasive), Geographical Information Systems (GIS) and Global Positioning Systems (GPS). The Technology Innovation Hub (TIH) on PPT will provide a unique platform for researchers, industries, stakeholders and end-users across multiple disciplines. The TIH aims to become a top contributor to many Government of India initiatives such as Make in India, Atmanirbhar Bharat Abhiyaan, and Start-up Ecosystem making India self-reliant in PPT. The TIH will follow a technology life cycle approach, addressing all stages viz. Knowledge-Development-Translation-Commercialization in the PPT Technologies. Besides, the TIH will align with the country's broad objective of using GIS as an essential component for empowering citizens and bring inclusive growth by mapping, monitoring, and analyzing the interplay between the various socio-economic factors that supports the sustainable development of the country. In addition, the Hub will primarily focus on Public Private Partnership (PPP) model to generate revenue through: (i) Research and development sponsorship from industries, government and start-ups in form of innovative products and services in PPT; (ii) linkage with industries, accelerators and Venture Capital to create funding ecosystem; (iii) training and consulting; (iv) standards development and policy creation for rapid adaptation of PPT across various stakeholders; and (iv) databank creation across strategic areas of PPT. The TIH on PPT will find and nurture new and innovative solutions for the interconnected grand problems in Positioning and Precision Technologies which include the development of precision timing and positioning devices (atomic clocks), precision sensors for indoor navigation, IoT devices for air/water/soil monitoring, AI/ML solutions for geospatial data processing, remote sensing applications to 3D terrain mapping, monitoring of agricultural and natural resources development, management and conservation and also towards addressing challenges related to disaster management.

The TIH on PPT will contribute to i) technology development; ii) applications; iii) human resource development; iv) start-ups; and v) international collaborations. For technology development, the Hub will focus on 1) Developing atomic clocks for GPS and navigation systems and their applications; 2) Developing solar-blind UV photodetectors for LIDAR; 3) High precision cyber-physical system based smart micromachining and nano finishing processes; 4) Indoor positioning systems; 5) Precision spectroscopy techniques for sensing applications; 6) Lightweight secure communication for PPT; 7) Data analysis and image processing techniques and visualization tools; 8) Decision making systems. For applications, the Hub will focus on 1) Increasing agricultural output by minimal use of chemicals and water using precision agriculture techniques; 2) Efficient planning for disaster management to minimize loss of life and property; 3) Management and monitoring of natural resources; 4) Proactive management of the environment and habitat; 5) Rapid response to urban search and rescue emergencies; 6) Planning and monitoring of urban and national transport infrastructure; 7) Enable deployment and monitoring of distributed energy systems such as Smart Grids; 8) Enable heterogeneous farming; 9) Atomic clocks for satellite networks useful in defence and civilian applications including guided missile defence systems and Autonomous Transport Systems; 10) Economic ultra-precision micro-nano machines for defence applications such as radome, precision lenses and mirrors; 11) Monitor citizen movement for ensuring social distancing; 12) Monitor overall mental health of citizens and provide timely interventions. The Hub will combine with a strong plan to translate their research commercial and social outcomes through dedicated translational infrastructure, training, partnerships with international and national industrial players, and engagement with the investor communities. The TIH on PPT will help bridge the gaps in PPT and its applications in the country's landscape by creating skilled manpower and indigenously developed technologies that address the needs of the country. The TIH will create a sustained ecosystem for developing innovative technology solutions and successfully transition them to industry via licensing and creating start-ups.

The TIH will operate as a not-for-profit Section-8 company, "IIT Tirupati Navavishkar I-Hub Foundation," which we recently incorporated (Dt: December 18, 2020). A total of 48 Faculty from 9 Departments of IIT Tirupati have shown interest in participating in this mission. The proposal has listed 9 product frameworks spread across multiple disciplines of engineering as listed below.

Table 1: Product Framework

S. No	Product Frameworks
1	Quantum Technologies for Positioning
2	Spectroscopy
3	Precision Agriculture
4	Precision Manufacturing
5	Natural/Built/Energy Resource Management
6	Disaster Management
7	Remote Sensing and Image Processing
8	Visualization Tools
9	Smart Cities

The proposal also presents 21 product ideas based on the above frameworks. These ideas are derived not only based on the research challenges but also from a product perspective including target beneficiaries, unique selling points (USPs), patents that could be filed, market revenue and industry participation. A very detailed plan is worked out keeping in mind the following points of importance, namely,

(i) Incubation of Startups
(ii) Involving Multiple Institutions
(iii) Patents
(iv) Human Resource Development
(v) Productization and Commercialization

From the project management perspective, every project will have an industry association right from its inception. Very strict monitoring of the progress of the projects will be put in place to ensure smooth and effective progress. INiF will establish the IIT Tirupati Incubation Centre facility to incubate new startups.

2. Context and Background

While the policy level and application requirements of PPTs have been spelt out clearly by India's policymakers, there are gaps in the availability of skilled manpower and indigenously developed technologies that can help the country deliver on their promise. These gaps impede the translation of the country's vision into tangible outcomes for society. INiF will help to bridge these gaps in PPTs and their applications. INiF will create a sustained ecosystem for not just developing innovative technology solutions but also successfully transition them to industry via licensing and the creation of start-ups.

We currently have a 90 member strong, young, enthusiastic and dynamic faculty engaged in conducting cross-disciplinary research and teaching in engineering, humanities and sciences at IIT Tirupati. The Institute is expected to have over 200 faculty members and 2500 students by 2024. Of the existing faculty, nearly half (48) of the faculty members are involved in R&D of PPT related areas such as atomic clocks and atomic sensors; remote sensing sensors; precision agriculture; water security; energy management; disaster management; image processing; transportation systems; advanced manufacturing and precision machining; smart cities. These faculty members have already published close to 150 original PPT related research papers in various international and national journals and conferences of repute. The rich expertise and connections form the core on which INiF will build its knowledge creation and technology development, in association with other academic and research institutions, user agencies and industries.

A key outcome of INiF is to make India self-reliant in PPT by developing cutting edge technologies and skilled manpower in this area. These will enable India to integrate the geo-spatial information from various resource management applications and develop national strategies, policies and related implementation frameworks and platforms.

INiF will become the most sought-after resource for technology, data and manpower for PPT in the country. Its knowledge repository on PPT will be the most accessed resource for everyone seeking information and knowledge in these areas. It will be the primary point of contact for connecting with the international and national experts in PPT. INiF will become a key resource and collaborator for national and international companies for technologies and manpower related to remote sensing, GIS, GPS and guidance systems. Further, the best Indian startups in PPT will identify INiF as the place where they started and want to continue engaging.

3. Problems to be Addressed

3.1 Grand Problems

Through a survey of experts in and out of the country, in this field, we have collected major Grand problems to be addressed under PPT. Basing on the inputs from few experts, who contributed to the survey, we have consolidated the specific problems under each of these grand problems to be addressed, current technology and research gaps, other relevant information to tackle these grand problems and the details of the benefiting agencies. The list of experts who contributed to the grand problems is listed in the below table. iNiF, IIT has identified the following grand problems on Positioning and Precision Technologies.

On the Positioning technologies, we shall be focusing on the development of

1. Atomic clocks with improved time localization
2. Navigation sensors for Satellites
3. Navigation sensors for accurate indoor localization
4. IoT and embedded hardware developments for various geospatial data applications

While on the Precision technologies iNiF aim at the state of the art propositions on

5. Geospatial data processing
6. Geospatial data applications

The technology developments on both Positioning and Precision technologies can also span over setting up of a

7. Highly precise National Geodesic Infrastructure
8. Communication and Network systems for PPT

Further, details of each of the above grand problems are presented in this section.

Experts List	Designation	Affiliation
Dr. Subhadeep De	Associate Professor	The Inter-University Centre for Astronomy and Astrophysics, Pune
Dr. Umakant D. Rapol	Associate Professor	IISER Pune
Dr. Mukund Kadursrinivas Rao	Chief Executive	Centre for Spatial Analytics and Advanced GIS (C-SAG), Bengaluru
Dr. Thejesh N. Bandi	Division Head	Clocks Division, ISRO
Dr. Yeshpal Singh	Associate Professor	University of Birmingham
Prof. Spiros Pagiatakis	Professor	York University, Canada
Dr. A. Jeyaram	CEO/Executive Director	SECON Private Limited
Dr. Uday Raj	Chief General Manager (Retd)	National Remote Sensing Centre, ISRO
Dr. Manish Saxena	Director	SATNAV-PRO, ISRO\
Dr. Pradeep K Srivastav	Adjunct Professor and Advisor	IIT Gandhinagar NIAS, Bengaluru KSRAC, Government of Karnataka, Bengaluru
Dr. Rakesh C Mathur	Senior Advisor	ESRI India Technologies Pvt. Ltd
Dr. Ravi Kumar DVS	Vice President	IIC Technologies Pvt. Ltd
Satyam Kushwaha	Wing Commander (Retd) Founder in Companies Director at IspA	Arms 4 AI, Scyale India Pvt Ltd Indian Space Association
Maj. Gen. Dr. B. Nagarajan	Visiting Professor,	IIT Kanpur

Positioning technologies

3.1.1 Grand Problem 1

Atomic clocks with improved time localization

3.1.1.1 *Grand Problem 1 (a)*

Grand Problem to be solved:

Transportable Optical Clock and space-qualified optical clock (Portable, rack-mountable optical Atomic clock with better than the part in 10^{19} instability) leading to Quantum sensors and timing devices. Further

(1) Ground commercial compact atomic clock technologies. *Target:* telecom, power hubs etc.
(2) Microfabricated atomic clock technologies. *Target:* hand-held GNSS receivers, portable precision navigation etc.
(3) High-performance ground atomic clocks. *Target:* network synchronisation, timing applications etc.
(4) High-performance space clock technologies. *Target:* GNSS, deep-space navigation, extra-planetary missions etc.
(5) Precision clocks synchronization methods and technologies.

Translating these into small and cost-effective practical devices.

Real-World Applications:

For any PPT related applications precision timing plays a key role, the transportable optical clock will be necessary for them. Development of remote positioning systems and tracking systems for locating tagged objects with better than 1-meter precision in every remote location. Timekeeping, Terrestrial and deep space Navigation for security and defence.

Identified Areas of expertise required to solve Grand Problem:

Atomic optical physics, engineers in mechanical, electronics, simulations, RF & Microwave Engineering, Quantum Optics, Hands-on expertise with cooling Atoms and Ions down to the vibrational ground state, Electronics miniaturisation and system integrators.

Benefiting agencies (Govt. agencies/stakeholders/end-users/industries):

Strategic organizations, communication industries, Space agencies, Defence agencies, Information technology departments and fundamental science explorers, ISRO (SAC, ISTRAC, URSC, HQ), NPL-Delhi.

3.1.1.2 *Grand Problem 1 (b)*

Grand Problem to be solved:

- If we want to make quantum sensors and timing devices a success for the economy, we need to achieve a Size, Weight, Power and Cost (SWAP-C) reduction. Once you have demonstrators allowing you to demonstrate the capability of quantum sensors in application-relevant environments. The long-term challenge is how to translate this into small and cost-effective practical devices. This needs sustained progress in all areas: fundamental research, development and commercialisation.

- Navigation systems will need significant long-term research activities. We need to understand the robust operation of sensors on highly dynamic platforms, the cross-coupling between different degrees of freedom, the hybridisation of different sensor technologies and the calibration of sensors, e.g. ensuring near-perfect orthogonality of measurement axes.
- Brain-machine interfaces will become a fascinating area of research, once we have started to understand the healthcare-relevant aspects of brain measurements. Here we will need the combination of new physics for operation with limited sensor numbers in noisy environments, neurosciences for the characterisation of brain responses and computer sciences to translate brain reactions into executable commands.
- Data extraction and understanding what the signals mean (mathematical inversion, machine learning, validation…). This depends on the availability of demonstrators and the ability to perform trials. However, this is a longer-term challenge, as it will take some time to cover all valuable application areas with trials and the necessary iterations for data extraction.

Real-World Applications:

This is going to revolutionise the way we do things- in all walks of life, including strategic and defence-related areas.

Directions in addressing the Grand problem:

- Multisensor systems are an emerging area, which will open a vast amount of possibilities to extract relevant information from the sensor data. Each sensor modality is limited in its capability to represent the entire information one is interested in. Looking at things from different angles, i.e. with different sensor modalities, will allow extracting information in a much more targeted way. This is likely going to need to combine sensor research with artificial intelligence and machine learning research.
- Quantum optimal control is a rapidly emerging technique, which tailors the interaction with the quantum probe particles in a targeted way to achieve particular sensitivity to one parameter of interest while providing robustness to fluctuations in others. This can also be used to tailor the generation of entangled states and deliver other sensitivity-enhancing schemes based on the shaping of the quantum wave function with optimal control.

Area of expertise required to solve Grand Problem:

- Atomic physics
- Laser cooling

Benefits (Govt. agencies/stakeholders/end-users/industries):

Academia-industry-defence and end users.

3.1.2 Grand Problem 2

Navigation sensors for Satellites and accurate indoor localization

3.1.2.1 Grand Problem 2 (a)

Grand Problem to be solved:

- High Accuracy and Seamless Service (HASS) - especially with technologies of alternative or complementary "beacons" for positioning, especially cellular base stations, WiFi routers, BLE beacons, RTLS, SLAM, or optical systems.
- Integrated Positioning Systems - indoor and outdoor positioning in a seamless manner.
- Sensor fusion for high-precision positioning and Cloud-based solutions for PPT which can be adaptive and robust techniques enabling high-precision navigation.
- Embedded, micro-integrated PPT user-end devices in transportation systems, citizen movements, commodity movements and any and every moving object.
- Precision smartphone accurate PPT devices for HAS systems.
- Integrated Earth and Planetary (moon, Mars etc) PPT - technology and applications.
- Policies for Advanced PPT and rights of citizens for collected PPT data. High-speed and high-precision atomic clocks for satellite positioning systems - integration with inertial systems
- Specifically LEO satellite Positioning systems design and architecture - future technologies of ring laser gyros, etc.
- Applications of PPT - precision farming; transportation and logistics; citizen tracking; avian/zoo-tracking; payload precision delivery systems; terrain tracking and geodesy applications and many others.

Specific Problem to be solved:

- Technology - design; architecting; configuration; proto-typing etc
- Applications - systems design; pilot applications etc
- Policy - policy studies
- Good workshops, conferences and studies will help.
- Create a local hub-and-spoke network with other universities (public and private); industries; NGOs and local governments for projects and applications.

Real-World Applications:

India has an active PPT space system, ground systems and application needs. IRNSS, Gagan etc are relatively dated technologies - the nation needs more advanced and futuristic technologies in PPT. Further, hardly any advanced research is going on in India for PPT this is very essential. Thus, these grand problems will build capability in the country in technology and applications.

Directions in addressing the Grand problem:

- Organise high-intensity consultation with experts - national and international through workshops and conferences in the next 3 months
- Create a TIH PPT Road Map in the next 6 months - for specific technology, applications and policy studies
- Formulate a network of institutional frames and MOUs with various institutions that can implement specific grand problem elements

- Identify and implement 4-5 high-impact projects for PPT in the next 2 to 3 years
- The document, Report and present outcomes of the projects under PPT

Area of expertise required to solve Grand Problem:

- System Design; Communications and Radio technology
- Chip design and manufacturing
- Geodesy and Earth modellers
- Mathematicians
- Application experts
- Spatial Analytics experts

Benefits (Govt. agencies/stakeholders/end-users/industries):

- Nation will benefit utmost - major contributions can be made to space positioning systems
- Defence agencies
- Industrial manufacturing
- User community and ultimately even to citizens

Collaborating/Partnering agencies for Grand Problem/Technology Development:

- Industries and Universities
- Public and private NGOs
- Local Governments
- National PPT Labs
- ISRO, Defence
- Civil Aviation
- Survey of India

3.1.2.2 Grand Problem 2(b)

Grand Problem to be solved:

GNSS, and Low Earth Orbiters for Integrated Earth observing system(s).

Specific Problem to be solved:

Geodesy (Precise positioning and gravity field), Climate and extreme weather studies, continental water storage

Real-World Applications:

Precise positioning and timing is the basis for all modern applications related to the grand problems identified above. The high precision measurements and determination of the Earth's gravity field and its changes in time is an absolute requirement for the precise positioning (e.g., the geoid) while monitoring its changes in time is indispensable for monitoring the global and regional continental water storage (necessary for life and health) through low earth orbiters (e.g. GRACE) as well as using regional and local terrestrial and areal platforms.

Important impacts in precision agriculture and forestry as well as natural resources.

Area of expertise required to solve Grand Problem:

- Gravity field of the Earth (geoid)

- Satellite missions
- geodesy and geodynamics
- Radio Occultations for atmospheric studies

Benefits (Govt. agencies/stakeholders/end-users/industries):

There are many mutual benefits at all levels of socioeconomic activities

Collaborating/Partnering agencies for Grand Problem/Technology Development:

Government, Academia and private industries

3.1.2.3 Grand Problem 2(c)

Grand Problem to be solved:

Low Earth orbit mini navigation satellites for improved Navigation applications

Specific Problem to be solved:

1. Vision-based / Laser-based / Radar-based Navigation technology and GNSS for improvement in PPT and navigation in Urban landscape
2. Interoperability of GNSS technologies satellite for better Navigation
3. Fusion of GNSS technology and 5G network

Real-World Applications:

1. *Vision-based / Laser-based Navigation technology and GNSS for improvement in PPT and navigation:* Vision-based / LiDAR-based / Radar-based navigation is very much essential GNSS based navigation system when a position sensor is not available. This happens in high dense urban scenarios and tree cover and other obstructions where GPS signals may not be reaching the navigator. This kind of technology should be integrated with IMUs, GNSS receivers etc for various applications. In the autonomous trend, this will provide a boost to the geospatial industry
2. *Interoperability of GNSS technologies satellite for better Navigation:* Allowing different codes from different reference systems both in time and coordinates of various navigational satellite systems has much more user advantage to have a simple receiver for tracking signals from several satellite navigation systems. Interoperability has another advantage for the user: it forces the systems to take up improvements coming from the other ones
3. *Fusion of GNSS technology and 5G network:* In view of interrupted navigational satellite signals / limited satellite availability in the urban landscape, accuracy is down degraded due to limited availability of satellite and multiple multipath. 5G network capabilities can be harnessed in conjunction with GNSS technology. A fusion of the 5G cm-wave with GNSS might result in higher positioning accuracies. Compatibility and interoperability of 5G and GNSS is necessary for greater application

Benefits (Govt. agencies/stakeholders/end-users/industries):

Expertise in GPS signal processing for a position in 3D space with communication and remote sensing technology

Collaborating/Partnering agencies for Grand Problem/Technology Development:

Government, Public industries

3.1.2.4 Grand Problem 2(d)

Grand Problem to be solved:

- Double precision geo-coordinates are the core of PPT. In GPS error budgeting, the ionosphere plays a major role.
- Research should be focused on developing technology on a real-time basis to model ionospheric attenuations in micro-regions of data collection to improve accuracies.
- Further tech development in L1, L2 and L5 frequencies to reduce the bandwidth and better Signal noise ratio. develop a strong space and ground segment to deliver high precision positioning
- Seamless integration of multi-platform GPS data for assured data at all times. GPS augmented GPS where GPS data is not received and RF data at human scale should be integrated automatically.

Specific Problem to be solved:

- Even after differential GPS deployment, multipath errors contribute to large errors in the positioning data.
- Tech development is essential to offset such errors on a real-time basis.
- Many real-time applications in urban regions are like autonomous vehicle tech depends on sub-millimetre positional accuracy.

Real-World Applications:

- Businesses are run across locations, events take place everywhere and anywhere.
- Location/positioning is the central factor in both the domains of applications strategic/defence and civil at different levels of governance, administration nationally, regionally and internationally.

Directions in addressing the Grand problem:

- Atmospheric/ionospheric modelling region wise on a real-time basis.
- A strong ground segment to include a good network of base stations with processing technology

Area of expertise required to solve Grand Problem:

- Communication tech
- Environmental engineering
- Geospatial technology

Benefits (Govt. agencies/stakeholders/end-users/industries):

Every segment government to non-government and every business field real estate to rocket science.

3.1.3 Grand Problem 3

IoT and embedded hardware developments for various geospatial data applications

Grand Problem to be solved:

IoT, quantum, high-accuracy positioning

Specific Problem to be solved:

- Satnav problem-1:
  - NavIC RTK based positioning receiver for high accuracy applications
- Satnav problem-2:
  - Integrated multi-sensor multi-modem system for fishermen

Real-World Applications:

- Satnav problem-1:
  - Emerging applications catering to precision agriculture, drone-based surveying, autonomous vehicles, etc. require high accuracy.
  - Real-time kinematic (RTK) with NavIC/GNSS as a component can provide solutions for such applications in an economical and compact form.
  - It will be used across various sectors as mentioned above in the country/world.
  - The processing software catering to positioning and RTK shall be provided as an open-source package.
  - This will be a useful development platform for the industry/start-up/academic community.
- Satnav problem-2:
  - Fishermen venturing into deep seas have to carry a suite of instruments, each providing different services like location, emergency alerts, depth information, etc.
  - A single system that integrates all these services, and uses NavIC/GNSS as a component, will be of immense value and convenience for the community.
  - The solution developed will be useful for fishermen of the country and world.

Directions in addressing the Grand problem:

- Satnav problem-1:

(i) Understand GNSS based positioning
(ii) Understand RTK techniques
(iii) Use RTK techniques to improve the accuracy of the GNSS solution
(iv) Develop NavIC based multi-GNSS carrier phase and RTK receiver
(v) Demonstrate
(vi) Develop products catering to high accuracy applications like precision agriculture, drones, autonomous vehicles, etc.
(vii) Provide the positioning and RTK software as an open-source

- Satnav problem-2:

(i) Study the suite of instruments being used by fishermen in the deep sea
(ii) Study the messaging services being provided by various GNSS like NavIC and Galileo

(iii) Develop an integrated solution utilizing these techniques
(iv) Develop an application along with a user-friendly GUI
(v) Extend the support to Indic languages
(vi) Translate into a product

Area of expertise required to solve Grand Problem:

GNSS based positioning, communication, instrumentation, algorithm development

Benefits (Govt. agencies/stakeholders/end-users/industries):

Satnav problem-1: End-users, govt. agencies and industries
Satnav problem-2: Primarily end-users

Collaborating/Partnering agencies for Grand Problem/Technology Development:

- The industry is capable of developing the technologies needed to address the above problems.
- TIH experts panel can provide guidance and hand-holding wherever required.

Precision technologies

3.1.4 Grand Problem 4

Geospatial Data processing

Grand Problem to be solved:

- Integration of AI/ML/DL, IoT, AR, Big Data Analytics with geospatial technologies.
- Digital Twins.
- 3D mapping technologies with < 10 cm precision to prepare a digital twin and to support the last mile challenges of PPT application.

Specific Problem to be solved:

- Improving farm yield by use of GIS with IoT, Drones, AI/M
- Use of geospatial in healthcare - Telehealth/Telecare/Telemedicine

Real-World Applications:

- Increasing farmer income by improvement in farm yield- aligned to the government's mission to double farmers' income by 2023.
- Provide affordable access to quality healthcare especially in remote areas.

Directions in addressing the Grand problem:

- Collaborate with relevant agencies to firm up the problem statement. Identify various stakeholders.
- Develop alliances with various stakeholders. Explore existing use cases in relevant domains

Area of expertise required to solve Grand Problem:

- Domain experts, knowledge of relevant technologies - GIS, Image processing, Computer Science, Data Sciences etc.

Benefits (Govt. agencies/stakeholders/end-users/industries):

- Farmers in case of applications in agriculture
- Citizens especially in remote areas.
- Will lead to optimum utilisation of healthcare resources - healthcare infrastructure

Collaborating/Partnering agencies for Grand Problem/Technology Development:

- ICAR, ICMR, geospatial industry, academic institutions

3.1.5 Grand Problem 5

Geospatial Applications

3.1.5.1 Grand Problem 5 (a)

Grand Problem to be solved:

- Realtime precession solutions for E-Governance

Specific Problem to be solved:

- TIH should found a mechanism to share the precession information in real-time with various stakeholders like Government, citizens, Industry and other beneficiaries

Real-World Applications:

- The precession information is need of the hour
- Any major project taken up by Central or State government based on precession positioning
- Any error in position will lead to the failure of other applications

Directions in addressing the Grand problem:

- Integration with real-time systems is very much required

Area of expertise required to solve Grand Problem:

- Software and tracking

Benefits (Govt. agencies/stakeholders/end-users/industries):

- Stakeholders include Govt., Citizens, Industry, R&D units

Collaborating/Partnering agencies for Grand Problem/Technology Development:

- Universities

3.1.5.2 Grand Problem 5(b)

Grand Problem to be solved:

1. Improving the quality of Star Sensors as well as post-processing of Satellite Imagery to allow strategic users to get highly accurate coordinates. This will help reduce dependence on foreign satellite imagery for targeting as well as other strategic requirements where high accuracy of coordinates in denied areas, matters
2. Develop technologies that allow us to overcome the limitations of non-availability of Ground Control Points for Enemy Areas to help our delivery systems as well as navigation attack systems to reach their target accurately.
3. Creating capabilities for automatic co-registration of satellite data which will save our huge time in terms o man-hours, IT eqpt, bring standards. Presently, each organization has huge data which is not accurately referenced to an accurate national base layer. Hence, for every project, huge man-hours are spent in creating this database which also means a huge cost. This is also a huge impediment for the application of AI/ML over large data no inaccuracies in layers of data unless they are accurately coregistered to a Reference Frame. Technology to help a user accurately coregistered data wrt to a user-defined reference frame will be a huge help for the users of imagery.

4. Detection of small tunnels being dug across borders used by Adversary to send terrorists inside India

Specific Problem to be solved:

- Capability to Develop a reference frame for neighbouring countries with sub-meter accuracy.
- Capability to accurately extract Ground Control Points for denied areas,
- Capability to accurately coregister imagery.
- Detection of tunnels in cross border areas.

Real-World Applications:

The above will give us strategic sovereignty in terms of getting highly accurate coordinates of enemy areas and make our delivery system highly accurate and hence increase their deterrence value. Besides this, it will reduce Over the target requirements due to assurance of their hitting the target effectively. Further, it will reduce the sensor to shoot time from a few hours (time for manual correction) to a few seconds which matters a lot for the strategic domain.

These technologies will also help the industry in terms of accurate mapping by reducing the requirement of applying ground control and giving us highly accurate images which can be used by the industry for various applications. It will cut precious man-hours required for manual correction of imagery to reference data.

It will also help us in creating a highly accurate base layer of high resolution which can be used as a national standard for the various government as well as industrial applications. bringing standards is of huge importance to leverage the opening of the Geospatial / RS domain as part of the government initiatives.

Directions in addressing the Grand problem:

- Accuracy of star sensors and platform electronics to undertake accurate acquisition as well as improving the post-processing techniques to improve the accuracy of imagery.
- An automatic co-registration effort is a work under progress by my own company.
- For tunnels, a combination of RS techniques which would include both imagery (optical, thermal, microwave) and seismic sensors could have a clue.

Area of expertise required to solve Grand Problem:

- Handling issues first hand while in my tenure at the National Security Council Section as well as while at DIPAC.
- Engaging in developing technologies as part of my startup for automatic co-registration.

Benefits (Govt. agencies/stakeholders/end-users/industries):

- Government, Defence/Strategic users/ industry by allowing us to provide accurate solutions to other countries.

Collaborating/Partnering agencies for Grand Problem/Technology Development:

- IIT-T, NRSC, ADRIN, HQ IDS, IAF/IA/IN, IB, Survey of India, Startups Community, Industry

3.1.5.3 Grand Problem 5(c)

<u>Grand Problem to be solved:</u>

- Routing over 3D digital maps for optimal flight planning required for delivery drones. Customised Planning, navigation and flight control for precision delivery drones needed for logistics, rescue and disaster management requirements.
- Millimetre level Guidance, Navigation and Control using multiple positioning sensors in real-time.
- Structure from Motion using terrestrial orbit and airborne imaging ranging sensors.
- GNSS solutions. CORS and its applications in GNC. Special emphasis on working with NAVIC in GNSS environment
- LiDAR Photogrammetry, specifically for focal plane LiDARS under development.
- Smooth switch from outside to inside environment.
- Simultaneous localisation and Mapping in real-time.

<u>Specific Problem to be solved:</u>

- Precision and Positioning support for the Last-mile challenges in applications like Logistics, Disaster Management, Search and Rescue, Defense sector.

<u>Real-World Applications:</u>

- The Precision and Positioning Technologies have reached a fair level of maturity when the imaging sensor is deployed in space and on aerial platforms. When it comes to terrestrial or unmanned aerial systems the demands on precision and its use in Guidance, Navigation and Control are much higher.
- It is necessary to work with multiple sensors in complementary mode and to carry out an integrated adjustment to achieve the necessary precisions. These solutions impact the last mile applications of the PPTs in both civilian and defence domains.
- The last mile costs in logistics are more than half of the total cost. Deploying improved PPTs to tackle these challenges can provide huge savings in manpower and fuel costs.

<u>Directions in addressing the Grand problem:</u>

- Detailed definition of the umbrella problem and identification of involved technologies as well as 1-2 specific use cases should be done in house by experts;
- Technology development should be done in close collaboration with and through funding by technology partners from startups, innovators, institutions.
- Use case demonstrations should be arranged with support from end-users like urban bodies, the logistics industry, DRDO, ISRO etc.
- Detailed documentation, patenting etc should be done by TIH and made available to the industry for taking forward.

<u>Area of expertise required to solve Grand Problem:</u>

- Multidisciplinary with core contributions coming from Electrical engineering, Geoinformatics, Computer Science

Benefits (Govt. agencies/stakeholders/end-users/industries):

- Government, Defence/Strategic users/ industry by allowing us to provide accurate solutions to other countries.

Collaborating/Partnering agencies for Grand Problem/Technology Development:

- ISRO for CORS with NAVIC;
- Urban Development Authorities for finalizing problem definition and Ground support;
- Startups/Industry involved in cutting edge UAV (drone) applications

3.1.5.4 Grand Problem 5(d)

Grand Problem to be solved:

- Accurate Positioning and precision technology with miniature size play an important role in providing solutions to natural resources management and disaster-related applications.
- Unmanned Aerial Vehicle(UAV), UAV Payload like low weight LIDAR, Camera, Thermal, Multispectral sensors and hyperspectral sensors play an important role in the years to come.

Specific Problem to be solved:

- Development of UAVs
- Development of UAV based sensors- LiDAR, Camera, Thermal sensor, MultiSpectral and Hyperspectral sensors.
- Development of precise positioning sensors GPS and IMU
- Processing software.

Real-World Applications:

- Working towards the " Make in India" concept. This may be the initial step growing towards tomorrow world leader concept.
- This technology is useful to generate geospatial data for better management of natural resources and monitoring disaster-related applications like urban floods and landslides

Directions in addressing the Grand problem:

- May be collaborating with industry and educational institutions.

Benefits (Govt. agencies/stakeholders/end-users/industries):

- Everyone gets benefited(Govt agencies, stakeholders, end-users and industry).

Positioning and Precision technologies

3.1.6 Grand Problem 6

Highly Precise National Geodesic Infrastructure

Grand Problem to be solved:

- Setting up of a " Highly precise National Geodesic Infrastructure "

Specific Problem to be solved:

- Redefining centimetre accuracy Indian Geodesic Horizontal and Vertical Datum.

Real-World Applications:

- The entire gamut of Geospatial technology and its applications depends on how accurate the reference frames are most of the countries in the world are way ahead of us in this area
- We 'do not' repeat ' do not' have precise reference datums to which we can claim our Geospatial Data refer to

Directions in addressing the Grand problem:

- National Centre for Geodesy, set up at the IIT Kanpur campus has already taken initiative in conducting a Brainstorming session on this subject with participation from various government organizations like Survey of India, ISRO, DRDO and many other academic and research institutions in the country.
- The recommendations finalized are being sent to the Department of Science & Technology, Government of India for further immediate necessary action.

Area of expertise required to solve Grand Problem:

- Knowledge in the subjects of Geodesy, Surveying and Mapping, Adjustment techniques and computer programming

Benefits (Govt. agencies/stakeholders/end-users/industries):

- Government of India departments, all the Geospatial industries in the country and the common man interested in Geospatial data.

Collaborating/Partnering agencies for Grand Problem/Technology Development:

- National Centre for Geodesy (NCG_IITK)
- Survey of India
- SAC
- NRSC
- Regional remote sensing centres
- State Survey departments and several IITs/ NITs

3.1.7 Grand Problem 7

Communication and Network Systems

<u>Grand Problem to be solved:</u>

- Continuous Operating Reference System (CORS) Network

<u>Specific Problem to be solved:</u>

Developing a make in India Solution

<u>Real-World Applications:</u>

All Developmental/ Infrastructure projects require this system.

<u>Directions in addressing the Grand problem:</u>

Focus on In house R& D

<u>Area of expertise required to solve Grand Problem:</u>

In-depth knowledge of GNSS, IRNSS (NavIC), GAGAN

<u>Benefits (Govt. agencies/stakeholders/end-users/industries):</u>

It will help in getting real-time precise positioning for all agencies generating Geospatial Data

<u>Collaborating/Partnering agencies for Grand Problem/Technology Development:</u>

- Survey of India

3.2 Major Problems to Address

The following are the other major problems to be addressed by INiF at IIT Tirupati

- Cost effective indoor positioning system for localization, mapping, navigation & path panning
- Accurate 24x7 profiling of the atmosphere to enable more accurate forecasting.
- Detection and quantification of pollutants and contaminants in the environment, and in biomedical, food processing applications.
- Optimizing the nutrients delivery based on the soil conditions for Precision Agriculture.
- Yield management and forecasting of price-sensitive crops
- Effective and timely maintenance in smart cities
- Real time data-driven disaster response management and service system
- Timely mental health intervention based on social media analytics and location information.
- Non-invasive technologies for damage assessment in machinery and infrastructure.
- Increase uptime and security of power distribution systems
- Compression and Authentication of data for IoT on-board computations and secure communication.
- Translation of PPT to industries, government verticals, and stakeholders.

3.3 Major Application Areas

1. Precision Agriculture

Global food security is one of the most critical problems and is directly related to the world socio-economic development especially in developing countries like India. The major issues to be addressed are: (i) how to increase productivity; (ii) optimal use of water resources; (iii) conservation of soil degradation; (iv) how to reduce the application of the pesticide; (v) improve the crop quality and reduce the production cost; (vi) improve the socio-economic status of the farmers. Precision agriculture (PA) is one of the advancements that have the ability to address the above issues and also provides on-site data guidance for decision making. The PA improves the agronomical, technical, environmental and economic perspective of the region. The major role of TIH in PA will be the use of advanced technologies and platforms which includes GPS receivers, Geographic Information Systems (GIS) and Remote Sensing techniques. The TIH majorly focuses on reducing the cost of PA, improving the technical expertise knowledge through skill development programs, the applicability of PA to small land holdings, and application of PA to heterogeneous cropping systems

2. Disaster Management

Most of the countries across the world, especially developing countries like India, are vulnerable to disasters in varying degrees due to their geophysical and climatological factors in addition to the effects of anthropogenic activities. Primarily disasters are caused by natural hazards or human-induced or result from a combination of both. The natural hazards are further subdivided into geophysical, hydrological, meteorological, climatological and biological. Earthquakes and cyclones fall in geophysical and meteorological, respectively. Hydrological factor mainly consists of floods and landslides. Around 58.6% of the country is prone to earthquakes, 12% to floods, and close to 5,700 km long coastline is at risk to cyclones. The catastrophic damage from hurricanes/cyclones is due to strong winds, heavy rains and storm surge. Floods are the most common and recurring natural hazards having severe economic, social and environmental consequences.

The total number of fatalities in 2019 due to 409 natural disasters were roughly pegged at 11,000. In addition to deaths, there is a severe loss to economies, and these disasters disrupt people's everyday lives, businesses, and organizations drastically. GIS and remote sensing techniques are essential tools to analyze, forecast and forewarn hazardous events through simulations and modelling. They enhance the efficiency of disaster risk management efforts. Data resources from satellites, automated weather stations, buoys help in natural hazard assessment and forecasting. Drones, GPS and thermal imagery devices help in positioning and saving the living and valuable assets during disasters and estimating the extent of the destruction. The high-resolution terrain data from remote sensing platforms are used to assess the extent and damage of floods and characterize flooding's spatial distribution. This spatial mapping provides reliable and accurate information to understand better the catastrophe and aggrandises the decision support systems (DSS) to cope with the disaster. The TIH focuses on the development of an Integrated Decision-making toolbox for preparedness, mitigation, and management. Focuses on floods, droughts, earthquakes, hurricanes, and combined extreme events. The project includes risk mapping and zonation based on the intensity of the disaster, type of population, emergency services, and disaster area's resilience. The dissemination and training of proposed tools will help stakeholders' leaders in the decision-making process

3. Natural Resources Management

Natural resources management (NRM) plays a vital role in the sustainable and socio-economic development of the world, especially in developing countries like India. The critical natural resources are land, water, air, forests, minerals and flora, and fauna. These natural resources provide raw materials for industries, food for livelihood, energy, and diversity in habitats. Due to an increase in population, industrialization, and climate change, there is a significant impact on natural resources, affecting the water-energy-food nexus. Several approaches, methods, tools, and techniques are available for the efficient planning and sustainable management of natural resources. Resource mapping and monitoring is the primary step for NRM. Remote Sensing and GIS are the modern tools that have led to generating large spatial datasets at continuous time intervals, which would have been difficult with traditional land-surveying techniques. These techniques are helpful in decision-making for sustainable NRM. The data repository and tools developed will help manage the regional natural resources for the decision-makers, modellers, stakeholders, public and private sectors working in the industry, government, and private agencies. A web-based tool will be created for the dissemination of the data and modelling resources. The data will be made available in the public domain and integrated into the various national resources databases, such as IndiaWRIS.

As India continues to develop, it is important to rapidly assess centres of biodiversity (Ghosh-Harihar et al 2019), its forest quality so that developmental activities can be focussed on specific areas. One of the challenges with changes in forest habitats is that it increases contact between humans and wildlife (Dobert et al) resulting in increasing conflicts and even disease transmission (Gupta et al 2020). Such interactions can be because of the spatial configuration of resources – forests, water etc, and can also be due to behavioural patterns of animals such as migration or dispersal. The use of remote sensing technologies to create high-resolution maps of natural resources – forests, grasslands, lakes etc. can be used by various decision-makers – the Forest Departments, town or city planners who can plan adaptation strategies and mitigation measures. Web-based visualization tools to understand the movement of animals can be created. The use of bioacoustics makes the project scalable to very large areas. Since several animals communicate through sounds that are transmitted over large distances, these signals can be easily recorded to understand and predict their behaviour.

4. Aims and Objectives

The TIH at IIT Tirupati aims to create a strong foundation and a seamless ecosystem for PPT 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 Hub development mechanism adopts a bottom-up revenue model in which the Hub's initiation is by government support, through NM-ICPS, for developing capabilities and gradual build-up of resource generation in the later years of the Section 8 company. The objectives of the TIH in PPT are as follows:

- Address gaps in the state-of-the-art of PPT including Developing atomic clocks for GPS and navigation systems and their applications; Developing solar-blind UV photodetectors for LIDAR; High precision cyber-physical system based smart micromachining; Indoor positioning systems; Precision spectroscopy techniques; Lightweight secure communication for PPT; Data analysis and image processing techniques and visualization tools; Decision-making systems;
- Develop PPT based solutions to address the country's needs in areas such as: Low-cost precision agriculture technology; Heterogeneous farming; Water security; Disaster management; Distributed energy; Environment and habitant monitoring; Natural resource management; Remote weather monitoring; Smart cities.
- Create a data bank of PPT related resources such as publications, patents and open-source data resources and software for the country.
- Dedicated GIS & Remote sensing laboratory facilities for analysis of field experiments, monitoring, and mapping of infrastructure, regional water resources, forest, and agriculture.
- Creating of technically skilled-cum-trained workforce through HRD.
- Developing a robust ecosystem to create commercial and social impact by supporting technology transfer to industry, stakeholders, and community.

- To pick up ideas from untapped sources in PPT and convert them into start-ups.
- To generate better awareness about entrepreneurship opportunities in PPT amongst India's masses and reach out to aspiring and existing entrepreneurs through active media outreach
- To expand the pipeline of potential incubatees through TBI
- To provide structured mentoring, guidance, prototyping grants, and seed-funding for ideas applying in PPT
- To build a vibrant start-up ecosystem in PPT by establishing a network between academia, financial institutions, industries and other institutions.

4.1 Outputs/Deliverables

The TIH shall develop industry-ready products with unique selling points based on translational research and development. The TIH will focus on creating new technologies in PPT such as:

(i) indigenous atomic clocks for space applications including navigation and sensing;

(ii) affordable and advanced day-light surveying sensors attached to aerial platforms such as drones for useful mapping of crop distress;

(iii) low-cost onboard computations and secure communication for real-time data transfer from sensors that have potential applications in emergency evacuation and rescue operations, transportation and defence;

(iv) customized networking and software platform for various domains of PPT;

(v) deep learning algorithms for image classification from small sample data, localization and tracking of cloud-motion or vehicles;

(vi) spatiotemporal dynamic models for catastrophic events useful in disaster management;

(vii) low-energy server-side and edge-side computing frameworks for data management;

(viii) advanced non-invasive technologies such as high-speed thermal imaging for damage assessment in machinery and infrastructure;

(ix) micromachining and nano finishing of ultra-precision components for PPT equipment.

Besides, it will bring core expertise in remote sensors, data analytics, image processing, visualization, artificial intelligence, and machine learning, lightweight security for distributed networks, and system integration for monitoring, integration, and analysis of spatially and temporally distributed resources to aid in effective decision making across multiple domains such as precision agriculture, high-precision navigation, emergency evacuation systems, water security, energy management, transportation, disaster management, health and well-being, and, mapping and monitoring of resources. The advancements in TIH will help governance, planning, and building the regional and national resources for decision-makers, regional farmers, stakeholders, municipalities, government, and private sectors.

The primary deliverables of the TIH include Translational Research, Human Resource Development (HRD), Start-up and Entrepreneurship, and International Collaborations.

1. Translational Research

The areas of expertise needed (but not restricted to) to develop technologies for the technologies mentioned above can be categorized as core and applied areas.

- **Core Areas**: Improvements to GPS technologies such as affordable and accurate atomic clocks; Precision manufacturing, Spectroscopy for non-invasive technologies, Precision agriculture, Image processing, Data science, Remote and non-invasive sensors (spectroscopy); Secure wireless communication and network; Indoor mapping.
- **Applied Areas:** Disaster management, Water management, Water grids, Energy grids, Smart Cities, Built infrastructure, Bathymetry, Underground utilities, Geo-tagging for land and crop management, traffic management, Social media analytics, Visualization, decision-making tools

IIT Tirupati and several other Academic Institutions have commendable research and development track record in each of these core and applied areas mentioned above. The Hub will, in turn, connect to all the researchers, institutes, centre of excellence in positioning and precision technologies and act as a hub and spoke model. TIH aims to bring together the best ideas in each of these fields under a single umbrella to arrive at cutting-edge products with Unique Selling Points related to the area of PPT in CPS. A list of 21 initial well thought out product ideas are enclosed with this proposal and detailed timelines. The Hub envisages close to 50 publications in the next 5 years.

2. Human Resource Development

In the next five years, the Hub envisages involvement of close to 50 Employees, 210 Undergraduate, 80 Masters, 32 PhDs, 3 Post-Doctoral Fellows, 2 Faculty Fellowships, 3 Chair Professors and 380 summer interns spread across multiple academic institutions, in solving various technical challenges related to the PPT in CPS. Besides, the Hub will fund short-term visiting fellowships and invite eminent professors.

3. Productization and Commercialization

The Hub's objective is to encourage patenting of ideas both National and International and ensure serious involvement of end-user agencies, established industry and/or start-ups in every project from its initial stages to ensure productization. The Hub will establish the Technology Incubation Center, enabling incubation of start-up companies to take forward the translational research ideas generated. The Hub will focus on developing a robust ecosystem to create commercial and social impact by supporting the transfer of technology to industry and the formation of start-ups. The Hub will adopt a structured and yet flexible framework in dealing with the complexities of marketing.

4. International Collaborations

The Hub will establish and strengthen the international collaborative research for cross-fertilization of ideas in PPT. It is envisaged to develop research collaborations with international academic & research institutions to advance CPS in PPT. The Hub aims to become an essential resource and collaborator for global companies in PPT. INiF will expand on these efforts by bringing in more international subject matter experts for symposia and seminars and structured researcher and industry exchange programs.

5. Strategy

5.1 Strategy for Technical Challenges

The strategy to address the technical challenges is to identify the core problems and issues involved for each of the products, understand the specific issues that the products address and connect them to industry partners for commercialization. At the core of this approach is the need to understand the practical problems solved by the CPS technology to be developed, the target beneficiaries and the unique selling point of the device or product that shall make it lucrative from a commercial point of view. Finally, a projection is made based on the deliverables and the benefits in terms of revenue generation estimated based on IP creation or the creation of a start-up. Every proposal submitted shall identify components at each of the above domains levels, namely: problem(s) identified, target beneficiaries and USP. Each of the products or technologies developed in turn shall have a core component and an applied component. INiF shall leverage the expertise and equipment/resources available at IIT Tirupati to address any technical issues. Ongoing efforts to establish cooperation with academic and research institutions in the country shall augment the efforts undertaken at IIT Tirupati with respect to the PPT (Precision and Positioning Technologies) vertical under NM-ICPS.

5.2 Human Resource Development Challenges

At IIT Tirupati, we have a strong ethos of developing next-generation skilled manpower derived from a diverse background of talent consisting of research scholars, senior year undergraduate students, graduates from other academic institutions and industries. Given the diverse and interdisciplinary nature of the proposed work, we anticipate human resource development from a variety of engineering and science disciplines leading to robust solutions in the PPT domain that address challenges across a wide range of industries - from precision timing to smart cities to social media analytic applications.

The human resource development efforts under the Hub can be broadly classified into two domains: Floating of courses/degree programs/certificate programs in PPT-oriented Cyber-Physical Systems and launching of Interdisciplinary Research programs (MS + PhD) in Cyber-Physical Systems with an emphasis on PPT applications. We envisage the launching of certificate programs focused on skill development, and more specifically, re-skilling. As the conventional manufacturing industry has come to saturation, the wide variety of fields introduced through this project opens up multiple job avenues in the fields, GIS & Remote Sensing, image processing, machine learning, precision manufacturing and data analytics. Preparation for Industry 4.0 in the context of cyber-physical systems will be at the top of the agenda. IIT Tirupati is committed to the vision of the Government of India of achieving all of these objectives outlined in the NM-ICPS DPR document.

The simulation frameworks/sand-boxes created through the Hub would be seamlessly used for education purposes. To re-skill senior manpower in the industry, online web-based programs will be launched. The Hub will actively involve itself in re-orienting some of the traditional courses including Satellite Image Processing; Deep learning for satellite image & data processing; Remote Sensing Data Analysis & Processing; Social Media Analytics; Spectroscopy and Sensing Applications; Machine Learning using remote sensing data for decision making; and, Decision support systems for resource management. On the Precision agriculture and manufacturing front, a skill development framework to educate and train the shop floor engineers and top floor managers on the realization of smart systems will be introduced. Research scholars and students working on a given project will be actively involved in the course delivery process as a teaching assistants. This will benefit the students of the course while at the same time the research scholar can also get the frameworks tested through the class. These insights also make the research scholar/student fine-tuned towards the translational part of the research and prepare them to be industry-ready.

6. Technology

The Hub focuses on six precision and positioning technologies namely:

(i) Atomic Clock
(ii) Precision spectroscopy techniques
(iii) Remote Sensing Sensors
(iv) IoT Systems for Indoor Navigation
(v) Precision Agriculture
(vi) High Precision Smart Manufacturing Systems for Advanced Applications

The following provides the details on each technology.

6.1 Atomic Clock

Position determination has been key to civilization development for thousands of years. With the establishment of Global Navigation Satellite Systems (GNSS; most prominently the Global Positioning System GPS) accurate positioning has found its way into virtually everybody's pocket in the form of compact and cheap chipsets in mobile phones (Figure 1). GNSS, however, is prone to certain technical limitations. Heavy tree coverage, urban or mountainous terrain or tunnels lead to positioning errors or total loss of signal which makes navigation, e.g. for flying in challenging terrain difficult to impossible. Inertial navigation allows determining one's position by knowing the starting position and continuous determination of all three translational and rotational degrees of freedom followed by integration and use of Newtonian physics. In practice, however, GNSS-free navigation over extended periods is troublesome since it leads to positioning errors due to intrinsic noise and drift behaviour of classical inertial navigation systems (INS).

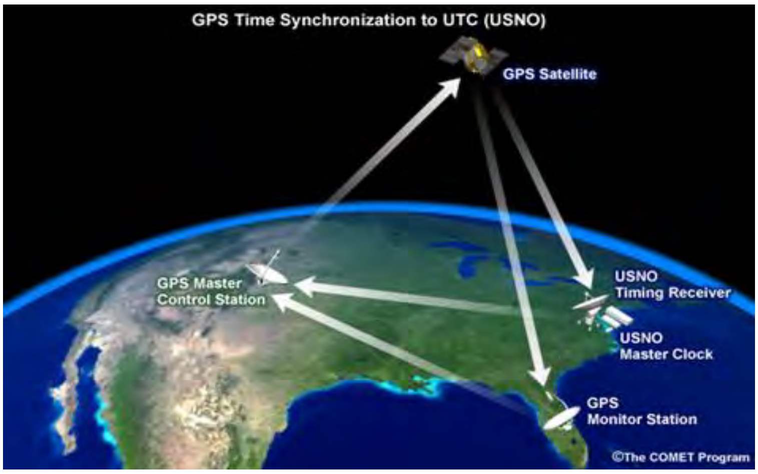

Figure 1: GPS time Synchronization using onboard atomic clocks

The Global Positioning System (GPS) is a global satellite system that enables us to define a GPS receiver's location anywhere on Earth. All it needs is the line of sight with 4 of the 31 GPS satellites that are circling the Earth. Developed and operated by the US Government, it became available for civilian use in the 1980s. Like with many new technologies, the scientists and engineers who developed the system could never have imagined what it would be used for 30 years later. Today, many businesses rely on GPS for their operations. It is used to navigate vehicles, map forests and agricultural lands, locate people in need of assistance, track movements of wildlife, packages, containers and vehicles, and countless other applications. Location-based services have become part of everyday life. We use our smartphones to determine where we are and how to get to our target destination, to measure speed and distance when we go running, to check the whereabouts of our pets, or to capture creatures in Pokémon Go.

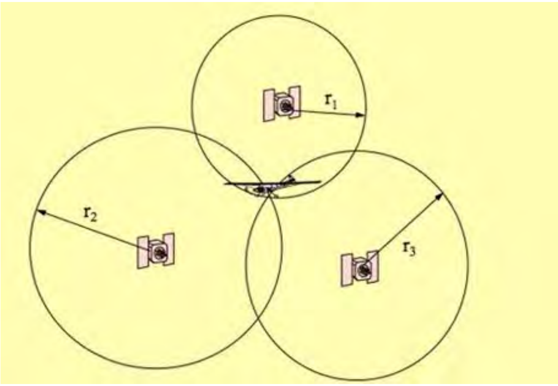

Figure 2: GPS navigation and positioning technique using trilateration – a geometric technique using multiple spheres to decipher the precise location of any object

In the future it will be possible to use quantum communication technology to synchronize more accurately, transferring time information directly between the quantum memories in GPS satellites. The result is the ability to pinpoint your location with much higher accuracy, theoretically up to 15 centimeters (Figure 2).

At the heart of all GPS systems for communication and navigation purposes lies an atomic clock for precise time synchronization and time delay calculations. Optical clocks represent the pinnacle of precise timekeeping. The most precise atomic clocks are based on optical transitions within neutral atoms or trapped atomic ions, by virtue of the tremendous progress made within the fields of laser stabilization, optical frequency combs, laser cooling and trapping of atoms and ions. These developments have allowed the realization of optical atomic clocks with unrivalled performances and fractional uncertainties well below 10^{-17}, finding applications in fundamental physics tests, relativistic geodesy and time and frequency metrology.

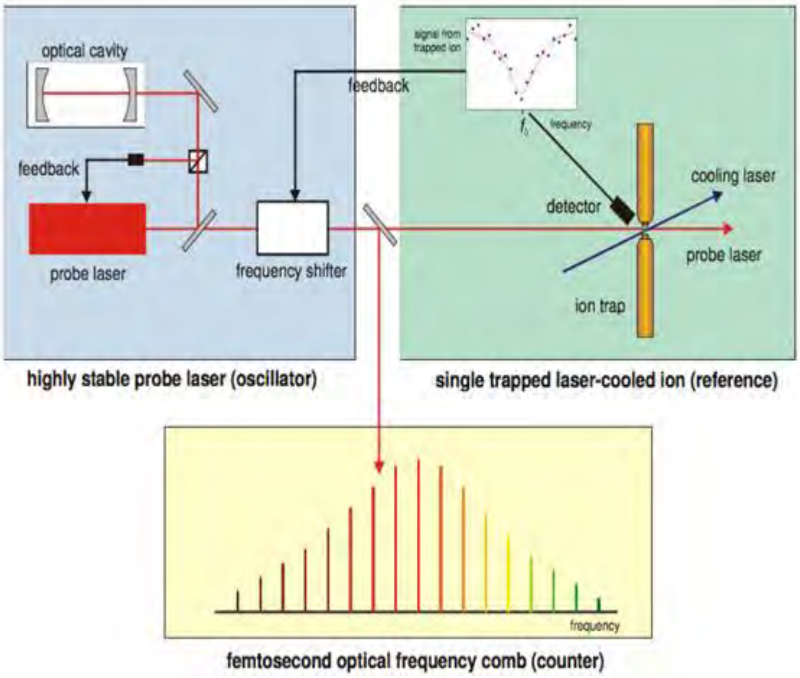

Figure 3: Schematic of an atomic clock. An ultra-stable oscillator (a laser) referenced to an atomic transition along with a counter (optical frequency comb) constitutes an atomic clock

Precise atomic clocks are key not only to establishing superior GPS and navigation systems but also a whole host of scientific endeavours such as VLBI (Very Long Baseline Interferometry). VLBI is important for the timing synchronization of radio telescopes that help image galactic events and phenomena and, enable spacecraft navigation. These atomic clocks are also important for allied industry such as the development of precise timing devices for mobile and internet communication and for time-stamping financial transactions. With the increasing penetration of internet connectivity, it has become imperative to ensure accurate network timing synchronization to ensure seamless connectivity to billions of users hooked up to the Web. Additionally, over the past few years, position-based social media services and entertainment systems have witnessed phenomenal growth. This growth has also increased the demand for precise network timing systems. Conventional hardware (FPGA - Field Programmable Gated Array) based network timing devices are slowly reaching their limit. Atomic clocks can help surpass this limitation with timing accuracies of a few parts per 10^{-18}. Recently, VLBI technology was used to take the first-ever image of a Black Hole by time synchronizing multiple radio telescopes spread over the globe using precision atomic clocks.

Atomic clocks are fundamentally the most accurate clocks to be ever realizable through modern technology [see Figure 3]. An atomic clock relies on the measurement of the energy difference between two energy levels. This energy level difference is a constant for a particular atom or ionic species used.

When an atom comes down from an upper energy level to a lower energy level, the difference in energy is emitted as light. One can measure the frequency of this light and determine the time. This in turn depends on the frequency of the source (microwave or optical) used to excite the atoms from the lower to the upper level. The more precise this frequency emitted by the source, the higher the probability of atoms landing in the upper energy level. The final goal is to perfectly tune the source frequency to the energy level difference of the atoms and then measure it.

The best atomic clocks in the world at NIST, USA or NPL, UK or PTB, Germany have a frequency uncertainty of a few parts in 10^{-18}. State-of-the-art atomic clocks with a fractional instability below a few parts in 10^{-17} or 10^{-18} can help us address issues related to accurate GPS positioning, superior mobile communication, precise timing synchronization and also help us address a host of fundamental physics problems such as the time variation of fundamental constants, the origin of dark matter, etc.

Atomic clock technology in the world has reached unprecedented levels. Some of the most notable groups in timekeeping are Prof. Jun Ye's group at NIST, USA, Prof. P. O. Schmidt's group at PTB Darmstadt, Germany and the National Physical Laboratory in the UK. Interestingly the accuracy of the atomic clock depends on the linewidth of the transition being used since it directly impacts the quality factor of the clock and in turn impacting the final uncertainty in the measurement of time. The Sr (strontium) atom lattice clocks at Prof. Jun Ye's group [1-3], Prof. H. Katori's group [7] at the University of Tokyo, and the NIST, Boulder, USA [4-6] while the Yb (Ytterbium) ion clock at PTB, Darmstadt, Germany [8] and the NPL, UK [9] have achieved a fractional uncertainty ranging from a few parts in 10^{-17} to 10^{-18}. These unprecedented accuracy levels have fueled investigation of fundamental physics problems such as precision tests of fundamental physics theories, studies on the time variation of fundamental constants and stringent tests of general relativity. Apart from this Paris based SYRTE Observatory and the NICT (National Institute for Communications and Technology), Tokyo, Japan are also a few of the prominent groups worldwide in atomic clock technology. Apart from this there are also established commercial manufacturers such as MicroSemi Corporation, Symmetricon, Hewlett Packard, etc., who make chip-based or maser-based atomic clocks.

Atomic clocks are characterized through their fractional frequency uncertainty and Allan-deviation measurements. The clock instability is quantified by the expression shown below:

$$\sigma_y(\tau) \approx \frac{1}{\pi}\frac{\delta_v}{v_0}\frac{1}{\sqrt{N}}\sqrt{\frac{T_c}{\tau}}$$

where $\delta_v =$ spectroscopic linewidth of the clock system, $v_0 =$ atomic frequency, $N =$ number of atoms or ions used in a single measurement, $\tau =$ averaging time, and $T_c =$ time required for a single measurement cycle.

Essentially $\sigma_y(\tau)$ tells us how the oscillator under test compares to an ideal one over the timescale τ. For everything else remaining constant, the clock instability is determined purely by the quantity (δ_ν/ν_0). This quantity(δ_ν/ν_0) is the inverse of the atomic quality factor Q. The Q-factor determines the precision with which the optical frequency of the source oscillator (laser) [see Figure 3] can be stabilized to an atomic resonance. In effect, this determines the precision with which the atom can be pumped from the lower to the upper energy level. It is easy to see that the Q-factor is higher for optical transitions compared to microwave-based transitions for the same linewidth.

Timekeeping has been at the core of the evolution of human civilization. With each progress in the accuracy of measurement of time, our understanding of nature, as well as the impact on our daily lives, has changed tremendously. Today's timekeeping is done with state-of-the-art atomic clocks [10-13]. The fundamental principle on which these atomic clocks [14,15] operate is through a frequency measurement of a narrow atomic resonance that has been made accessible through tremendous developments in laser cooling and trapping, laser stabilization and laser spectroscopy. However, given the complexity, spatial footprint and energy requirements of these atomic clock systems, their penetration into the space industry has been limited. These are the reasons why there is currently a sustained global activity related to research and development programs for developing portable atomic clocks. Portable atomic clock technology has gained a tremendous push as a fundamental application for state-of-the-art quantum technologies.

Atomic-clock-quality timing and synchronization underpin a broad range of technologies and infrastructures. GPS, telecom, power distribution, surveillance, mineral exploration, space applications, etc. require a frequency uncertainty at the level of 1 part in 10^{-11} to 10^{-15}. Dr. Arijit Sharma's group is trying to develop portable atomic clocks for space-based applications - for instance, navigation using GPS systems coordinated through onboard atomic clocks as part of the research proposal for the Positioning and Precision Technologies vertical. The development of atomic clocks embodies very aptly the nomenclature and philosophy of this vertical. This project shall also target precision timing devices for network synchronization. The proposed project has an impetus to drive VLBI technology for space geodesy and deep-space navigation.

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6.2 Precision spectroscopy techniques

Precision spectroscopy-based sensors have potential applications in atmospheric monitoring, medical, agriculture, food processing, pollution control, chemical analysis, industrial process control, etc. [1, 2]. These applications utilize ultra-violet (UV), visible, infra-red (IR), wavelength regions for sensing via emission, absorption, Raman, fluorescence, and other spectroscopic processes. Due to the rising concern about the quality of vital things such as air, water, food, etc. and strict Government rules and regulation, enhanced adoption of spectroscopy-based techniques is being observed in the novel areas of societal importance. An industry report published in Aug 2018 valued the U. S. process spectroscopy market size at USD 14.08 billion in 2017 [Report ID: 978-1-68038-561-8]. The report forecast exponential growth in this sector.

The current project is motivated towards the precise detection and quantification of pollutants in the ambient air. In the first phase, we plan to develop a cavity ring down spectrometer (CDRS) with ultra high detection sensitivity for Hg atoms. Harmful irreversible toxic effects due to exposure to mercury are well known and confirmed in various studies. The World Health Organization (WHO) has recognized mercury as one of the 10 pollutants in the world. Naturally, Hg founds in the earth's crust, however, human activities like mineral extraction, fuel combustion, industrial processing etc. could also release the Hg in ambient air. The Hg atom present in the air could enter into water bodies either directly or indirectly. The microorganism could further convert it to a highly toxic methylmercury compound that can first enter into creatures living in water and later into humans and other animals who consume them. The 2018 technical background report of the global mercury assessment reported the following sources of mercury pollution (see Table 1).

The report estimated that more than 75,000 newborns in the United States each year may have an increased risk of learning disabilities associated with in-utero exposure to methylmercury. Currently, in India, pollution due to mercury is about 50 times higher than in Europe and the USA. Indian industries contribute to about 40% of the total mercury pollution in our country. In order to understand how to mitigate the ill effects of mercury contamination of the environment, it is highly essential to develop high-precision instruments to accurately monitor and control Mercury pollution.

Given the rising concern about the increase in the pollutants in the environment, the detection and precise quantification is the need of the hour. In the long term, the project also aims to extend the detection and quantification of other pollutants such as lead, As, NO, NO2, SO2, etc. The proposed product is not only essential in ensuring a safe industrial operation but also helps the pollution control bodies to monitor the environment accurately. To the best of our knowledge currently, no industry is manufacturing the CDRS spectrometer in INDIA. The team aims to strengthen the Make in INDIA movement by manufacturing the highly sophisticated CDRS spectrometer in INDIA

Table 1: Typical mercury emissions from different industrial sources

SOURCE	AMOUNT(Kg)
Artisanal and small scale mining	8,37,658
Stationary combustion of coal	4,73,777
Non ferrous metals production	3,26,657
Cement production	2,33,168
Waste from products	1,46,938
Vinyl chlorine monomer	58,268
Biomass burning	51,860
Ferrous metal production	39,903
Chlor-alkali production	15,146
Waste incineration	14,944
Oil refining	14,377
Stationary combustion of oil and gas	7,130
Cremation	3,768

In the initial phase of the vertical, the project is motivated towards the precise detection and quantification of mercury (Hg) atoms in the environment. In spite of the tremendous advantages of using mercury in our lives, one cannot afford to ignore the significant detrimental effects mercury has in our daily lives. The World Health Organization (WHO) has recognized mercury as one of the 10 most harmful pollutants in the world [6]. Currently, in India, pollution due to mercury is about 50 times higher than in Europe and the USA [7, 8]. Indian industries contribute to about 40% of the total mercury pollution in our country. To understand how to mitigate the ill effects of mercury contamination of the environment, it is imperative to develop an understanding of how to detect and quantify the amount of mercury prevalent in the ambient environment. Given the rising concern about the increase in the pollutants in the environment, the detection and precise quantification is the need of the hour [8].

In the long term, the project also aims to extend the detection and quantification of other pollutants such as lead, As (Arsenic), NO (Nitrous Oxide), NO_2 (Nitrogen dioxide), SO_2 (Sulphur dioxide), etc. The proposed product is not only essential in ensuring a safe industrial operation but also helps the pollution control bodies to monitor the environment accurately. To the best of our knowledge currently, no industry is manufacturing the CDRS spectrometer in INDIA. The team aims to strengthen the Make in INDIA movement by manufacturing the highly sophisticated CDRS spectrometer in INDIA. Besides the technical product development, we would also like to develop spectroscopic education kits for UG and PG level experiments. Spectroscopy is an equally fundamental subject and it is continuing to play a significant role in the foundational development of various streams like Quantum Mechanics, Quantum information technology, Quantum computing, atomic and molecular physics, chemistry, material science, etc.

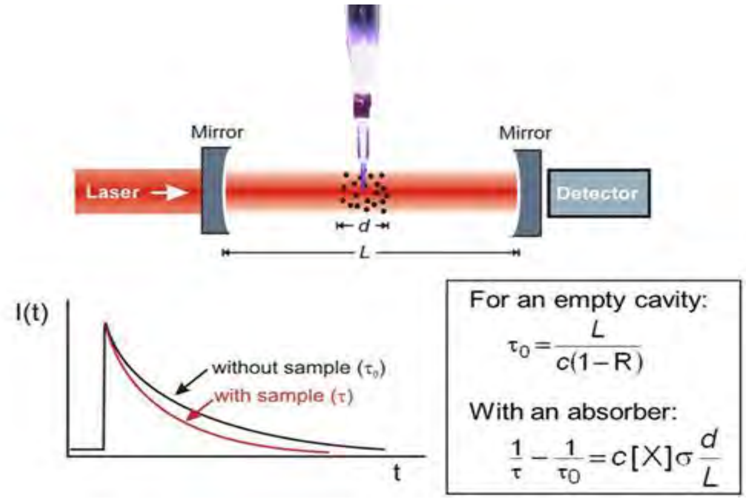

Figure 4: Schematic of cavity ring-down spectrometer setup

Under the proposed vertical, we plan to develop a laser absorption-based Cavity Ringdown Spectrometer (CRDS) that has an ultra-high detection sensitivity than normal direct absorption techniques [3, 4, 5]. In CRDS, the absorption path length is enhanced by several orders of magnitude by trapping the laser beam in an optical cavity. Therefore, the detection sensitivity is correspondingly enhanced by several orders of magnitude as compared with the conventional single-pass absorption spectroscopy. A small fraction of the laser beam leaks out in each round trip to a photo-detector that monitors the decay of light intensity within the cavity, and the decay time constant (ring-down time), rather than the change of the light intensity, is measured. Thus, the performance of the technique is almost unaffected by the fluctuation noise of the laser source. Absolute absorbance (consequently the analytic concentration) is determined by measuring the ring-down times with and without an absorbing species in the cavity. A typical ring-down event (ring-down decay) is of the order of microseconds, depending on the physical parameters of the cavity and the absorption features of the species. A schematic of the CRDS is shown in Figure 4.

A wide variety of instrumental methods has been developed for the determination of environmental mercury. Sophisticated analytical techniques include atomic absorption spectrometry (AAS), atomic emission spectrometry (AES), quadrupole mass spectrometry, inductively coupled plasma (ICP)/mass spectrometry (ICP-MS), etc. These instrumental methods provide high sensitivities for monitoring trace amounts of mercury in the environment. Among them, cold-vapour atomic absorption spectrometry is frequently used to accurately measure mercury due to its simplicity and good reproducibility. However, the original forms of mercury in the sample are destroyed in the process of such techniques. Thus, the detected amounts of mercury are total forms of mercury including Hg0, Hg2+, CH3Hg+ and other organic mercury complexes. A challenge exists to differentiate mercury forms in various samples using instrumental-based methods.

The maximal sensitivity of mercury detection using commercial portable systems based on atomic absorption spectroscopy (**AAS**) is at the level of 0.1 ng/m^3 (~ 30 ppb (parts per billion)) with about 5-15 minutes of averaging time. However, it should be noted that field-portable mercury detectors vary substantially in the amount of mercury they can detect, their sensitivity, the time taken to respond to changes in mercury levels and the factors which may affect their readings. Investigators who use field-portable mercury detectors should understand how the instrument operates, be able to evaluate whether the instrument is operating correctly, and assess whether environmental factors may affect the instrument's readings. The proposed method of mercury detection in the ambient environment, based on cavity ring down spectroscopy (**CRDS**), is a more sophisticated non-invasive technique whereby we may detect atomic mercury (Hg) in the ambient environment in a non-destructive manner at the ppt (parts per trillion) level with 5 minutes of averaging time.

The idea is that in case there is a small leakage of mercury in the air surrounding any area having any human presence, there should be a mechanism to verify its existence even if the exposure is in trace amounts. Exposure to mercury – even small amounts – may cause serious health problems, affecting the brain and kidneys, and is a threat to the development of the child in utero and early in life. In this scenario, a **CRDS** instrument shall be critical to determine if the area is safe for humans and animals. The situation will become more critical if the area has a hospital, or a school or an office building nearby.

In the initial phase of the vertical, the project is motivated towards the precise detection and quantification of mercury (Hg) atoms in the environment. In spite of the tremendous advantages of using mercury in our lives, one cannot afford to ignore the significant detrimental effects mercury has in our daily lives. The World Health Organization (WHO) has recognized mercury as one of the 10 most harmful pollutants in the world [6]. Currently, in India, pollution due to mercury is about 50 times higher than in Europe and the USA [7, 8]. Indian industries contribute to about 40% of the total mercury pollution in our country. To understand how to mitigate the ill effects of mercury contamination of the environment, it is imperative to develop an understanding of how to detect and quantify the amount of mercury prevalent in the ambient environment. Given the rising concern about the increase in the pollutants in the environment, the detection and precise quantification is the need of the hour [8].

In the long term, the project also aims to extend the detection and quantification of other pollutants such as lead, As (Arsenic), NO (Nitric Oxide), NO_2 (Nitrogen Oxide), SO_2 (Sulphur dioxide), etc. The proposed product is not only essential in ensuring a safe industrial operation but also helps the pollution control bodies to monitor the environment accurately. To the best of our knowledge currently, no industry is manufacturing the CDRS spectrometer in INDIA. The team aims to strengthen the Make in INDIA movement by manufacturing the highly sophisticated CDRS spectrometer in INDIA. Besides the technical product development, we would also like to develop spectroscopic education kits for UG and PG level experiments. Spectroscopy is an equally fundamental subject and it is continuing to play a significant role in the foundational development of various streams like Quantum Mechanics, Quantum information technology, Quantum computing, atomic and molecular physics, chemistry, material science, etc.

The spectroscopic techniques are playing an essential role in various streams of science and engineering such as Quantum Mechanics, Quantum information technology, Quantum computing, atomic and molecular physics, chemistry, material science, etc. Therefore, along with building the theoretical knowledge, the experimental understanding of the spectroscopic techniques is highly essential at UG and PG levels. In this light, we would also like to develop advanced spectroscopic education kits for UG and PG level experiments to train students in precision spectroscopic techniques.

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6.3 Day-Time Raman LIDAR for Atmospheric Remote Sensing

Remote sensing of the atmosphere broadly refers to the activity of sensing events of prime importance through sensors at remote places without direct contact with the event being observed. The observations of atmospheric moisture and temperature profiles are essential for the understanding & prediction of earth system processes [1]. These are fundamental components of the global and regional water cycles and they determine the radiative transfer through the atmosphere and are critical for cloud formation and precipitation.

Also, it is expected that the assimilation of high quality, lower-tropospheric water vapour content (WV) and temperature profiles will result in a considerable improvement of the weather forecast models, particularly with respect to extreme events. High resolution measurements of a vertical column of WV during the passage of weather events are required to understand and model characteristics of severe systems. Regular, in situ mode of measurement of WV using GPS sonde (a normal method of measurement of WV column) ascents fail to provide a vertical column of water vapor due to change their path during abnormal wind circulations during storm or weather events. Moreover, in situ measurements provide point measurements of the vertical structure of WV and cannot provide its temporal variation. Hence, to obtain the variability in the vertical structure of WV, one has to depend on the remote sensing (RS) method of measurement of WV. Usually, RS instruments provide high vertical resolution measurements of WV.

Lidars remotely sense atmospheric WV using Raman and DIAL techniques. The Raman Lidar (Lidar is an optical analogue of radar, using pulses of laser radiation to probe the atmosphere) is an active, ground-based laser remote sensing instrument to measure water-vapor mixing ratio and several cloud- and aerosol related quantities with good precision. A standard state-of-the-art Raman lidar uses a laser (typically Nd: YAG) which emits light at multiple wavelengths. A beam expander reduces the beam divergence. The back scattered light from the atmosphere is collected with a telescope. A multi-channel receiver separates the elastically back scattered signals at the laser multi-wavelength input signals and the Raman signals of nitrogen and water vapor detected by sensitive detectors (usually photomultipliers) in single photon counting mode. The system detects elastic back scattering signals, vibrational-rotation in elastic Raman signals of Nitrogen at 387nm and vibration-rotation Raman signals of water vapor at 407nm. From these signals, the profile of the water-vapor mixing ratio and the temperature profile in the atmosphere can be derived. The Raman scattering cross sections are several orders of magnitude smaller than those for elastic scattering. Therefore, Raman lidars work with high laser pulse energy, relatively large telescopes, and efficient detectors on the basis of single-photon detection. The functional blocks of a Lidar are shown in Figure 5.

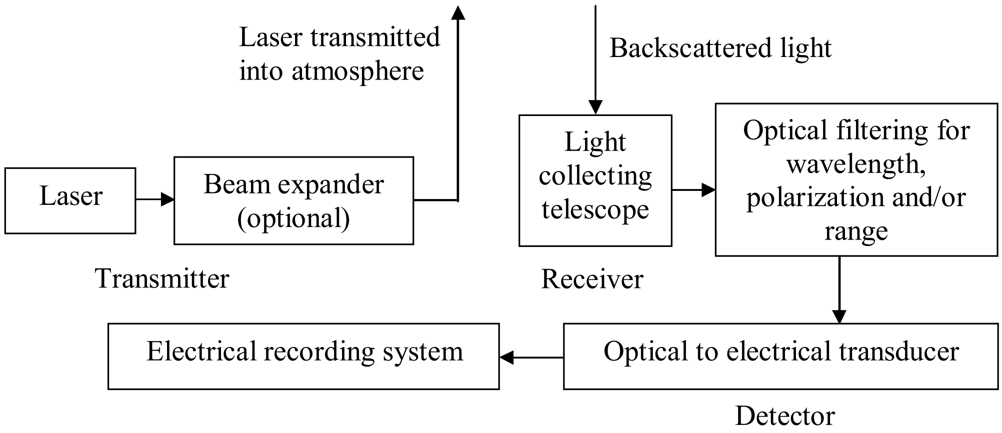

Figure 5: Block diagram of Lidar

Such Raman Lidar systems were successfully developed across the globe for better weather forecasting, for example by the Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) of USA [2] and at high altitude station of India [3] and at NARL [4]. The Raman Lidar developed at NARL (National Atmospheric Research Laboratory), Gadanki uses a UV laser at 355nm wavelength for sensing water vapor distribution. A group at NARL has developed a combined Raman elastic backscatter lidar (CREBL) technology for remote sensing the lower atmospheric water vapour during nocturnal periods. The technology was granted Indian patent status recently in 2020 [5]. An article authored by Sangeetha et al., [6] describes the developed lidar technology and also provide an innovative means to merge the signals detected using different optical acquisition techniques. Figure 6 presents the multi-wavelength capability of developed CREBL. The technology uses a 355 nm laser and is demonstrated to measure the spatial distribution of WV, aerosol and clouds covering the lower atmosphere [4]. However, the limitation of this technology is such that it works only during night periods. The reason behind the limitation was the poor Raman scatter strength of trace species from the atmosphere when compared to strong elastic backscatter by particles/molecules during daylight.

Usually, the measurements should collect data for longer periods of time (for example 10 years for the case of ARM [1]) autonomously 24 hours per day, 7 days per week to study, and hence improve the existing atmospheric models. However, most of the existing LIDARs in India, as well as elsewhere, are working only at night time due to the very weak backscattered Raman signal, masked by the ambient light at daytime. On the other hand, if one employs a suitable solar-blind detector with pre-amplifier configurations with the dimensions matching that of optics used in the existing system, daytime profiling could be carried out. Developing such systems will be required in order to assess the effect of aerosols on cloud precipitation characteristics locally.

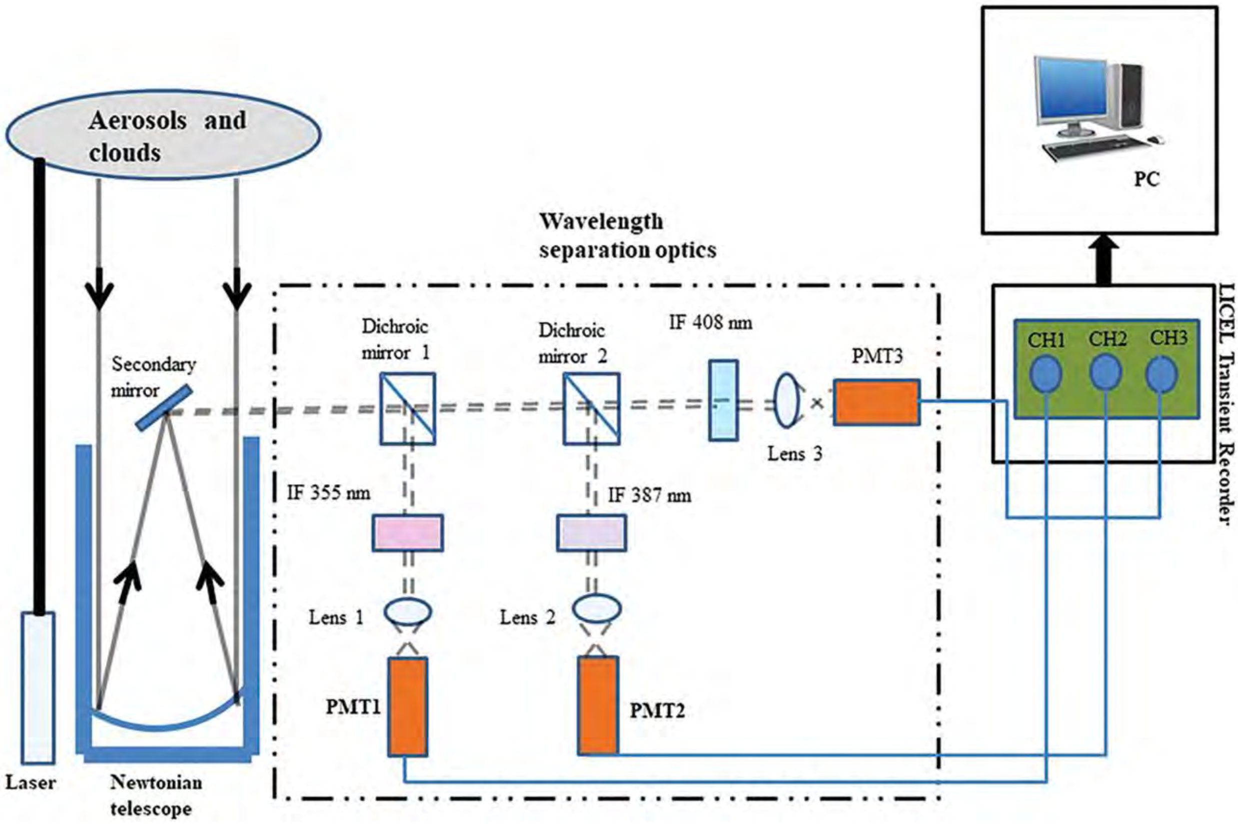

Figure 6: Combined Raman elastic backscatter lidar (CREBL) technology

Recently, Raman lidars were developed for operation at 266 nm, a wavelength region that is considered solar blind. The advantage of this technology is that in this spectral range lidar works in the daylight period and obtains Raman scatter from atmospheric trace spices [7]. However, to realize such technology, advanced detecting devices with efficient optical collectors are required at the 266 nm wavelength range of atmospheric operation. The objective of this activity is to design and develop solar-blind UV detectors for in-elastic Raman back scattered signal with associated electronics. The add-on module will be capable of daytime profiling of the atmosphere, which is currently restricted to night-time operation due to the noise caused by background ambient light. The proposed detector assembly upon successful development and testing will be integrated with the existing Raman-Lidar at NARL with the help of collaborators from NARL.

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6.4 Indoor Positioning and Navigation

Indoor positioning and navigation is a rapidly growing market globally with an estimated cumulative annual growth rate of 27.9% by 2023 [1]. The major contributors in this market are countries from North America, Europe and Asian countries like Japan and China. However, the Indian market is also expected to witness faster growth due to the rise in connected devices, adoption of Bluetooth and surge in adoption for Indoor positioning. The Indoor positioning system is an important infrastructure of indoor space and plays a major role in managing the Indoor spaces by opening a whole new world of applications. An indoor positioning system (IPS) is a network of devices that can determine the location of any person or object precisely in an indoor environment. The location information thus obtained, enables a number of location-based services in commercial and residential spaces for both day-to-day applications and mission critical applications [2 - 6].

The following are some of the key applications for residential and commercial environments as well. The applications failing in Healthcare, Retail, Manufacturing, Logistics and Warehousing, Public and Office Spaces, domains have greater relevance in the Indian Market.

Residential

Childcare: Monitoring the health and activity of infants and kids in an indoor environment is a challenging task spanning the entire day and night cycle. A wearable device or distant sensing unit to monitor and inform the vitals and activities of a child towards a hazardous situation can be of help to the family.

Elderly Monitoring: Assistance in navigation and operation is a primary concern arising with the old in a domestic environment. The presence of location-aware devices with intelligent functionalities can prove to be of substance.

Appliance control: Maintenance of temperature conditioning in the house, controlling appliances such as washing machines and refrigerators and adjusting illumination based on the human presence for localization to come into play.

Security: Accessibility control for admission to restricted places and locating security breaches require precise positioning and tracking methods. To safeguard against theft and plan for emergencies can be assisted with location-based services.

Similarly, non-residential infrastructures, where horizontal and vertical constructions are frequent, present additional spatial requirements for automation. In such environments, resource and service provisioning is of great concern due to the underlying cost. This requires the support of optimization techniques that demonstrate the applicability of indoor localization for commercial and public spaces:

Commercial Spaces

Occupancy Analysis: Conserving electric energy is of great concern for commercial environments. Activities of employees and assisting appliances trigger continuous electricity consumption at times, raising the need for optimal energy usage frameworks. Such intelligent techniques require knowledge about occupants in the space of consideration. Localization can be useful in identifying and locating the inhabitants for objectives such as automated lighting control and heating, ventilation and air conditioning (HVAC).

Patient Monitoring: To record and monitor the vitals and activities of a patient in a medical facility is of high importance for doctors and nursing staff. This requires the dissemination of accurate information in real-time. Hence, detection of critical conditions and informing them of the relevant available nursing stations or doctors can be of great help with location-based information.

Assisting Handicapped: For a person with a physical disability especially with vision impairment, the assist of a localization system for identification, navigation and interaction can turn out to be a great help.

Underground location-: Establishments such as mineral mines require a lot of human and machine mobility in challenging environmental conditions. The location information in the form of applications, delivering digitized maps and navigation assistance, can be of great help for the workers and machinery deployed in such depths.

Surveillance: Defence establishments and government organizations of high importance require a robust service framework for monitoring every private entity without fail. Hence, positioning and tracking based applications can play a vital role in such scenarios.

Background: The concept of an indoor localization system is bound to be formed upon the implementation of positioning methods. Past researches in this regard have experimented with localization with technologies such as Radio communication standards, Visible Light, Magnetic Field, Vibration, Sound and Inertial sensors deployed with suitable algorithms for position estimation. Each implementation of a localization solution can be segregated into two parts, namely, method and technology. Methods of positioning are mostly algorithms, build to work on the technologies mentioned above.

Over the past few decades, based on the technologies used in different application domains for positioning and navigation such as GPS, Laser Scanning, Radio Frequencies etc. as referenced in Figure 7, it is quite a clear notion by now that each approach has its limitations of accuracy and coverage. Thus, rationalizing a hybrid approach seems justifiable in all respects.

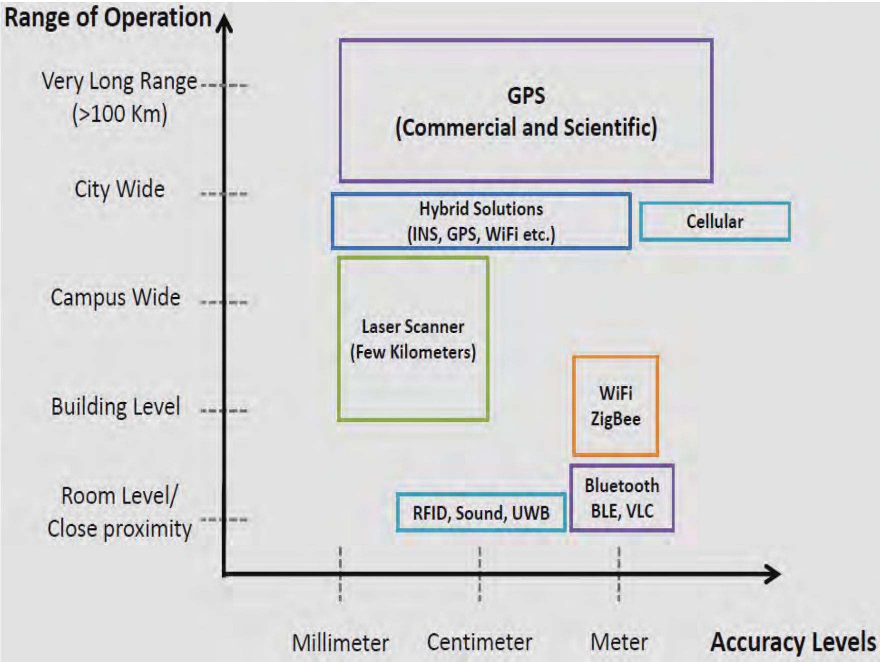

Figure 7: Range vs Accuracy of different Positioning Technologies

For positioning purposes, a communication signal can be analyzed to provide transmission-related observations such as time, direction and phase or its strength and channel characteristics. As mentioned earlier, Indoor location estimation can be implemented most by the radio wave communication technologies such as WiFi, Bluetooth, ZigBee, RFID. Additionally, usage of Visible light, Magnetic Field, Sound, Vibration and inertial sensors have been experimented with to provide standalone and hybrid solutions. A brief comparison of different positioning technologies is shown in**Error! Reference source not found.** [7].

Further, these methods will not work accurately at any time or place or on any device without involving any calibration [8 and 9]. Therefore, it is necessary to look into the problem of positioning infrastructure to make it a one-stop solution for different use cases. The other related activities of an

Indoor positioning system are occupancy estimation, indoor navigation, occupants' (or pedestrians') behaviour and their movement.

Table 2: Suitability of Positioning Technologies

Type	Coverage	Power	Deployment	Accuracy	Remarks
WiFi	High	Moderate	Moderate	Moderate	Available in most of today's smart devices makes it a primary candidate for such implementations.
Bluetooth	Moderate	Moderate	Moderate	Moderate	Available in most of today's smart devices but due to low range and auxiliary technique.
BLE	Low	Low	Moderate	Moderate	Promising technology potential for short-range deployments. Need for hybrid and stand-alone experimentation
ZigBee	High	Low	Moderate	Moderate	Yet to be explored standard though implemented discretely for hybrid solutions, carries the potential for short- and long-range applications.
RFID	Low	Low	Low	High	Promising standard for short-range identification. The potential candidate for meter level localization in hybrid solutions
UWB	Low	Low	Moderate	High	Applicability to short-range scenarios due to low energy and high bandwidth characteristic, preferable with cooperative positioning
Cellular	High	High	High	Low	Unreliable measurements over time. High infrastructure cost
Sound	Low	Moderate	Low	High	Effective for LOS conditions, the potential for combination with WiFi, Bluetooth and ZigBee style communications
Magnetic Field	Moderate	High	High	Moderate	Varying characteristic with uncertain measurements, additional hardware cost.
Visible Light	Moderate	High	Moderate	Moderate	Upcoming constructions with energy-saving establishments will have technologies such as LED as a must; moreover, visible light is one of the basic needs.

Occupancy estimation is a critical element in an Indoor environment due to its potential use in controlling electrical systems and devices such as lighting, air-conditioning and ventilation. It also has a high potential towards improving the performance of demand-driven applications that in-turn requires fine-grained occupancy information to optimize the trade-off between energy consumption and user comfort. Occupancy estimation over varying methods and technologies has been researched over the last decade.

Table 3 shows the different technologies used for occupancy estimation and the level of occupancy [10]. However, it is not easy to procure sensory data and estimate the occupancy information accurately due to the hardware cost and deployment challenges.

Table 3: Various Occupancy Estimation Approaches

Sensor Type	Accuracy	Intrusiveness	Cost	Level of Occupancy
PIR	Low	Low	Low	Presence, Location
CO2	Low	Low	Low	Presence, Location, Count, Activity
Camera	High	High	High	Presence, Location, Count, Activity, Count, Tracking, Identity
Ultrasonic	Low	Low	Low	Presence, Location
Vibration	Medium	Low	Low	Presence, Location
Sound	Low	Medium	Low	Presence, Location
Environmental	Medium	Low	Low	Presence
Wearable	High	Low	Medium	Presence, Location, Count, Activity, Count, Tracking, Identity
Tag-Based	High	Low	Low	Presence, Count, Location, Identity
Smart device-based	High	High	High	Presence, Location, Count, Activity, Count, Tracking, Identity
Network activity	Medium	High	Low	Presence, Location, Count, Activity, Identity
Electricity usage	Medium	Low	High	Presence, Location, Activity

Indoor navigation plays a key role to reach various locations in an indoor environment such as restaurants, restrooms, and grocery shops based on the user's requirements. Also, the constraints on navigation vary across different users. Typically, people prefer to use escalators than stairs when they are carrying weights. Likewise, elderly people prefer to use lifts rather than stairs. Similarly, people evacuation routes are important in indoor environments. Evacuation simulation is mainly used for fire evacuation and other emergency situations. People have different personalities (e.g. walking speed, personal memory and psychological condition) which may influence their navigation choices. They also behave differently in different social contexts and as a result, they may have different expectations on how other people around them will move in response to their movements. In panic situations, they try to move faster than in normal situations, and interactions with others become physical in nature. People become nervous, which sometimes leads to blind actionism and often leads to pushing. Limited points of exit and lack of complete information of the locations can lead to situations of disaster. Therefore, it is desirable to make navigation decisions by considering the users' requirements and preferences and further computing evacuation routes by considering users behaviour.

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6.5 Precision Agriculture

This activity falls under the umbrella of "Technologies for Precision Agriculture" with a focus on "generating real-time soil property maps & controlled release of fertilizers" for low-rainfall regions such as the Rayalaseema region of Andhra Pradesh. India and other countries of the world facing food security issues and require tools to assist cultivation, measure yields and reduce risks in agricultural operations. Soil fertility, the capability of the soil to support plant production, is of prime importance and maintaining soil fertility has been a major concern of agriculturalists. Moreover, soil fertility monitoring and management are important for sustainable food production and maintenance of the environment.

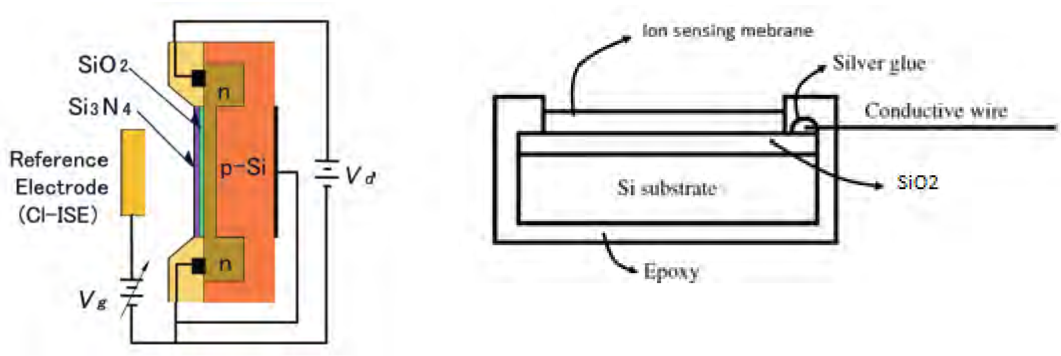
Over ages, the natural cycling of soil fertility (through soil nutrients) has occurred from the soil to plants and animals, and then back to the soil. Complex nutrient cycles involve a range of physical, chemical and biological processes. The lack of essential soil nutrients hinders plant growth and severely limit crop yields [1]. The plant productivity and quality can be improved by adopting ideal fertilizer management. At the same time, sub-optimal or excessive use of fertilizers leads to severe environmental damage in the areas of intensive crop production. To optimize the fertilization practices, it is therefore essential for plant producers to assess the nutrient availability in their soils as well as to monitor and correlate their availability with the growth of the crops. Accurate, cheaper, and more easily accessible methods for plant and soil mineral analyses are required to enable this.

For an ideal precision agriculture system, soil property monitoring sensors are located in direct contact with, or close to, the ground and integrating with other sensors, signal conditioning and processing elements, and changes the fertilizers application rate by efficiently controlling the nutrient delivery [2]. Most of the on-the-go sensors and the processing units require sufficient time for measurement, integration, adjustment on the field and the variable rate fertilizers require additional information such as the yield potential of the crop.

Using real-time, on-the-go sensors with controllers, a map-based approach may be more desirable because of the ability to collect and analyze the data, make prescriptions, and conduct the variable rate application in more steps [3]. In addition, multiple layers of information such as yield maps and other types of imagery can be pooled together using GIS software to manage and process spatial data. Based on the developed soil property maps in small scale farming, efficient delivery of the nutrients can be attempted.

The prime objective of the current activity is to generate soil property maps using on-the-go soil property (soil pH, soil temperature, soil moisture, soil nutrients) sensor networks. Using the developed soil maps, precision techniques for efficient nutrient delivery mechanisms will be explored and demonstrated. An integrated technology solution using real-time soil maps for controlled fertilizer release for precision agriculture is being proposed.

For generating soil maps for precision agriculture, a host of sensors and the integration in the form of a network are required [4]. Many types of soil property measurement techniques are developed for precision agriculture such as Electrochemical, Electromagnetic Optical & radiometric, acoustic, mechanical and X-ray based techniques [5]. Among all the techniques, Electrochemical sensors provide the most important type of information needed for precision agriculture — soil nutrient levels and pH [5]. As conventional ion-selective electrodes used in the lab measurements of pH are fragile, transistor based pH sensors will be investigated. Among them, Ion Sensitive Field Effect Transistor (ISFET)-based pH sensors are commercially available [6]. As the ISFET based pH sensors are expensive, less reliable in terms of a number of usages and ambient light sensitive, Extended Gate Field Effect (ExFET) configurations will be studied [7]. ExFET uses conventional MOSFET in addition to the thin-film sensor head attached to the gate (Figure 8). The sensor head is usually a metal-oxide thin film capable of detecting the pH of the electrolyte/soil.



(a) (b)

Figure 8: Cross sectional view of (a) ISFET pH sensor and (b) ExFET sensor head

Various metal oxides are the potential candidates such as ZnO, TiO_2 etc. We would like to consider both the materials in a thin film, nano sheets, nano rods and porous material form. Their structures will be defined and fabricated using state-of-the-art thin film deposition and lithography techniques. The effect of various substrates will also be considered. The reference electrode will also be deposited on the same substrate as that of the active region. The fabricated pH sensor will be tested against the standard pH sensors for soil pH measurements. A temperature sensor will also be integrated with the pH sensor for nullifying any drifts in pH due to temperature variations. Alongside, soil macronutrient sensors will be developed independently using the similar ExFET structure with ion selective coatings on the sensing membrane so as to selectively detect N, P and K in the soil. Finally, the integration of all the sensors onto a single substrate and interfacing with a microprocessor will be attempted (Figure 9).

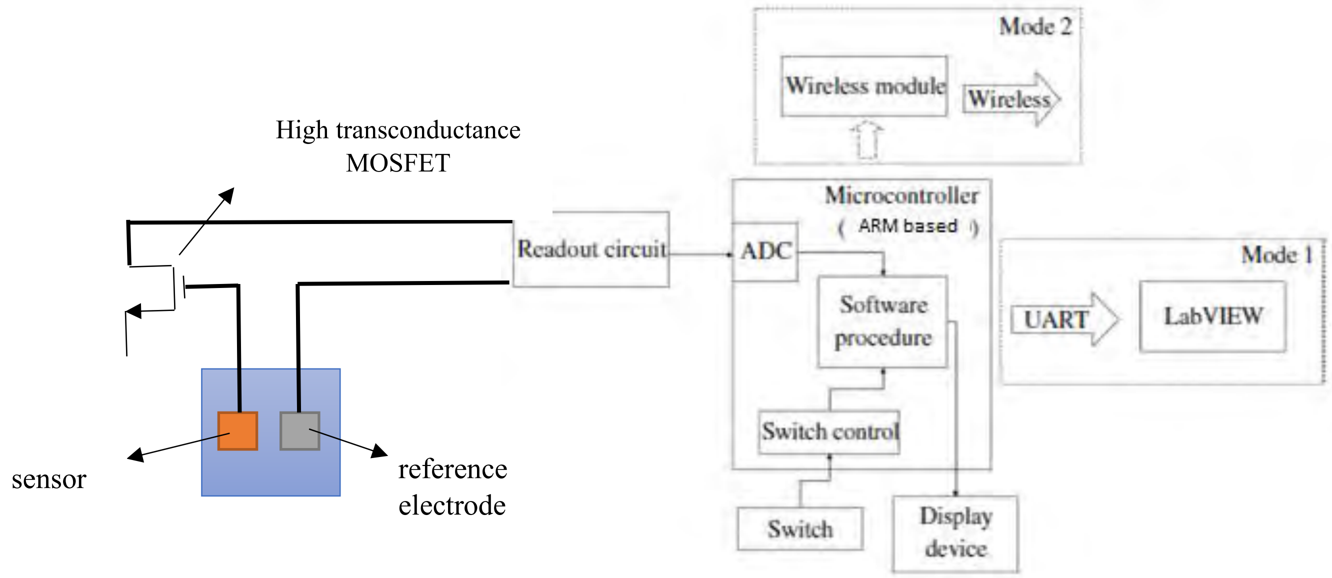


Figure 9: Block diagram of a typical sensor node. Fusion of multi sensors with processing elements is targeted

Alternatively, a portable X-ray based fluorescence measurement system will be developed to detect the micro and macro nutrients to augment the developed electrochemical sensors [8]. To this end, we propose to develop a digital platform to reduce the time involved in the entire process of farming thereby improving the yields and making farming viable while minimizing environmental pollution. The work includes a) development of a novel hybrid wireless sensor architecture to automate the process of data collection regularly from fields at an affordable cost, b) development of data analytics methods for processing information collected from fields for water management, crop growth monitoring, and field analysis, c) development a digital platform spatial soil property mapping for information dissemination among farmers and other stakeholders, as well as to motivate next generation young tech-savvy rural Indians for agriculture work, d) test and demonstrate the effectiveness of the above digital platform through real world pilot trials. Based on the sensors data across a small-scale farm, soil property maps will be developed. Using the real-time spatial soil property maps, an important technology application such as controlled nutrient delivery will be demonstrated.

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6.6 High Precision Smart Manufacturing Systems for PPT Applications

Demands for increasing precision in the manufactured products have been evolving in almost all industrial sectors ranging from planes, trains, automobiles, printing electronics and optical surfaces, scientific and analytical instruments, medical and surgical tools, and traditional and renewable power generation. At the root of all these technologies are increasingly advanced machines and controls. Precision engineering has also been promoted as the pursuit of determinism in manufacturing processes. In this view, the lack of precision that often comes from a lack of repeatability is considered a lack of attention to casual effects within the process. Further, advanced manufacturing technologies like Metal Additive Manufacturing (AM) have been receiving wide adaptability recently due to their unlimited design freedom to manufacture the customized components for various applications. If AM is going to gain a significant market share it must be developed into a true precision manufacturing method. Precision tolerances have been achieved with metal Additive Manufacturing, but this has been less by following the principles of precision engineering. It is very important to address the problems related to precision manufacturing in conventional and advanced manufacturing processes for the benefit of the Indian industry.

In the present vertical, Precision Manufacturing, efforts will be invested to address various problems related to the areas - precision additive manufacturing, precision machining, and precision finishing as shown in Figure 10. A smart hybrid precision wire arc additive manufacturing machine is proposed under the area of precision additive manufacturing.

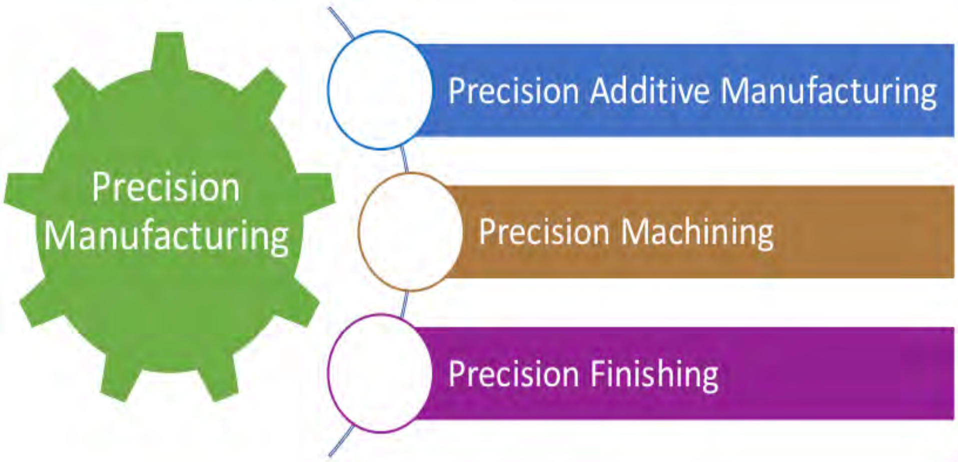


Figure 10: Areas focused under precision manufacturing

Wire arc additive manufacturing is a novel variant of additive manufacturing to manufacture large size customized products. However, the repeatability of the product is the major issue for the commercialization of the process. This is due to various problems like dimensional inaccuracies, non-homogeneous metallurgical and mechanical properties, and the distortions and residual stresses in the products. To address these problems and to commercialize the WAAM process a machine learning-based feedback control system will be developed. Next, it is proposed to develop a methodology to design and manufacture the patient-specific implants in very little time economically under the area of precision additive manufacturing. The present timelines for the end-to-end development of medical implants are prohibitively high as they are currently designed manually. Further, the methodology currently followed to manufacture the defectless implant is expensive and time consuming as it involves material wastage due to multiple experiments. To address these problems, the automated design of patient-specific medical implants will be developed following the deep learning technique. Subsequently, the digital twin of additive manufacturing to minimize the manufacturing time and cost, as well as to improve the product quality will be developed.

Under the area Precision Machining, the development of high precision auto wheels for electric vehicles is proposed to help the electric vehicle manufacturing sector. While high-performance, light-alloy wheels can greatly enhance a car's appearance and individuality, their manufacture requires a high degree of machining quality. In order to achieve the necessary accuracy, one stops the machining process at various stages to manually measure key dimensions. This is a time-consuming and error-prone practice. Manually calculating and updating tool offsets, combined with remachining, meant that processing a complete wheel will take several minutes. Focusing on process setting and in-process control, the proposed project will focus on improved product quality and reduce the overall cycle time. The accuracy of the finished product will be increased using an advanced probing system, as the position of each part can be checked before any machining takes place. The real-time size/position of key features can be fed back to the CNC control automatically, allowing tool path offsets to be updated if necessary. As a result, the manual, time-consuming and error-prone methods previously used to control the process are no longer required.

The three-dimensional products in the aerospace, medical, and defense fields require ultraprecision machining to fulfil their functionalities. Further, the material ranges from easy to machine soft materials to difficult to machine hard materials. To address these requirements, we are proposing to develop indigenous smart machines for the various finishing technologies under the area of Precision Finishing. Various finishing technologies addressed here include Ultra Precision Mechanical Micromachining, Ultra Precision Laser Micro and Nano Polishing, Smart Hydrodynamic Polishing, Electrochemical Spark System for Freeform Metallic Structures, Micro Abrasive Flow Finishing, Smart Hybrid Drag Mass Finishing, and Smart Hybrid Chemo-Magnetorheological Abrasive Finishing.

These technologies form the backbone for the development of GPS and non-invasive remote sensing equipment. The focus of the hub is also laid in the development of application-based products leveraging the current remote sensing technologies and the vast data resources available in the country. Software and Embedded platform-based products addressing the potential problems of local relevance across all the 9 categories of the identified product frameworks are envisaged.

7. Target Beneficiaries

Translation of research output from the laboratory to functional technological products and services is an important goal of any research program. The recent boom in global research investments in precision and positioning technology programs shows our trust in their potential to generate crucial technologies of a not too distant future. Furthermore, a long-term vision is critical in such evolving fields where solutions to the gaps in technologies will almost certainly come from unexpected and unexplored ideas. The hub aims to strike a healthy balance between the two approaches.

The primary focus of this research hub is to maximise the translation of research ideas into technologies. In this direction, the hub will engage with local industries from the early stages. This early engagement of industries will not only help in directed research and development but also help in looking for a solution holistically. This would enable bringing all the themes under the hub under one roof for enabling a solution. IIT Tirupati has a large pool of young students at various levels. These students will be engaged in the research, development and translation of research ideas into products. One of the key outcomes of the technology innovation hub is to develop indigenous technology. In most of the conventional research that is carried out in frontier areas of science, the use of high technology devices and high subsystems, a large chunk of the equipment and components are mostly imported. Also, during the execution of research work, several innovative ideas come up. There are two fronts on which we envisage work in technology development, which include:

1. Development of high-end test and measurement instruments, systems, and components for enabling reduction on reliance on imported systems – driving towards "AatmaNirbhar Bharat" and supporting the Make-In-India initiative.
2. Translation of laboratory-scale experiments into portable equipment, algorithms and systems for commercial production.

We aim to create an ecosystem of engineers and technology developers who will bridge the gap between academia and industry. The TIH at IIT Tirupati will provide the support system to translate novel ideas into mature technologies through innovation through the TBI (Technology Business Incubator). Building blocks are envisaged for supporting innovation and the start-up ecosystem. The targeted beneficiaries are listed below:

- Government Agencies and Public Sector Units
- Established Industry Majors
- Start-up Companies

- Mentoring through pre-incubation
- Students and Industry Professionals
- Targeted training programs for innovation
- Focused internships
- Embedded innovation opportunities for students and industry professionals
- Grand challenges in key technology areas
- Academic Institutions

The most important contribution of the Hub would be to share the knowledge gained in understanding of Positioning and Precision Technology areas by the collective group of researchers with the public in the form of publications, reports and products. The Hub will also collaborate with Indian start-ups that are implementing these standards in their products. From the research and development work taken up by the proposed hub, there is a wide scope for start-ups in the areas mentioned in the product framework.

Based on initial interaction among the faculty the following **21** initial product ideas along with target beneficiaries, projected cost, timelines, market potential, outcomes and risks are listed. The initial round of discussions is completed with all participating agencies and interested business partners and stakeholders. A detailed version of these initial product ideas along with other ones that will be submitted in due course will be further scrutinized by a technical committee constituted by the Board of INiF and decisions will be made on support. The product ideas span across all the 9 frameworks mentioned earlier in this proposal. A summary of the ideas is included in a tabular format under each product. It includes details of the proposed products to be developed under the following heads:

a) Product Title
b) Practical Problem it solves
c) Target Beneficiaries
d) Industry Collaborators (Indian/MNC/PSU)
e) Unique Selling Point
f) Timeline
g) Academic Collaborators
h) Total Funding Required
i) Projected Revenue Generation
j) Gantt Chart

The following subsections show details of products under each product framework.

7.1 Quantum Technologies for Positioning

Product – 1	Trapped ion atomic clock
Practical Problem That It Solves	Positioning and navigation (GPS), timing synchronization of mobile networks and ISPs (Internet Service Providers), position based (mobile) services, communication
Target Beneficiaries	The primary target beneficiaries are as follows: 1. Global positioning systems (GPS) for civilian (**NaVIC**) and defense purposes 2. Defense services (warhead delivery, secure communication and navigation) 3. Timing devices for ISPs (internet service providers) 4. Timing devices for mobile networks and mobile communication 5. Network synchronization 6. Disaster management through GPS 7. Financial time stamping 8. Mobile manufacturers 9. Transportation 10. Power stations, power networks and power grids 11. GPS IoT enabled Smart city applications 12. Mining, exploration and earth geodesy 13. VLBI (Very Long Baseline Interferometry) 14. Deep space navigation and space geodesy
Industry Collaborator(s) with classification (Indian/ Multinational/PSU)	1. LEOS Unit, ISRO Peenya Bengaluru 2. XILINX Corporation (Multinational) 3. New Age Instruments & Materials Pvt. Ltd., Haryana
Unique Selling Point	State-of-the-art precision, and a target frequency uncertainty of a few parts in 10^{-16} (Minimum target frequency uncertainty at a few parts in 10^{-15}) for precision timing devices

Product – 1 (Continued)	Trapped ion atomic clock
Timeline in Months	• Design and construction of a linear Paul trap for trapping $^{40}Ca^{+}$ ions – 0-6 months • Development of stable RF and DC electronics for trapping ions and minimizing ion micromotion – 6-12 months • Construction of a high finesse cavity for ensuring a narrow linewidth clock laser – 0-10 months • Establishment of laser locking (frequency stabilization) to stable reference cavities – 12-18 months • Develop a sub 1 Hz linewidth laser for clock spectroscopy at 729 nm – 18-24 months • Perform Allan deviation measurements on clock laser stability – 24 – 30 months • Setup beat-note measurements with an optical frequency comb – 30 – 36 months • Characterize the clock laser frequency in terms of first and second-order frequency shifts due to micromotion, laser intensity, ambient magnetic field, polarizability, black-body radiation, etc. – 36 – 54 months • Perform Allan deviation measurements on clock frequency – 36 – 54 months • Perform error-budget calculations on observed clock frequency – 50 – 60 months
Academic Collaborators (Indian/Foreign) with full Designation	• Dr. Arijit Sharma, Asst. Professor, IIT Tirupati • Prof. Sadiq Rangwala, LAMP Group, RRI Bengaluru. • Prof. Dmitry Budker, Matter-Antimatter Group, Helmholtz-Institut Mainz, Germany and Dept. of Physics, UC Berkeley, CA, USA • Dr. Umesh R. Kadhane, Assoc. Professor, Dept. of Physics, IIST Trivandrum, Kerala • Dr. M. S. Giridhar, LEOS Unit, ISRO, Peenya, Bengaluru, • Dr. Umakant D. Rapol, Assoc. Professor, IISER Pune • Dr. Subhadeep De, Assoc. Professor, IUCAA Pune, • Dr. Amar Vutha, Asst. Professor, Dept. of Physics, University of Toronto, Toronto, Canada • Dr. Subhasis Panja, Senior Scientist, NPL, New Delhi, • Mr. Subhamoy Chakraborty, Research Scholar, IIT Tirupati
Total funding Required	INR 1.50 Cr (Equipment: Laser systems (for ionization, cooling and spectroscopy sub-1Hz linewidth Clock laser system at 729 nm with 500mW output power referenced to an optical cavity - INR 1.2 crores Mirrors, lenses, waveplates for 729 nm, 866 nm, 854 nm, 850 nm, 397 nm and 393 nm and associated optomechanics - INR 0.20 crores, Vacuum pumps (ion pump) - INR 0.10 crores)
Number of Patents	1
Projected Generation	INR 20-25 crores over 10 years (actuals depending on how much funding is received for the project)

Gantt Chart

Task	**Yr 1**	**Yr 2**	**Yr 3**	**Yr 4**	**Yr 5**
Procurement and installation lasers for Calcium ($^{40}Ca^{+}$) ion cooling and clock transition	■				
Development and construction of the ion trap and vacuum system for atomic clock	■	■			
Cooling and trapping of Calcium ($^{40}Ca^{+}$) ions		■			
Development of high finesse cavity for stabilization of narrow band laser for clock transition		■			
Setting up of optical frequency comb for absolute referencing of clock laser frequency		■	■		
Development and characterization of clock laser using a frequency comb		■	■	■	
Fractional uncertainty measurements and error budgeting			■	■	■
Dissemination of knowledge and results; commercialization of technology			■	■	■

7.2 Spectroscopy

Product – 2	Cavity Ring-Down Spectrometer as a non-invasive sensor for position based detection of harmful pollutants
Practical Problem That It Solves	Precise location-based spectroscopic detection of hazardous chemicals, pollutants and AQI (Air Quality Index) monitoring. The device is a non-invasive sensor that shall be geo-tagged for continuous real-time position-based monitoring of the environment. The product shall aid in monitoring, record and collecting data in real-time from potential pollution hotspots using current position-based devices (GPS). Thus, it shall help in mitigating air pollution at the national and global level by reducing damage to life and property through position-based pollution monitoring and control. The costs of urban air pollution amount to 2% of gross domestic product (GDP) in developed countries and 5% in developing countries. The numbers work out substantially higher if we account for the loss of GDP due to harmful chemicals such as Arsenic and Mercury that pollute land and water bodies. These hazards can be substantially mitigated through the use of position-based sensors based on CRDS (Cavity Ring Down Spectroscopy).
Target Beneficiaries	The primary target beneficiaries are as follows: 1. Environment (land, water and air) pollution monitoring and control bodies (Pollution Control Boards) of different states and union territories. 2. Air Quality Index (AQI) monitoring stations 3. Major traffic zones and intersections 4. Cement, Chemicals and Fertilizer industry 5. Petroleum and petrochemicals industry 6. Hospitals and Health care centers 7. Paint and dye industry. 8. Mining and ore processing industries.
Industry Collaborator(s) with classification (National /Multinational/PSU)	1. Advanced Photonics, Mumbai (National) 2. New Age Instruments & Materials Pvt. Ltd., Gurgaon - 122001, Haryana, INDIA (National) 3. TESTRIGHT Nanosystems Pvt. LTD., New Delhi (National) 4. ATOS Instruments Marketing Services, Bangalore (National) 5. Sandvic Components, New Delhi (National)

Product – 2 (Continued)	Cavity Ring-Down Spectrometer as a non-invasive sensor for position based detection of harmful pollutants
Unique Selling Point	1. GPS-enabled pollution monitoring system for Class 10 air pollutants and hazardous chemicals like (As) Arsenic, Aerosols and (Hg) Mercury. 2. Enables rapid identification of pollution hotspots. 3. System compatible with vapour and liquid-based target samples. 4. Portable nature, lightweight, with a small spatial footprint. 5. State-of-the-art precision, detection sensitivity down to part-per-billion (PPB, 1 part in 10^9). 6. Capability to measure multiple pollutants in real-time. 7. The entire unit shall be put in a 19-inch rack and could be positioned anywhere using drones and tracked in real-time using GPS. 8. A position-based network of these sensors can be created to enable accurate data acquisition and data streaming in real-time to identify pollution hotspots. 9. Complements efforts undertaken for Web-based Geo-Spatial Tools for Pollution Monitoring and Management in Product 13.
Timeline in Months	● Procurement and installation of equipment such as CW Ti: Sapphire laser systems, Manpower recruitment – 0-12 months ● Technology Development (Developing optical sensor for Cavity Ring-Down Spectrometer, developing experiment and benchmarking observations)– 0-48 months ● HRD and skill generation – 0-60 months ● Dissemination of results and commercialization of product/technology – 48-60 months
Academic Collaborators (Indian/Foreign) with full Designation	1. Dr. Arijit Sharma, IIT Tirupati 2. Dr. Reetesh Kumar Gangwar, IIT Tirupati 3. Dr. Suresh Jain, IIT Tirupati 4. Dr. Oded Heber, Weizmann Institute of Science, Israel 5. Prof. Alika Khare, IIT Guwahati 6. Dr. L. N. Rao, IISc Bangalore 7. Prof. Rajesh Srivastava, IIT Roorkee
Total funding Required	Rs. 1.5 Crores for equipment under Technology Development
Number of Patents	1
Projected Generation	Rs. 20-25 crores over 10 years (actuals depending on how much funding is received for the project). This includes saving of loss of life and damage to property, thus directly impacting our nation's GDP (gross domestic product).

Gantt Chart

Target	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Procurement and installation of equipment such as CW Ti: Sapphire laser systems, Manpower recruitment					
Technology Development Developing optical sensor Cavity Ring Down Spectrometer, developing experiment and benchmarking observations Development of various absorbing media with varying concentrations of species Spectroscopy kit development for education					
HRD and skill generation					
Dissemination of results and commercialization of product/technology					

7.3 Precision Agriculture

Product – 3	Spatial soil property mapping using on-the-go-soil sensors for Precision Agriculture
Practical Problem That It Solves	1. Spatial soil property mapping for precision agriculture 2. Indigenous technology development of soil sensors for micro and macronutrient detection 3. Technology application of soil nutrient maps for precision Agriculture: Intelligent delivery mechanisms
Target Beneficiaries	Agriculture Agencies and farmers
Industry Collaborator(s) with classification (Indian /Multinational/PSU)	1. Honeywell (Multi-national) 2. Nirvapate (Indian) 3. Zuari Agrochemicals (Multi-national) 4. Elvikon India (Indian)
Unique Selling Point	1. Creation of real-time soil property maps combining ICT and sensor development 2. Integrated solution for soil property quantification 3. Portable, low-power, field operable soil property sensors 4. The intelligent nutrient delivery mechanism based on the developed soil property maps
Timeline in Months	60 months
Academic Collaborators (Indian/Foreign) with full Designation	**<u>Indian:</u>** 1. Dr. N. N. Murty, Electrical Engineering, IIT Tirupati 2. Dr. Vijaya Kumar G, Electrical Engineering, IIT Tirupati 3. Dr. Prasanth V, Electrical Engineering, IIT Tirupati 4. Dr. Vikram Kumar P, Electrical Engineering, IIT Tirupati 5. Dr. Venkata Ramana B, CSE, IIT Tirupati 6. Dr. Madan Mohan A, Mechanical Engg, IIT Tirupati 7. Dr. Ravi Sankar M, Mechanical Eng, IIT Tirupati 8. Dr. Anand TNC, Mechanical Engineering, IIT Madras 9. Prof. Ravikrishna RV, Mechanical Engg, IISc, Bangalore **<u>International:</u>** 1. Dr. Swagat Kumar, Dr. A Behera, and 2. Prof. Yonghu-ai Liu, EdgeHill University, UK, **<u>Industry Collaborator:</u>** 1. Dr. Sudhanand Bandi, ZACL-ADL, Tirupati

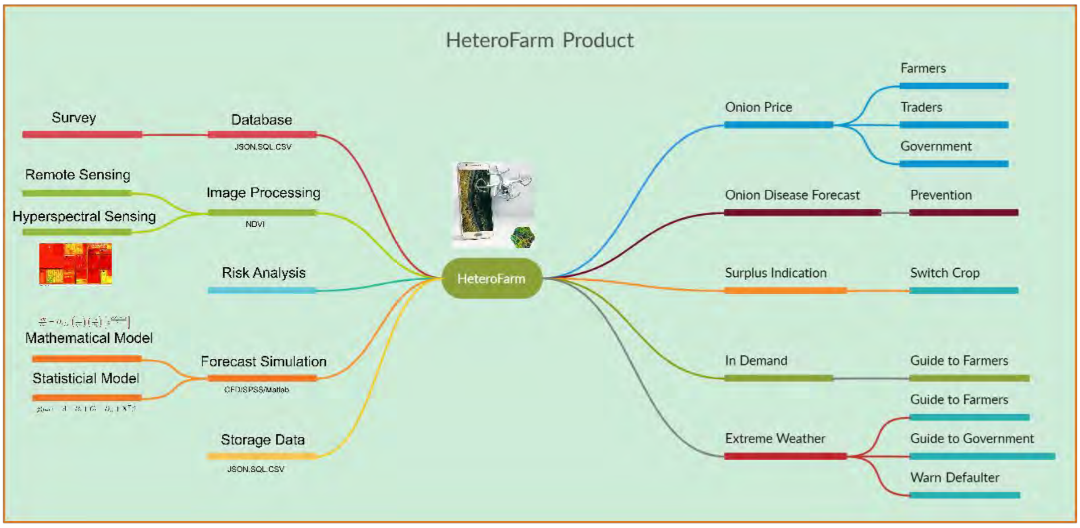
Product – 3 (Continued)	Spatial soil property mapping using on-the-go-soil sensors for Precision Agriculture
Total funding Required	1. Sensor fabrication (e-beam evaporator) : Rs. 15 Lakhs 2. Sensor characterization (ellipsometer): Rs. 30 Lakhs 3. PCB prototyping machine: Rs. 12 Lakhs 4. SMU, x-ray sources: Rs. 8 lakhs 5. Electrical measurement units (function generators, power supplies, oscilloscopes): Rs. 15 Lakhs 6. Commercial sensors, drones for aerial imaging: Rs. 10 lakhs 7. Reference Electrodes: Rs. 2 Lakhs 8. Consumables (substrates, chemicals, etc.): Rs. 5 lakhs 9. Contact Angle measurement system (for the reliability of sensors under soil solutions): Rs. 13 Lakhs 10. Field Imaging Camera and accessories: Rs. 12 Lakhs 11. Micro Injection moulding: Rs. 15 Lakhs 12. Micro extruder: Rs. 15 Lakhs 13. Soil property testing charges: Rs. 3 Lakhs **Total: Rs. 150 Lakhs**
Number of Patents	At least 4 patents are envisaged
Projected Generation	Rs. 20 Crores (10 years)

Gantt Chart

Task	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
procurement of equipment, field visits for requirements	■				
Simulation studies, fabrication and characterization of soil sensors, field testing, development of ICT platforms, development of nutrient delivery mechanisms		■	■		
Sensor integration and fusion, process optimization by field trials, development of controlled nutrient delivery mechanism.		■	■		
Field deployment and integration of the sensors with the delivery systems, soil map creation			■	■	
Integration of technology components and demonstration, and technology transfer				■	■

Product – 4	HeteroFarm-Geospatial Crop Management Solution
Practical Problem That It Solves	Given the soil type, seed rate, weather and other parameters • to predict a suitable crop for the region • to predict the productivity of a particular crop During Initial Crop Growth: • Quality assessment of the sapling and prediction of crop using weather forecast model, remote sensing data, image processing and hyperspectral imaging Crop Yields Monitoring and Predictions: Using remote sensing data, image processing and modelling • Quality assessment and monitoring of the crop • Predictions and Pilot study Expected Yields at every stage: • Predictions and Risk analysis Web and App Development: • Guidance about the amount of yield, crop diseases, storage, switching to different crops
Target Beneficiaries	Farmers, district agricultural officers, crop traders and vendors, research scientists working in agricultural engineering, commodity exchange, and various state and central agricultural ministries.
Industry Collaborator(s) with classification (Indian/ Multinational/PSU)	ICAR, NCFC, Venkateswara Agricultural College. ICAR Onion and Garlic Research centre, NCDEX, ICAR-IASRI, Crop Insurance Companies, CropX, RRSC
Unique Selling Point	Unified software solution for crop Management for given soil or a given crop. Quality assessment, monitoring, predictions and risk analysis through Spatio-temporal data modelling and instruments
Timeline in Months	60 Months
Academic Collaborators (Indian/Foreign) with full Designation	1. Dr. Panchatcharam Mariappan, IIT Tirupati 2. Dr. Girish Kumar Rajan, IIT Tirupati 3. Dr. Ananya Lahiri, IIT Tirupati 4. Dr. Ishapathik Das, IIT Tirupati 5. Dr. Roshan Srivastav, IIT Tirupati 6. Dr. Ramakrishna Sai Gorthi 7. Prof. M. V. S. Naidu, Sri Venkateswara Agricultural College 8. Dr. Hukum Chandra, National Academy of Agricultural Science 9. Dr. Saranya Kshatriya, IIT Tirupati 10. Dr. Kavita Sutar, CMI
Total funding Required	Rs. 1.5 Crores (Equipment: Hyperspectral Imaging Camera and High-Quality Camera, Field Spectrometer, Drones and other accessories: Rs. 0.75 Crore, Satellite Image data Purchase and data collection from NASA, Planet.com and ISRO: Rs. 0.75 Crore)
Number of Patents	2

Projected Revenue Generation	Rs. 20 Crores (10 Years)



Gantt Chart

Target	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Literature Survey, Geological Crop Survey, Model Development, Parameter Identification	■				
Prediction Algorithm Development using remote sensing data and other relevant information, Quality Assessment	■	■	■	■	
Crop yield prediction, risk analysis, crop monitoring app development, Pilot study	■	■	■	■	■
Web-Framework frontend, backend development and App development, Repeat of Beta Version and study of market value				■	■
The release version of the product and commercialization				■	■

Product – 5	Remote sensing of atmosphere using Daytime Raman Lidar
Practical Problem That It Solves	1. Atmosphere remote sensing round the clock for predicting extreme weather events (i.e. disaster assessment). 2. Quantification of water vapour content in the atmosphere using daytime Raman Lidar
Target Beneficiaries	Meteorological departments
Industry Collaborator(s) with classification (Indian/ Multinational/PSU)	NARL, Gadanki
Unique Selling Point	1. Solar-blind UV Raman backscattered signal detector and electronics assembly for the daytime operation of Lidar. 2. Complete technology solution for Lidar assembly for atmosphere remote sensing. 3. QWater vapour detection in the atmosphere and quantification under daytime conditions.
Timeline in Months	60 months
PERT Chart	0-12 months: Equipment procurement, Detector simulation studies 12-24 months: Detector fabrication, characterization studies, designing of gain stages, Comparing the performance with PMTs, Developing UV detectors for other wavelengths 24-36 months: Developing UV detectors for other wavelengths, Testing 36-48 months: Assembly, testing 48-60 months: Integration and commissioning, technology transfer
Academic Collaborators (Indian/Foreign) with full Designation	1. Dr. Y Bhavani Kumar, NARL Gadanki 2. Dr. G. Vijaya Kumar, Electrical Engineering, IIT Tirupati. 3. Dr. N. N. Murty, Electrical Engineering, IIT Tirupati 4. Dr. Prasanth V Electrical Engineering, IIT Tirupati 5. Dr. Vikram Kumar P, Electrical Engineering, IIT Tirupati
Total funding Required	Photodetector QE equipment : Rs. 20 Lakhs Photon counting electronics and optics : Rs. 30 Lakhs Optical sources : Rs. 25 Lakhs Lithography : Rs. 70 Lakhs Consumables : Rs. 5 Lakhs **Total:** Rs. **150 Lakhs**
Number of Patents	At least 2 patents are envisaged
Projected Generation	Rs. 10 Crores (10 years)

7.4 Precision Manufacturing

Product – 6	Precision Guided Hydrodynamic Polishing Process for Metal and Ceramic Nano Surfaces
Practical Problem That It Solves	1. GPS lens require ultra-precision finishing, mostly these precision systems are imported 2. GPS components require ultra-polished surfaces for precision integration (Precision assembly), these are expensive. 3. PlanPolishing of advanced ceramic (SiN, SiC) sensors used in Missile warheads (DRDO) etc should withstand at various temperatures 4. Most of the precision machines require ultra-precision guideways along with positioning sensors. India needs this type of advanced technologies (Mostly imports). 5. High precision components in satellite navigation systems undergo high-temperature differences along the trajectory. So these are made with ceramics with high polishing requirements (50 nm).
Target Beneficiaries	1. DRDO, Defense services (Navigation) 2. ISRO (VSSC, Thiruvananthapuram) 3. Interferometry and Metrology Companies
Industry Collaborator(s) with classification (Indian/ Multinational/PSU)	1. APJ Abdul Kalam Missile Complex (RCI), Hyderabad 2. ISRO, Trivandrum 3. DRDL, Hyderabad 4. GTRE, Bangalore
Unique Selling Point	1. Global positioning systems require many precision components 2. Most of the 3. Hydrodynamic Polishing is a unique process that has patents possibility 4. Most of the GPS precision components are imported. So this process development may reduce imports (*Make in India*). 5. Because of soft abrasives, no scratches will be observed so sub nano surface can be achieved (<1.0 nm) 6. Not only the machine technology but here novel cutting tool technology also can be patented and commercialized to me India self resilient (*Aatma Nirbhar Bharat*)
Timeline in Months	36 months
PERT Chart	0-6 months: Design of the Hydrodynamic Finishing System 07-15 months: Procurement of various components 16- 24 months: Development of Hydrodynamic Finishing system 25-36 months: Checking of sub nano finishing capability and patenting. Then demonstration to various suitable industries and research laboratories.

Product – 6 (Continued)	Precision Guided Hydrodynamic Polishing Process for Metal and Ceramic Nano Surfaces
Academic Collaborators (Indian/Foreign) with full Designation	1. Dr. Mamilla Ravi Sankar, Mechanical Engineering, IIT Tirupati 2. Dr. Subba Reddy, Mechanical Engineering, IIT Tirupati 3. Dr. Ramesh Singh, Mechanical Engineering, IIT Bombay
Total funding Required	1. Stepper/Servo Motor based X-Y-Z stage: Rs. 8 Lakhs 2. Base Machine Structure: Rs. 8 Lakhs 3. Rotary and reciprocating attachments: Rs. 9 Lakhs **Total:** Rs. **25 Lakhs**
Number of Patents	At least 2 patents are envisaged
Projected Generation	Rs. 5 Crores (10 years) ❖ Selling the Precision Guided Hydrodynamic Polishing (PGHP) Processes to research laboratories and industries ❖ SHP System technology transfer royalty charges to various Industries (Year wise Royalty charges) ❖ Selling of novel bonded and unbonded abrasive cutting tools to finishing companies and Indian research labs ❖ Consultancy finishing work from various auxiliary organizations who require finishing on their advanced materials (This can start after machine building at IIT Tirupati from 3rd year itself)

7.5 Natural/Built/Energy Resource Management

Product – 7	Cost Effective, Robust, and Scalable Platform to enable Location Based Services for Indoor Environments.
Practical Problem That It Solves	There is a great need for a wide range of location-based services to help in our day-to-day lives and mission critical scenarios as well, for both commercial and residential spaces. This requires a robust, reliable, and scalable yet cost effective Indoor positioning system to operate in normal conditions as well as in emergency situations where the positioning infrastructure may be damaged. The platform could serve as a universal platform by offering well defined interfaces to build a wide range of location-based applications. It consists of different hardware and software components such as proximity, radio, acoustic, light, infrared, vibration and magnetic sensors, navigation hardware, mapping hardware, software to receive, store, and analyze data, dashboards.
Target Beneficiaries	Airports, Hospitals, Logistics, Shopping Malls, Educational Institutes, Public and Private Offices and Others.
Industry Collaborator(s) with classification (Indian/ Multi national/PSU)	Kaiinos Technologies
Unique Selling Point	A cost effective, robust and scalable platform with a short learning curve
Timeline in Months	48 months
Academic Collaborators (Indian/Foreign) with full Designation	1. Dr. Gowri A., Assistant Professor, Department of Civil Engineering, IIT Tirupati 2. Dr. Jayanarayan TT, Assistant Professor, Department of Computer Science Engineering, IIT Tirupati 3. Dr. Ramakrishna G., Assistant Professor, Department of Computer Science Engineering, IIT Tirupati 4. Dr. Ravi Prakash Iyer, Visiting Professor, Department of Computer Science Engineering, IIT Tirupati 5. Dr. Vikram Kumar Pudi, Assistant Professor, Department of Electrical Engineering, IIT Tirupati 6. Dr. Venkata Ramana Badarla, Associate Professor, Department of Computer Science Engineering, IIT Tirupati
Total funding Required	Rs. 1.5 Crores (Data Purchase, Equipment and Software Development)
Number of Patents	-
Projected Generation	Revenue from consulting services would begin from the end of year 1. In a period of 5 years 8 Cr. Details in Annexure.

Gantt Chart

Target	Yr1		Yr2		Yr3		Yr4	
Survey of positioning methods and technologies	■							
Positioning infrastructure	■	■	■	■				
Occupancy estimation methods	■	■	■	■	■	■		
Data collection, processing, visualization	■	■	■	■	■	■		
Control system	■	■	■	■	■	■		
Route planning and crowd modelling	■	■	■	■	■	■		
End user application					■	■	■	■
Integration, testing, performance optimization					■	■	■	■
Final report and manuals generation							■	■

Annexure

Objectives

Objectives of developing this product are to build cost-effective hardware bundled with a comprehensive & tested Navigation and Mapping Toolkit which is useful across diverse industries and uses cases. This toolkit is aimed to improve data capture speed with minimum technical know-how. It also should reduce repeated visits to sites for acquiring different datasets. Modular hardware will be developed enabling scalability for future use cases through additional sensor data.

Revenue projections

This product needs a bootstrap funding of about Rs. 3 to 3.5 crores over a period of 4 years for prototyping the hardware, testing it in the lab, marketing it and development of the toolkit including the software. Over a period of 5 years, this product is expected to generate a revenue of 8 to 8.5 crores.

About Kaiinos

KAIINOS, part of the IIIT-H ecosystem, develops algorithms for feature extraction, classification of data coming from sources of location information like IoT, Satellite, LIDAR etc. The goal of the development of these algorithms is to reduce manual intervention and enhance the productivity of valuable resources in analyzing spatial data. In order to enable organizations to take advantage of location information generated in their day to day operations, we offer services in Geospatial Process Development and Implementation. Our products and add on services help enterprises migrate from traditional statistics based information systems to geospatial decision support systems.

To achieve this we help enterprises to

- Re-define existing processes to incorporate the dimension of location into them
- Re-engineer existing systems to suit the spatio-temporal needs of decision support.

Also, we offer consultancy services in designing models which capture the rationale behind the spatial changes and develop predictive simulations to help managers in decision making.

Product – 8	Lightweight Secure Communication for IoT in PPT Applications
Practical Problem That It Solves	Securing communication in various PPT applications is a critical aspect as most of the communication occurs over the unsecured wireless channel. Ensuring secure communication is of paramount importance in precision positioning systems which are being used in many practical scenarios such as GPS in navigation, aviation and asset tracking or monitoring. The product addresses the following practical problems a) secret key management and distribution of keys over a distributed wireless network such as IoT and sensor networks used for Positioning and Precision Technologies. Developing a secure sensing framework is a challenging task for distributed networks such as IoT integrated with the GPS network. b) Authentication is a critical aspect of any secure communication technique. GPS which is widely used in many devices are susceptible to spoofing attacks and it aims to develop a seamless authentication mechanism for such scenarios especially for commercial and defence applications. c) Developing lightweight secure communication protocols as most of the existing security techniques are not suitable for such scenarios due to the intensive computation involved in such techniques.
Target Beneficiaries	Defense, Smart Agriculture, Smart City, Drone Communication, Asset monitoring
Industry Collaborator(s) with classification (Indian/ Multinational/PSU)	Datakrew Pvt. Ltd. (Indian) Silence Laboratory Pte. Ltd. Singapore (International) BEL-CRL (Probable, National)
Unique Selling Point	The integration of GIS and IoT has led to the development of new ways to address various real-life problems and the security of data communication is a critical aspect in such integration. The research would facilitate lightweight and easily deployable protocols with the following key features a) Relies on the randomness present in the environment or the system which is difficult to clone by an unauthorized user b) Exploits contextual information for authentication of devices c) Easily integrates with authentication, encryption and compression algorithms d) Can strengthen the security of the GPS navigation system The proposed schemes can be integrated with other secure schemes at the higher layer.
Timeline in Months	60 Months

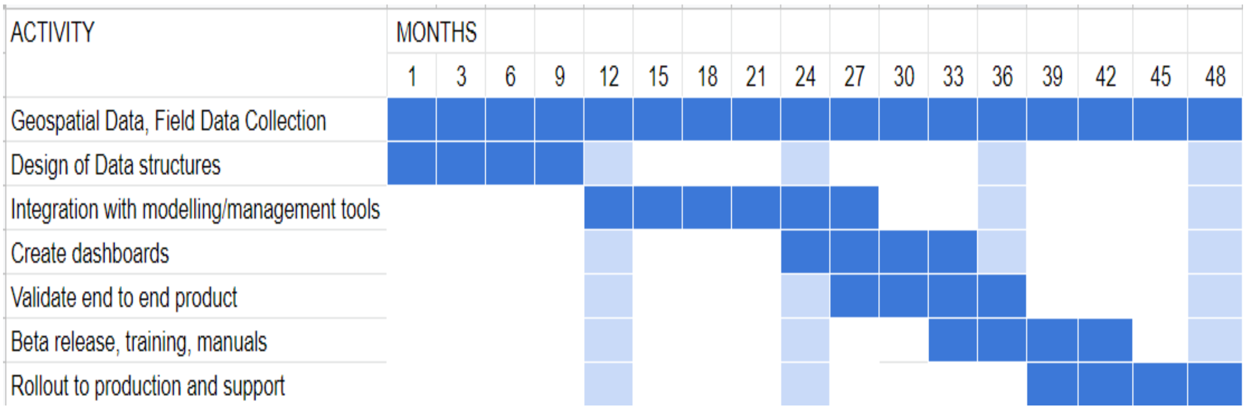
Product – 8 (Continued)	Lightweight Secure Communication for IoT in PPT Applications
Academic Collaborators (Indian/Foreign) with full Designation	(1) Dr Parthajit Mohapatra, Assistant Professor, IIT Tirupati (2) Dr Vikramkumar Pudi, Assistant Professor, IIT Tirupati (3) Prof Tony Quek, Cheng Tsang Man Chair Professor, Fellow of IEEE, Sector Lead, SUTD AI Program, Singapore University of Technology and Design, Singapore
Total funding Required	Rs. 1.3 Crores (Equipment Budget only) + Rs. 20 Lakhs (for travel, contingency and other miscellaneous expenses)
Number of Patents	4 envisaged
Projected Generation	Rs. 20 Crores over 10 years

Gantt Chart

Tasks	**Yr 1**	**Yr 2**	**Yr 3**	**Yr 4**	**Yr 5**
Procurement of Equipment	■				
Development of the framework and architecture	■	■			
Development of protocols/algorithms, simulation and performance analysis.		■	■	■	
Development, demonstration and verification of the developed prototype		■	■	■	■
Preparation of reports, publications, and IPs		■	■	■	■
Manpower training for skill development	■	■	■	■	■

Product – 9	Web-based Natural Resources Management using Geospatial Database and Tools - Emphasis on Water, Vegetation, Agriculture, and Forest
Practical Problem That It Solves	Water scarcity, food security, forest dynamics, large-scale disturbances, minerals, management of large lakes/reservoirs, adaptation to changing environment, climate change, and human influence on natural resources
Target Beneficiaries	Central/State Government agency, industry, forest department, municipality, farmers, institutes, and researchers The web-based tools will assist the authorities, decision-makers, and stakeholders in understanding the various scenarios and possibilities to plan water, vegetation, and forest resources, to build local capacities and assets in different forms including economic, physical, social, cultural, and environmental while providing solutions to the problems associated with the resources. The web-based tools will help to strengthen the understanding of resource management at all levels from local to center and 'Empower both local authorities and communities as partners to efficiently manage the resources These tools help in building and strengthening local capacities with a focus on local issues, resources, and people by providing training and understanding the planning and management of natural resources.
Industry Collaborator(s) with classification (Indian/Multinational/PSU)	Hexagon Technologies (India), NIH, India Survey of India Central/State Forest Departments
Unique Selling Point	Integrated decision-making tools Out of the box analytics Domain-specific dashboards for different organizations and resources A large database helps the decision-makers to learn from spatial-temporal changes and derive useful information for the efficient management of natural resources. Made in India
Timeline in Months	48
Academic Collaborators (Indian/Foreign) with full Designation	1. Dr. Roshan Srivastav, IIT Tirupati, 2. Dr. Robin, IISER Tirupati
Total funding Required	Rs. 1.5 Crores (Terrestrial + Airborne LIDAR and Bathymetry Rs. 1.25 Crores and Site Visit + Contingency = Rs. 25 Lakhs) The equipment will be shared in Product Nos: 10,12,13
Number of Patents	0
Projected Generation	The goal is to have a minimum of 25 customers (medium to large stakeholders) in the first 5 years after launching the product. Per customer payout is expected to be Rs. 10 lacs per annum; for 25 customers, this will yield Rs. 12.5 crores. As an intangible benefit, this will save 100 times this value, as natural resource management strategies will optimize their resources and make informed decisions.

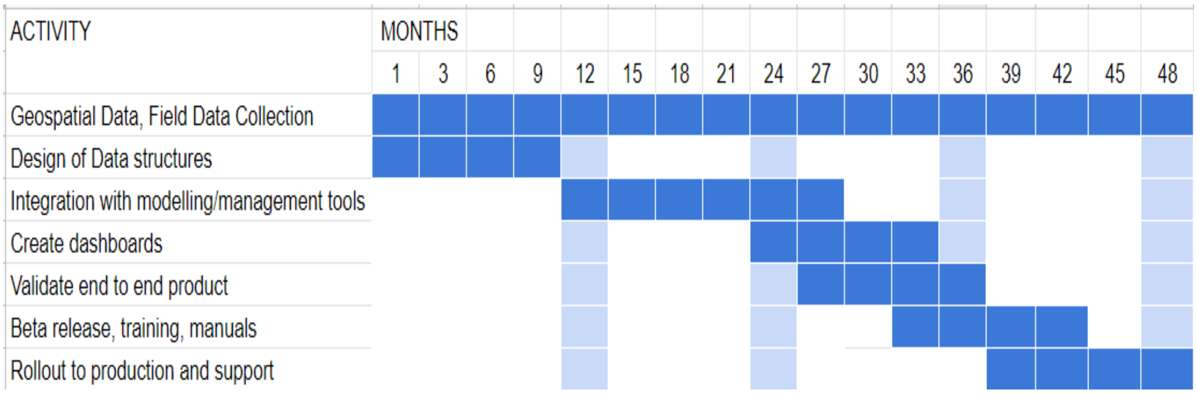
Gantt Chart


ACTIVITY
MONTHS
1
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
Geospatial Data, Field Data Collection
Design of Data structures
Integration with modelling/management tools
Create dashboards
Validate end to end product
Beta release, training, manuals
Rollout to production and support

Product – 10	Web-based Built Infrastructure Resource Management Solutions
Practical Problem That It Solves	Digital Elevation Model - hydrologic modelling, terrain stability, soil mapping, avalanche, landslides Digital Surface Model - Encroachment, Vegetation management, view obstruction Digital Terrain Model - relief maps, Bathymetric Survey - Flood, inundation, the contour of streams and reservoirs, leakage, scour and stabilization, water-quality studies, dam removal, biological and spill, storage and fill in reservoirs and ponds Underground utilities, Pipelines, and Power lines Archaeological sites - location, distribution, and organization of past human cultures Geo-tagging - land management Underground burrows - animal habitat Land-use land-change - urban planners
Target Beneficiaries	Central/State agencies, Industries, Municipalities, Urban planners, Institutes, and Researchers The web-based tools will assist the authorities, decision-makers, and stakeholders in understanding the various scenarios and possibilities to plan water, vegetation, and forest resources, to build local capacities and assets in different forms including economic, physical, social, cultural, and environmental while providing solutions to the problems associated with the resources. The web-based tools will help to strengthen the understanding of resource management at all levels from local to center and 'Empower both local authorities and communities as partners to efficiently manage the resources These tools help in building and strengthening local capacities with a focus on local issues, resources, and people by providing training and understanding the planning and management of natural resources.
Industry Collaborators With classification (Indian/ Multinational/PSU)	1. 3rdi, 2. Hexagon Technologies, 3. ESRI, 4. NIH, India 5. Survey of India
Unique Selling Point	Integrated decision-making tools Out of the box analytics Domain-specific dashboards for different organizations and resources
Timeline in Months	48
Academic Collaborators (Indian/Foreign) with full Designation	1. Dr. Roshan Srivastav, Assistant Professor, IIT Tirupati 2. Dr. K.N. Satyanarayana, Professor, IIT Tirupati 3. Dr. Abhijit Ganguli, Associate Professor, IIT Tirupati 4. Dr. Nandini Rajamani, Assistant Professor, IISER Tirupati
Total funding Required	Rs. 1.5 Crores (GPR, Thermal Imaging Camera = Rs. 1.15 Crores + data collection, data purchase, travel, and contingencies = Rs. 35 Lakhs) The equipment will be shared in Product Nos: 9,12,13

Product – 10 (Continued)	Web-based Built Infrastructure Resource Management Solutions
Number of Patents	Nil
Projected Generation	The goal is to have a minimum of 25 customers (medium to large stakeholders) in the first 5 years after launching the product. Per customer payout is expected to be Rs. 10 lacs per annum; for 25 customers, this will yield Rs. 12.5 crores. As an intangible benefit, this will save 100 times this value, as digital information will optimize their resources and make informed decisions.

Gantt Chart



Product – 11	High Precision controllers for smart grid applications and Energy Management Systems
Practical Problem That It Solves	Precision and reliability are critical in the time and frequency synchronization of power network nodes used in Smart Grid applications. Precision timing technology helps accelerate a broad range of Smart Grid operations, such as fault detection and protection. Smart Grid substations manage the optimal regulation of electrical power in the network, including existing power plants, distributed renewable energy and end consumers. Precise time synchronization is poised to play an even more significant role, as intelligent two-way power grids become fully functional. This product would design precision controllers and protection systems for smart grid based on high precision timing technologies for various smart grid applications such as travelling wave fault detection and location, Wide Area Protection, Synchrophasors, and Digital Fault Recorders. This product aims at improving the response time of existing fault detection and protection devices, thereby avoiding blackouts, improving the reliability of power to the consumers, and saving huge amounts of money. Spatial mapping of energy bottlenecks, energy lines and energy management systems through precision positioning techniques and GIS is essential for the decision-makers. GIS-based tools, in addition to the high precision controllers, will be useful to accurately locate the point of failure, manage the grid assets and thereby reduce the response time and avoid cascading power outages.
Target Beneficiaries	Industries (Phasor measurement Units, Digital relays, Digital Fault Recorders), Smart Cities, Central/State owned Power Utilities
Industry Collaborator(s) with classification (Indian/Multinational/PSU)	Schweitzer Engineering Laboratories Pullman, WA. USA Multinational
Unique Selling Point	1. Make in India 2. One stop solution for precision timing for smart grids 3. User friendly, and compatible with existing protocols for Smart Grid 4. Scalable: From a few tens to hundreds 5. Faster and real time operation. 6. State of the art precision synchronization and solutions to timings requirements from 0.5 microseconds to a few milliseconds in grid applications. 7. Avoids cascading grid failure and saves money
Timeline in Months	48

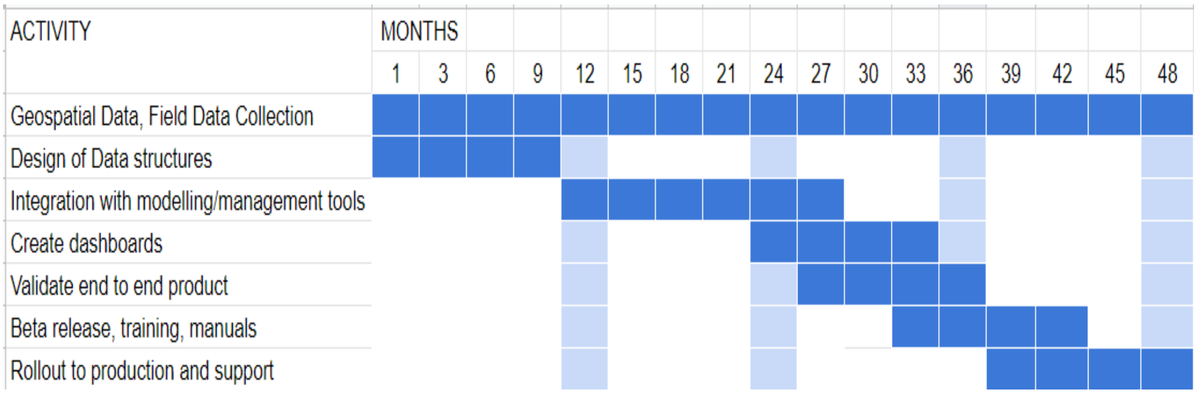
Product – 11 (Continued)	High Precision controllers for smart grid applications and Energy Management Systems
Academic Collaborators (Indian/Foreign) with full Designation	1. Dr Vignesh V, IIT Tirupati 2. Dr Roshan Srivastav, IIT Tirupati 3. Dr Arijit Sharma, IIT Tirupati 4. Dr Anurag Srivastava, Assistant Professor Director, Smart Grid Demonstration and Research Investigation Lab (SGDRIL), School of Electrical Engineering and Computer Science, Pullman, USA
Total funding Required	Rs. 1.5 Crores Digital Simulator: Rs. 75 Lakhs; Relays, Phasor measurement Units with GPS: Rs. 40 Lakhs; Software interfaces (for offline phasor simulations and interfacing with the real-time simulator): Rs. 35 lakhs
Number of Patents	2
Projected Generation	Rs. 20 Crores INR in 10 years

ACTIVITY	MONTHS							
	0	**6**	**12**	**18**	**24**	**30**	**36**	**48**
Survey of existing technologies	■	■						
Algorithms of high precision data		■	■					
Offline and real time simulation of the algorithms			■	■	■			
Manufacturing prototype and testing					■	■	■	
Pilot Deployments in a typical smart grid control application							■	■

7.6 Disaster Management

Product – 12	Web-based Geo-Spatial Tools for Disaster Modeling and Management
Practical Problem That It Solves	Integrated Decision-making toolbox for preparedness, mitigation, and management. Focuses on floods, droughts, earthquakes, hurricanes, and combined extreme events. The project includes risk mapping and zonation based on the intensity of the disaster, type of population, emergency services, and resilience of the disaster area. The dissemination and training of proposed tools will help stakeholders' leaders in the decision-making process.
Target Beneficiaries	Central and state agencies, industries, municipalities, city planners, etc. Disaster Management Plans focus on all sectors of people and institutions. Involves SMEs, the Private sector, Public-Private Partnership, the involvement of the corporate sector in capacity building and resources development, knowledge management, etc. The web-based tools will assist the authorities, decision-makers, and stakeholders in understanding the various scenarios and possibilities to make India disaster resilient across all sectors, helping to build local capacities starting with the poor and decreasing significantly the loss of lives, livelihoods, and assets in different forms including economic, physical, social, cultural and environmental while enhancing the ability to cope with disasters at all levels.
Industry Collaborator(s) with classifications (Indian/ Multinational/PSU)	Indian: Hexagon Technologies, ESRI, NIH, Survey of India, NRSC, National Disaster Management, National Institute of Disaster Management, National Disaster Response Force, NARL. Multinational: Planet.com
Unique Selling Point	● Integrated decision-making tools (Models: Flood, Drought, Cyclones, Earthquakes) ● Out of the box analytics ● Domain-specific dashboards for different organizations and disasters ● A large disaster database helps the decision-makers to learn from disasters and, derive useful information on the lessons after every disaster ● Make in India
Timeline in Months	48 months
Academic Collaborators (Indian/Foreign) with full Designation	1. Dr. K. N. Satyanarayana, Director, IIT Tirupati 2. Dr. Roshan Srivastav, Assistant Professor, IIT Tirupati 3. Dr. Roman Babu, Assistant Professor, IIT Tirupati 4. Dr. Chandrashekar Bahinipati, Assistant Professor, IIT Tirupati
Total funding Required	Rs. 75 Lakhs for equipment + Rs. 75 lakhs (data collection, data purchase, travel, and contingencies)
Number of Patents	NIL
Projected Generation	The goal is to have a minimum of 25 customers (medium to large stakeholders) in the first 5 years after launching the product. Per customer payout is expected to be Rs. 10 lacs per annum; for 25 customers, this will yield Rs. 12.5 Crores. As an intangible benefit, this will save 100 times this value, as disaster preparedness will optimize their resources and make informed decisions. Automatic maintenance alerts ensure more compliance, as well.

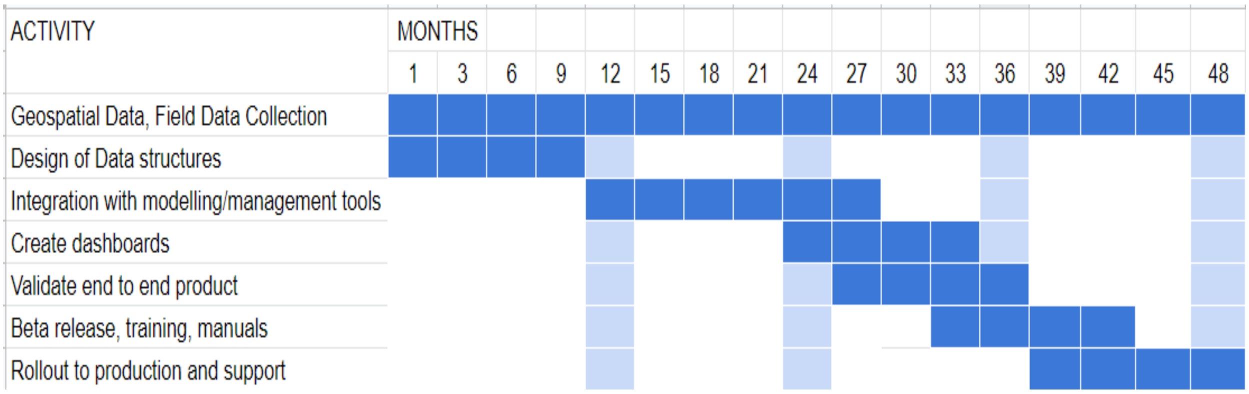
Gantt Chart


ACTIVITY
MONTHS
1 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48
Geospatial Data, Field Data Collection
Design of Data structures
Integration with modelling/management tools
Create dashboards
Validate end to end product
Beta release, training, manuals
Rollout to production and support

Product – 13	Web-based Geo-Spatial Tools for Pollution Monitoring and Management
Practical Problem That It Solves	Pollution and waste management plans focus on all sectors of people and institutions especially pollution control boards, researchers, and stakeholders. Involves SMEs, the Private sector, Public-Private Partnership, the involvement of the corporate sector in capacity building and resources development, knowledge management, etc. The project includes risk mapping and zonation based on the intensity of the pollution and the type of population. The tools include crowd-sourcing information to assist the planners to identify the risk zones. The involvement of the public by crowdsourcing enhances information, knowledge transfer, and capacity building. Building local capacities and assets in different forms including economic, physical, social, cultural, and environmental while providing solutions to the problems associated with the pollution
Target Beneficiaries	The web-based tools will assist the authorities, decision-makers, and stakeholders in understanding the various scenarios and possibilities to plan all sectors, help to build local capacities and assets in different forms including economic, physical, social, cultural, and environmental while providing solutions to the problems associated with the pollution. The web-based tools will help to strengthen the understanding of pollution risk governance at all levels from local to center and 'Empower both local authorities and communities as partners to reduce and manage pollution risks' These tools help in building and strengthening local capacities with a focus on local issues, resources, and people by providing training and understanding the various effects of pollution on their livelihood.
Industry Collaborator(s) with classification (Indian/ Multinational/PSU)	1. AECOM 2. Hexagon Technologies, 3. NIH India
Unique Selling Point	Integrated decision-making tools for pollution Out of the box analytics Domain-specific dashboards for different organizations and disasters A large pollution database helps the decision-makers to learn from previous pollution disasters and derive useful information for efficient preparedness and management against pollution. Make in India
Timeline in Months	48 months
Academic Collaborators (Indian/Foreign) with full Designation	1. Dr. Roshan Srivastav, IIT Tirupati 2. Dr. Shihabudeen Mayilekal, IIT Tirupati 3. Dr. Suresh Jain, IIT Tirupati
Total funding Required	Rs. 40 Lakhs. (Rs. 10 Lakhs for equipment and Rs. 30 Lakhs for Sample collection, analysis, travel, and contingencies)
Number of Patents	0

Product – 13 (Continued)	Web-based Geo-Spatial Tools for Pollution Monitoring and Management
Projected Generation	The goal is to have a minimum of 25 customers (medium to large stakeholders) in the first 5 years after launching the product. Per customer payout is expected to be Rs. 5 lacs per annum; for 25 customers, this will yield Rs. 6.25 crores. As an intangible benefit, this will save 100 times this value, as pollution monitoring and management strategies will optimize their resources and make informed decisions. Automatic maintenance alerts ensure more compliance as well.

Gantt Chart



7.7 Remote Sensing and Image Processing

Product – 14	Satellite Image Classification, Land-Use Land-Cover mapping
Practical Problem That It Solves	● Currently, only OBIA and manual annotations are only in place for nationwide land-use classification, localization and land cover mapping. ● Given the recent advancements of deep learning approaches for image classification, deep learning-based temporal data processing enables accurate change detection to update the land use or agricultural growth and enable precise mapping of land use and land cover. ● Further, recent developments in data fusion and data generalization approaches, enable the generation of high-resolution land-use land-cover mapping models for Indian scenarios, to automate this classification and localization task across the country.
Target Beneficiaries	ISRO- NRCS, Hyderabad.
Industry Collaborator(s) with classification (Indian/ Multinational/PSU)	GD, LULC, ISRO- NRCS, Hyderabad. ISRO- NRCS, Hyderabad.
Unique Selling Point	High-resolution land use, land cover mapping is of great importance in many regions for resource identification, mapping, & monitoring. Specific focus is in 1. Quantifying the land use in building/agriculture over time through DL based change detection. 2. Accurate DL based solution for large scale land use and land cover mapping.
Timeline in Months	48 Months
Timeline Details	0- 6 months: Data Acquisition, Preparation & Literature Rev 7-12 months: Existing DL Models testing and Validation 13-18 months: Evolving with the SOAT DL model and Application 19-24 months: Performance Analysis on large real data and development to the product level 25-30 months: Compact model design for real-time applications & App creation 31-36 months: Real time demonstration 37-48 months: To customize these product developments in further applications related to anomaly detection, precision Agriculture, monitoring with change detection in smart cities.
Academic Collaborators (Indian/ Foreign) with full Designation	1. Dr. Rama Krishna Gorthi, Associate Professor, IIT Tirupati 2. Dr. Ramiya, Assistant Professor, ESS, IIST
Total funding Required	Rs. 60 Lakhs
Number of Patents	1
Projected Generation	Rs. 8 Crores (10 years): The developed software will be in place in the NRSC Bhuvan platform and contributes to improvements in accuracy on all land use land cover based applications.

Product – 15	Auto-annotate for Satellite Image Classification
Practical Problem That It Solves	❖ Pixel level annotation in satellite imagery is a key bottleneck for the application of many deep learning approaches for Satellite Image classification tasks. ❖ Annotating large remote sensing data from few manually labelled image data.
Target Beneficiaries	Satellite & Medical Image Processing Applications, where data annotation is a challenge.
Industry Collaborators with classification (Indian/ Multinational/PSU)	RRSC, Bangalore
Unique Selling Point	Development of Auto-label enables pseudo-generation of reasonably large ground truth in i) Land use, land cover classification, ii) Change detection, iii) forest and iv) agricultural applications and many more areas. Thus, will be in very high demand.
Timeline in Months	48 Months
Timeline Details	0- 6 months: Data Acquisition, Preparation & Literature Review 7- 12 months: Existing DL Models testing and Validation 13- 18 months: Evolving with the SOAT DL model and Application 19-24 months: Performance Analysis on large real data and development to the product level 25- 30 months: Compact model design for real-time applications & App creation 31- 36 months: Real time demonstration 37-48 months: To customize these product developments in further applications related to anomaly detection, precision agriculture.
Academic Collaborators (Indian/Foreign) with full Designation	1. Dr. Rama Krishna Gorthi, Associate Professor, IIT Tirupati 2. Dr. Subrahmanyam Gorthi, Assistant Professor, IIT Tirupati 3. Prof. Linga Reddy, University of Agder, Norway university 4. Prof. Ettiene Memin, Director, Fluminance, INRIA, France
Total funding Required	Rs. 60 Lakhs
Number of Patents	1
Projected Generation	Rs. 8 Crores (10 years): The developed software will be in place in the ISRO Bhuvan platform and contributes to automated annotation & ground truth data generations for many satellite image classification tasks.

Product – 16	Prosperity Mapping from Satellite Image Data
Practical Problem That It Solves	❖ Assessment of the poverty regions from satellite image data provides a clear idea of the current prosperity index of a region and prosperity index map of all the regions across the country. ❖ It enables localization of regions to be developed, provides strategic quantified information for planning, development and monitoring of any specific regions in the country and the economic standard of the country.
Target Beneficiaries	Planning & Economic developments of the country
Industry Collaborators with classification (Indian/ Multinational/PSU)	SAC Ahmedabad, ISRO
Unique Selling Point	❖ Currently, the poverty scale of a region is assessed by the local & individual data collection procedures. However, through localized land use and land cover maps in a given region, prosperity can be quantified as a prosperity index of that region. ❖ Such a prosperity index across all the regions in the country generates a prosperity map enabling automatic quantification of the developments of that region and time to time assessment and monitoring of the prosperity index map across the country. ❖ Though there is a huge resource of satellite image data over the whole nation, land use/land cover mapping from them is partially available, such a prosperity mapping based on the urban developments and agriculture etc. is an unattempted/unsolved and significantly important problem in India. ❖ Given the ability of start of the art deep learning-based image segmentation techniques, their application enables identifying the number of houses, roads and vegetation across the country from satellite imagery. This enables prosperity indexing of every localized region and enables consistent and continuous monitoring of the nationwide developments.
Timeline in Months	48 Months
Timeline Details	0- 6 months: Data Acquisition, Preparation & Literature Review 7- 12 months: Existing DL Models testing and Validation 13- 18 months: Evolving with the SOAT DL model and Application 19-24 months: Performance Analysis on large real data and development to the product level 25- 30 months: Compact model design for real-time applications & App creation 31- 36 months: Real time demonstration 36-48 months: To customize these product developments in further applications related to smart transportation systems, monitoring with change detection in smart cities.

Product – 16 (Continued)	Prosperity Mapping from Satellite Image Data
Academic Collaborators (Indian /Foreign) with full Designation	Dr. Rama Krishna Gorthi, Associate Professor, IIT Tirupati. Mr. Litu Rout, SAC Ahmedabad, ISRO Dr. S. Manthira Moorthi, Division Head, SAC, Ahmedabad, ISRO
Total funding Required	Rs. 50 Lakhs
Number of Patents	1
Projected Generation	Rs. 8 Crores (10 years): The developed software will be in place in the ISRO Bhuvan platform and contributes to the monitoring of economic developments and quantified economic growth.

Product – 17	Disaster Response Dashboard
Practical Problem That It Solves	In the face of disasters, there is a one stop software platform that coordinates activity workflows, alerts, action items, and connects service providers to service consumers. Disaster Response Dashboard will be provided as a back-end service with diverse front-end technologies - web, smartphone and telephone. The software backend integrates high quality GIS, socio-economic and administrative data coming from diverse sources and services responses.
Target Beneficiaries	Civilians experiencing a disaster, National Disaster Response Force, Service organizations of Government and NGO, Service Volunteers and Third-party players.
Industry Collaborator(s) with classification (Indian/ Multinational/PSU)	Facebook international organization, USA.
Unique Selling Point	It is the first of its kind and novel, unified, one-stop platform for data-driven integration of service providers, volunteers, administrators, media and victims for effective management and response to a disaster. The innovation in software architecture includes service store, disaster response as a service and event-based system with diverse human interfaces, backend computational services and data storage mechanisms.
Timeline in Months and Details	36 months 1st year - Development and Unit testing over prior scenarios 2nd year - Deployment and field level testing for specific scenarios 3rd year - Self sustained maintenance and source of human resources
Academic Collaborators (Indian/Foreign) with full Designation	[Principal Investigator] Dr. Y. Kalidas, Assistant professor, Dept. of CSE, IIT Tirupati. [Co-PI] Dr. Olivier Telle, Researcher at CNRS, France and Visiting Fellow at Centre for Policy Research, New Delhi. [Collaborator] Dr. Ashok Srinivasan, William Nystul Eminent Scholar Chair and Professor, Department of Computer Science, University of West Florida.
Total funding Required	Rs. 18 Lakhs for 3 years for Manpower. No equipment required
Number of Patents	1
Projected Generation	Revenue is generated in the form of employment and sponsorship from government, NGO and other sources. After 5 years 30 people would be stationed in TIH funded by different agencies. 30*12*Rs. 50000 = Rs. 1 Crore 80 lakhs annually.

Task ID	Task	H1	H2	H3	H4	H5	H6
T1	Development/Refinement of GeoInsightsParser module for Disaster Response Maps (including FB's GeoInsights data base)	x	x				
T2	Development/Refinement of MappingModule through API with Open GIS System (PyQGIS) to load property sets	x	x				
T3	Development/Refinement of module for mapping with road networks – (including FB Open Street Maps)	x	x	x	x		
T4	Development/Refinement of VisualizationModule to present layered annotations in maps	x	x	x	x		
T5	Development/Refinement of Event Store and integration with Mapping and Visualization Modules	x	x	x	x		
T6	Development/Refinement of Service Store and integration with Mapping and Visualization Modules	x	x	x	x		
T7	Development/Refinement of Service Registration module	x	x	x	x		
T8	Development/Refinement of Victim Registration module	x	x	x	x		
T9	Development/Refinement of Workflow System for the administration of activities through people and processes	x	x	x	x		
T10	Development/Refinement of Secure Communications module	x	x	x	x		
T11	Emulation of a synthetic disaster scenario and unit testing of the software system			x	x		
T12	Testing of the software system on the past disaster of Mumbai floods and synthetic administrative processes and responses			x	x		
T13	Field level deployment for the 2021 monsoons/other scenarios and evaluation				x	x	
T14	Customization of the system for disaster specific scenarios				x	x	x
T15	Installable version and release of open source for administrative bodies to adopt the system				x	x	x

Product – 18	AuDisCo – Autonomic Distributed Computing for Power Efficiency
Practical Problem That It Solves	To meet the service time constraints in processing big data characterized by volume, variety, and velocity (3V's) generated by various Cyber-Physical System (CPS) applications.
Target Beneficiaries	Developers of autonomous system applications for surveillance applications; Automation industries (mainly the ones where manual intervention is required to be minimal and teleoperation is crucial); Software industries working towards energy efficiency in the area of distributed computing for CPS.
Industry Collaborator(s) with classification (Indian/Multinational/PSU)	Collaborator: Xilinx (confirmed for autonomous drones for surveillance applications), envisaging Asea Brown Boveri (ABB) for possible collaboration and Siemens Automation for possible collaboration. Later, most of the medium and large-scale industries which intend to go about predictive/preventive maintenance from big data shall also be potential beneficiaries.
Unique Selling Point	1. The development of an autonomic computing platform is key to any Cyber-Physical Systems (CPS) infrastructure; It provides a good opportunity for commercialization since most of the industrial and autonomous applications will depend on energy-efficient computational testbeds for seamless big data processing for their applications to meet their service time constraints. 2. Potential applications include Autonomous systems such as Drones/UAVs, Electric Vehicles, Telerobotics, and Remote monitoring & control of manufacturing systems. These are applications where precise timing and synchronization of various geographically distributed subsystems is crucial, hence the autonomic testbed plays a key role.
Timeline in Months and Details	36 months 1st year: Development of distributed computing testbed 2nd year: Interfacing the testbed with big data sources and development of control theoretic models and autonomic controllers for service time management. 3rd year: Integrated testing of the testbed for the developed models of the computing testbed with the automation and autonomous systems.
Academic Collaborators (Indian/Foreign) with full Designation	1. Dr. Sai Krishna, Assistant Professor, IIT Tirupati, 2. Prof. Diwakar Krishnamurthy, Professor, University of Calgary, Canada 3. Dr. Ramkrishna Pasumarthy, Associate Professor, IIT Madras
Total funding Required	Rs. 75 Lakhs (Dedicated power Edge servers, Fog devices and networking accessories, Modular Production systems)
Number of Patents	1
Projected Generation	It is planned to generate revenue by means of training programs, workshops and development of PoC's for industries and Research Labs. The estimate per year is Rs. 120 Lakhs

Gantt Chart

ACTIVITY	MONTHS						
	00	**06**	**12**	**18**	**24**	**30**	**36**
Survey of existing technologies in Big data Analysis and refining the problem formulation	■	■	■				
Establish Computational Testbed for Distributed computing and establish connectivity to various production systems via the Fog and Cloud network			■	■			
Modelling and validation of automation testbed with respect to a potential CPS application				■	■		
Complete demo of PoC development for a particular CPS application					■	■	■

7.8 Visualization Tools

Product – 19	VisD^2 - A software platform for **Vis**ualization of data during **D**isaster management to support **D**ecision making
Practical Problem That It Solves	Appropriate use of tools for visualization in disaster management supports risk decision makers. For example combine inundation maps (remote sensing), GPS readings, and other data, to inform community risk decision makers. These visualization tools provide clear orthographic views of potential risks over wide areas which help facilitate expert analysis. Virtual Reality (VR), Augmented Reality (AR), and Mobile AR (MAR) and Citizen Science provide opportunities to investigate alternative modes of visualisation and interaction for a citizen, volunteer, and expert during disaster engagement. These tools provide increased support to communicate during the disaster as a precautionary measure. The tool will enable the user to track an unspecified location, populate it with building geometry, and visualise an augmented reality during a disaster (such as floods). The visualization tools will provide an opportunity to immerse the user in a visualisation whilst simultaneously experiencing the observed world environment. Augmented reality provides a range of benefits to the planning and design process such as location based information applications to support understanding of landscape futures and the environment.
Target Beneficiaries	Central and state agencies, industries, municipalities, city planners, etc. Disaster Management Plans focus on all sectors of people and institutions. Involves SMEs, the Private sector, Public-Private Partnership, the involvement of the corporate sector in capacity building and resources development, knowledge management, etc.
Industry Collaborators with classification (Indian /Multinational/PSU)	3rdi (Indian) NRDM
Unique Selling Point	● Mobile-Integrated App for integrated decision-making ● Easy-to-use ● Disaster-specific augmented reality environments for different organizations and disasters ● Pre-loaded disaster maps to assist the volunteers and field experts ● Make in India
Timeline in Months	48

Product – 19 (Continued)	VisD^2 - A software platform for **Vis**ualization of data during **D**isaster management to support **D**ecision making
Timeline Details	0-12 months - Recruitment of staff, Literature Review, Exploration of visualization techniques, Data mining and cleansing 13-24 months - Data mining and cleansing, Development of visualization platform 25-36 months - Development of visualization platform, Application of platform for disaster management 36-48 months – Field deployment and continuous improvement of products
Academic Collab.(Indian/ Foreign) with full Design.	1. Dr. Sridhar Chimalakonda, Assistant Professor, IIT Tirupati 2. Dr. Roshan Srivastav, Assistant Professor, IIT Tirupati 3. Dr. K. N. Satyanaryana, Professor, IIT Tirupati
Total funding Required	Rs. 65 Lakhs (Data Collection, Field Surveys and Visits, Virtual Reality Systems - HTC/ Oculus, Touch Screen Monitors, Microsoft Hololens)
Number of Patents	
Projected Generation	Rs. 100 Crores (expected revenue for 10 years) As an intangible benefit, this will save 100 times this value, as disaster preparedness will optimize their resources and make informed decisions. Automatic maintenance alerts ensure more compliance, as well.

7.9 Smart Cities

Product – 20	IR image-based condition monitoring & fault diagnosis of electric utilities
Practical Problem That It Solves	Geographical Information System and Spatial Informatics Techniques have come as the boon to solve many problems in the Smart Grids. The risk of blackouts is increasing on the power grid due to ageing infrastructure, and a lack of automation systems that monitor the condition of critical equipment at substations and elsewhere on the grid. For example, transformer fluid leaks or internal insulation breakdown cause overheating that leads to failures, but many utilities don't have automated thermal detection systems that reveal these problems. Power Utilities are looking for ways to address these issues and improve the reliability of electric power delivery while reducing expenses. Infrared (IR) thermography can play a major role in preventing unplanned outages that result from substation component failures. The proposed tool would monitor the heat signatures of equipment through state-of-the-art image processing techniques and these automated systems provide remote detection and alarm signals. GIS-based real-time maps will be used for mapping of complete electrical networks including low voltage systems and customer supply points. This allows an operator to dispatch maintenance personnel to a substation before equipment fails. This GIS-based tool will be useful to accurately locate the point of failure, thereby reducing the response time (time taken to repair the faulty equipment/transformer/distribution feeder) and avoiding cascading power outages.
Target Beneficiaries	Smart Cities, Central/State owned Power Utilities
Industry Collaborator(s) with classification (Indian/Multinational/PSU)	APSPDCL, India Eaton, India
Unique Selling Point	1. Make in India 2. Automated health monitoring with minimal man-in-loop 3. Prognostic and automated health monitoring of assets. 4. Easy deployable in the existing substations. Minimal installation and maintenance costs. 5. User-Friendly Visualization 6. Quick response time and saves money by avoiding costly maintenance Reduces downtime of the substation equipment
Timeline in Months	36
Academic Collaborators (Indian/Foreign) with full Designation	1. Dr Vignesh V, Assistant Professor, IIT Tirupati 2. Dr Ramakrishna Gorthi, Assistant Professor, IIT Tirupati 3. Dr Anurag Srivastava, Washington State University, Pullman, USA
Total funding Required	Rs. 55 Lakhs Thermal Imaging Camera: 3 Nos: Rs. 45 Lakhs Front end Interface to Grid Simulator: Rs. 7 Lakhs Consumables: Rs. 3 Lakhs
Number of Patents	1
Projected Generation	Rs. 8 Crores INR in 10 years

Gantt Chart

ACTIVITY	MONTHS						
	00	**06**	**12**	**18**	**24**	**30**	**36**
Survey of existing technologies and Image Processing Algorithms for automated condition monitoring	■	■	■				
Conditioning monitoring algorithms on synthetic data			■	■			
Testing and validation on field data				■	■		
Pilot Deployments in a typical substation					■	■	■

Product – 21	SMART Vehicle Framework and Algorithmic Toolkits to Identify Infrastructure Assets with Precision
Practical Problem That It Solves	Identify smart city networks in real-time, including, but not limited to roadway pavement assets and conditions (distress identification, mapping, and rehabilitation recommendations) as well as advanced road traffic management systems (automatic vehicle identification and tracking). This product will be used to recognize and identify the aforementioned in a precise manner through geospatial tools (GIS and GPS) with the smart vehicle, while analyzed through deep learning and image processing techniques, in order to solve problems in an urban conglomerate (location-wise positioned on to the asset and vehicles) while also providing solutions such as roadway network and traffic management.
Target Beneficiaries	Smart City; Roadway Agencies; Public Works Department; National Highways Authority of India; Survey of India; Database management authorities
Industry Collaborator(s) with classification (Indian/Multinational/PSU)	**Potential:** AECOM, Kaiinos, Andhra Pradesh Road Development Corporation, National Highways Authority of India, Central Road Research Institute, **Probable:** Geological Survey of India, relevant GIS & IT team.
Unique Selling Point	Uses state-of-the-art geospatial tools with smart sensors on the vehicle to localize, identify and recognize assets and vehicles in real-time; deep learning and image processing tools for analysis; novel and indigenously developed toolkit(s) and analytical framework that is portable and editable; Can be replicated elsewhere with the developed framework; Supports AatmaNirbhar Bharat and Make in India initiatives
Timeline in Months	36
Timeline Details	0-6 Months: Development of the Smart Vehicle 3-24 Months: Develop algorithms (toolkits) to capture conditions of road pavement infrastructure assets; Develop advanced road traffic management system 12-36 Months: Testing and validation of algorithms; product release
Academic Collaborators (Indian/Foreign) with full Designation	1. Dr. Krishna Prapoorna, Associate Professor, IIT Tirupati 2. Dr. A. Gowri, Assistant Professor, IIT Tirupati 3. Dr. Ramakrishna Gorthi, Associate Professor, IIT Tirupati 4. Dr. Vignesh V, Assistant Professor, IIT Tirupati 5. Dr. Samuel Labi, Professor & Director, Next Generation Transportation, Systems (NEXTRANS), Purdue University School of Civil Engineering 6. Dr. Hosin "David" Lee, Professor, Civil and Environmental Engineering, Seamans Center for the Eng. Arts and Sciences
Total funding Required	Rs. 65 Lakhs (Vehicle: Rs. 10 Lakhs, Cameras and Sensors (High-quality HD cameras, line scan and areas scan laser sensors): Rs. 50 Lakhs (Image Processing Tools along with Software Development, and Consumables: Rs. 5 Lakhs)
Number of Patents	4
Projected Generation	Rs. 25 Crores INR in 10 years

8. Management

8.1 Hub Governance

INiF will be set up as a Section 8 not-for-profit company with the Director and Dean Sponsored Research and Consultancy of IIT Tirupati as members of the Board of Directors. A memorandum of understanding will be signed between IIT Tirupati, DST, and INiF. A draft copy of the same will be shared for consideration by DST NM-ICPS shortly after the formation of the Section 8 company. A Hub Governing Body (HGB) will also be set up as prescribed by the funding agency norms and will be responsible for the overall deliverables of this proposal. The rest of the governance structure of INiF is shown in Figure 11.

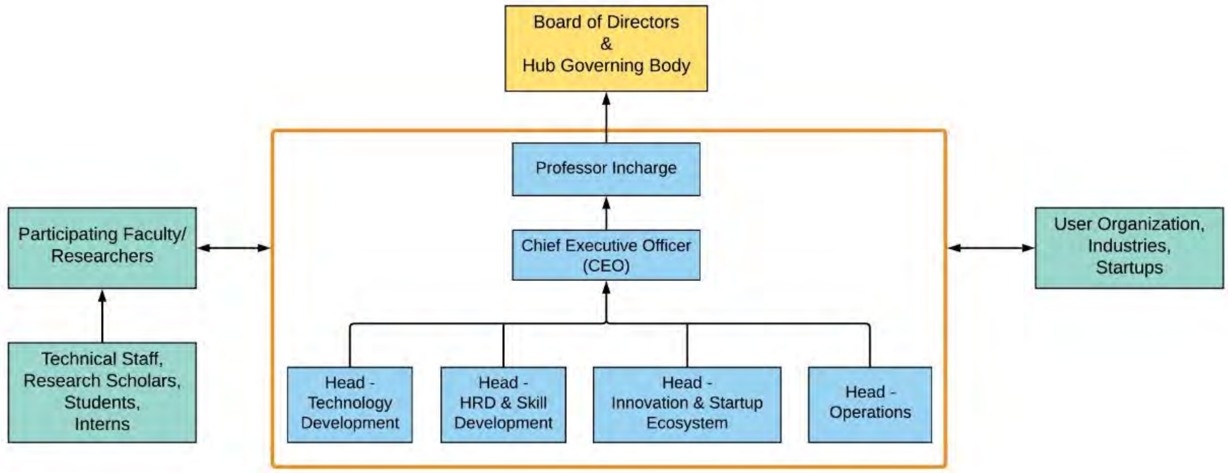


Figure 11: Governance of INiF

A Professor In-charge of INiF will be appointed with experience in commercialization and industry relations related to PPT. The Professor-in-Charge will primarily be responsible for outreach and evangelizing INiF and, will build INiF's relationships with the industry and other external collaborators. A full-time Chief Executive Officer will be appointed to manage the operation of the Hub and execute the strategy set by HGB by working closely with Professor In-charge. Four Heads who will be reporting to the CEO will be responsible for Technology Development, HRD & Skill Development; Innovation & Start-ups, and Hub Operations respectively. Their individual roles and responsibilities are as follows:

- Head of Technology Development is responsible for identifying and managing impactful projects in PPT. Activities under this division's purview include sending out a call for proposals, and, selection and execution of the projects.

- The Head of HRD & Skills Development is responsible for identifying and managing the best project staff for various projects and disbursing of various fellowships. This division will also be responsible for designing and rolling out various training programs related to PPT.
- Head of Innovation and Start-up is responsible for protecting the intellectual property generated under the various projects, translating that research to products, and licensing & start-up activities. As part of these activities, the division will also provide training and internship opportunities in various aspects of advanced technology commercialization. To support the start-up activities, a Technology Business Incubator (TBI) will be set up under this division. The TBI will roll out various programs to evangelize and train people in starting and growing advanced technology-based ventures. In addition, the TBI will fund and incubate spin-offs & start-ups related to PPT.
- Head of Operations is responsible for Finance, HR of Hub's internal staff and external consultants, IT infrastructure and Administration.

The participating faculty/researchers will be supported in various aspects of research, product development, marketing, and outreach activities by the respective Heads at INiF. The technical staff, research scholars, students and interns shall work under the guidance of the participating faculty/researchers. In addition, the hub will form a project review committee consisting of two technical experts, one industry/user organization, a Professor in charge, concerned Head (Technology Development or HRD or Innovation & Start-ups) and Chief Executive Officer.

8.2 Project Selection and Evaluation

INiF proposes to achieve the outcomes discussed in Section 11 over the first five years of its evolution. Key to the successful achievement of the targets is a careful selection of projects funded by the Hub in areas of PPT for CPS. These projects will be assessed based on their contributions to the state-of-the-art in Positioning and Precision Technology & Software. In addition, the project's potential to create direct social and economic impact and spill-over effects on skills development and the commercialization eco-system will be assessed. All project proposals will be reviewed by the project review committee. Typical steps undertaken to select and monitor the projects are described below.

Step 1: Proposal Submission and review:

The INiF shall encourage proposals from Indian Academic Institutions, Indian Startup companies, and established companies in India that will be considered for technical and financial support. The proposals will be evaluated in terms of the following parameters:

- **Problem Statement and Solution Definition:** The urgency and the impact of the problem that the proposal is trying to solve and the synergy of the proposed solution with the mandate of the INiF.
- **Technical Feasibility of the Solution:** Feasibility of the solution and the competency of the proposing team to deliver the solution.
- **Timeline and Resource Requirements:** Feasibility of developing a solution based on the proposed timelines and resource requirements.
- **Competitive Advantage:** Competitive advantage of the proposed solution compared to the existing solutions in the market along the key dimensions of importance to the target customers.
- **Impact Assessment:** Financial and social impact of the project
- **Intellectual Property**: Likely intellectual property generated by the project and its commercializability.
- **Commercialization Strategy and Support:** The feasibility and practicality of the strategy used to commercialize the intellectual property generated. This could be through the creation of a spin-off or licensing to an existing entity.
- **Commitment of Industry Partner or User Organization (If any):** Financial and in-kind resources that the industry partner is willing to commit to the project and likelihood of the partner being able to fulfil those commitments.

The project review committee will evaluate the proposals along with these parameters and will send the shortlisted proposals and the committee recommendations to the HGB for approval. The proposal investigators will be encouraged to take advantage of other grants for additional funding and resources (if required).

Step 2: Memorandum of Understanding and Funding

- Once the approval of the HGB is obtained, an MoU will be signed between the proposing partner and INiF which shall detail the project plan with milestones and resource requirements, timelines, IPR ownership, Capital assets and Royalty. In case, IIT Tirupati is involved in the project, the Institute will also be a party to the MoU.

- Funding for the project will be released by INiF in a phased manner subject to the delivery of milestones agreed upon in the MoU. All payments including monthly salary for staff and payment to vendors will be disbursed by the INiF directly. The only fund transfer to another participating Institution would be a nominal overhead decided on a case-by-case basis.

Step 3: Monitoring of projects

The proposals will be monitored frequently to effectively manage technology risk and resource utilization.

- A technical / business mentor from the INiF will be assigned for each project as and when required.
- Every project staff would be required to submit regular progress reports (Level 1)
- Review of the progress reports would be carried out on a monthly basis by the concerned Heads and any areas of concern are highlighted to the project review committee. (Level 2)
- A quarterly review of projects will be done by the project review committee to recommend any course corrections. (Level 3)
- A half-yearly progress report of various projects undertaken shall be presented to the HGB by the CEO. (Level 4)

8.2.1 Project Evaluation

Evaluation is key to enhancing the overall effectiveness of the proposed initiative in reaching its stated goals and objectives. Based on the importance of this evaluation procedure for all the projects, activities and resources, we have made a clear, structured and quantified procedure for the same, through the indicators suggested as per the blue book of the DPR. This will be helpful for the accomplishment of the stated goals and objectives; this in turn is important to make informed decision making and resource allocation. Further, to conveniently document the evaluation process and for transparent monitoring of the same with stakeholders, we plan to interface these with the web interface. We note that this evaluation is a regular, ongoing and incremental process. Thus following is the proposed process of the TIH evaluation procedure at IIT Tirupati.

All the proposed projects under TIH and the overall TIH activities, progress and developments will be evaluated in their status to accomplish the following objectives

1. Technology Development
2. HRD & Skill development

3. Development of the Center
4. Innovation, Entrepreneurship & Start-up ecosystem
5. International Collaboration (R&D and HRD)

We propose the following indicators for qualitative and quantitative mapping of the progress of the projects and the hub.

Indicators	Milestones / Qualitative & Quantitative metrics of evaluation
Input Indicators	As discussed above Step 1 to Step3 and monitoring of the process (L1 to L4) are part of input indicators. Specifically following helpful in quantifying the same 1. Meeting the timelines in releasing the funds 2. Meeting the timelines in the submission of the reports by respective projects under L1 to L4 3. Scheduling the review meetings 4. The progress of the scientific staff (JRF/SRF/Postdoctoral fellow) employed in the projects under the TIH shall be monitored through an annual evaluation scheme based on the report filed followed up by an interview. This will help ensure the project remains aligned to the timely execution of targeted objectives outlined and ensure non-performers to be removed from their positions. Apart from the annual review, the scientific manpower recruited may need to give a half-yearly seminar based on their activities to monitor their progress. They shall be encouraged to publish their work in reputed peer-reviewed journals. We expect that the scientific staff should be able to publish at least one peer-reviewed article per year.
Processes Indicators	The PI shall conduct an annual review meeting with all the stakeholders of the project - the funding agencies, the business/industry partners and the administrative body of the Hub. He shall also submit an annual progress report describing the progress of the major activities and tasks concerning the key milestones of the project. He and his team shall give detailed presentations on the progress of the project and address any concerns the stakeholders might have. The review comments of the Heads, PRC and Hub governing body constitute the basis for processes indicators. The PI shall take remedial steps to ensure and address the issues as per the recommendations of the

	stakeholders that may help ensure timely execution of project milestones. Specifically, the feedback rating in L2 to L3 reviews assesses the process indicator.
Output Indicators	The percentage of meeting the timelines for i) set goals ii) utilizing the funds quantify the output indicators. The performance of each project under the TIH shall be closely monitored against the proposed PERT/GANTT chart outlined by the PI when submitting the proposal to the TIH HGB (Hub Governing Body).
Outcome Indicators	The overall outcome of the projects, skill & HR development by the Hub meeting the targets sent by the hub provides the outcome indicator.
Impact Indicators	The publications, patents, number of skill development programmes, trained manpower, nurtured startups and collaborations that evolve from time to time are the impact indicators for the Hub. A cost to benefit analysis shall be implemented for each project to gauge the impact of each project.

To effectively manage the projects of the PPT program, a Cloud-based information and project management platform will be created. This will have both computational and storage facilities, which will be accessible to all projects funded by INiF. It will also have a centralized Web Portal for Management, which will provide collective information on all the activities' running status under the PPT program. Such a portal will be a dynamic repository of information on all activities/components, resources, and outputs, associated with the PPT program. This will be continuously updated for monitoring the progress of the PPT program by the Management Unit. The information will be used for a periodic review of the PPT program for seeking guidance from the Committee. The information will also be shared with all the stakeholders and participants in the PPT program to ensure synergy. The funding to set up the Web portal and its maintenance is be part of INiF’s infrastructure budget.

9. Time Frame

9.1 TIH activities

In general, the implementation of the TIH shall involve, apart from the many administrative actions, the following major activities:

1. Formation of Section 8 company, creation of a Hub Governing Body as per the norms specified under the grant, the appointment of Professor In-charge, CEO, and Heads of Technology Development/HRD & Skill Developments/Innovation & Start-ups/Operations.
2. For day-to-day activities, TIH will be hiring regular staff such as technical officers, assistants, accounts, purchase and administration).
3. The other important periodic activities include
    a. Calling for proposals
    b. Evaluation and selection of proposals
    c. Review (quarterly or mid-term) of proposals and products proposed
    d. Preparation and Publication of progress reports
4. Infrastructure development: IIT Tirupati is in the process of developing its infrastructure in 548 acres of allotted land. The Institute constructed a completely operational Transit Campus in an area of 35 acres in the permanent campus. The main campus construction (Stage 1) is in progress and is expected to be completed by March 2022. The Institute will be developing an infrastructure space of 20,000 square feet for the establishment of TIH. To initiate the functioning of TIH, the institute has identified about 5,000 square feet of space in the transit campus. The Institute will add additional 15,000 square feet of space after completing the Stage 1 campus construction. The Institute has demarcated 18 acres of land earmarked for the development of the research park. After establishing the research park, TIH will be shifted to Research Park.

Of these, we expect the activities listed under the first two points to be completed in the initial six months. It is clear from the above-proposed timeline that some of them are one-time activities while the remaining need to be carried out periodically or based on the need. The Hub senior management consists of Professor in charge & CEO with support and mentorship of the Hub Governing Body (HGB) will undertake the activities in time so that the aims of the TIH are achieved.

9.2 Proposed products time frame

The following tables provide proposed 21 product target goals and their respective timelines for every six months interval.

Targets: Year 1: 0-6 Months

Target Goals	Contributing to Product Numbers
Design and construction of a linear Paul trap for trapping $^{40}Ca^+$ ions; Construction of a high finesse cavity for ensuring a narrow linewidth clock laser	1
Procurement and installation of equipment such as CW Ti: Sapphire laser systems, Manpower recruitment; Technology development; HRD and skill generation	2
Procurement of equipment, field visits for requirements	3
Literature survey, Geological crop survey, Model development, Parameter identification; Prediction Algorithm development using remote sensing data and other relevant information, Quality assessment; Crop yield prediction, risk analysis, crop monitoring app development, pilot study	4
Equipment procurement, Detector simulation studies	5
Design of the Hydrodynamic Finishing System	6
Survey of positioning methods and technologies; Positioning infrastructure; Positioning infrastructure; Occupancy estimation methods; Data collection, processing, visualization; Control system; Route planning and crowd modelling	7
Development of the framework and architecture for authentication and lightweight secure communication	8
Geospatial data, Field data collection	9,10,12,13
Design of data structures	9,10,12,13
Survey of existing technologies	11
Data acquisition, preparation & literature review	14,15,16
Development and unit testing over prior scenarios	17
Development of distributed computing testbed	18
Exploration of visualization techniques, Data mining and Cleansing	19
Survey of existing technologies and Image Processing Algorithms for automated condition monitoring	20
Development of the Smart Vehicle; Develop algorithms (toolkits) to capture conditions of road pavement infrastructure assets; Develop advanced road traffic management system	21

Targets: Year 1: 7-12 Months

Targets Goals	Contributing to Product Numbers
Construction of a high finesse cavity for ensuring a narrow linewidth clock laser; Development of stable RF and DC electronics for trapping ions and minimizing ion micromotion	1
Procurement and installation of equipment such as CW Ti: Sapphire laser systems, Manpower recruitment; Technology Development; HRD and skill generation	2
Procurement of equipment, field visits for requirements	3
Literature Survey, Geological Crop Survey, Model Development, Parameter Identification; Prediction Algorithm Development using remote sensing data and other relevant information, Quality Assessment; Crop yield prediction, risk analysis, crop monitoring app development, Pilot study	4
Equipment procurement, Detector simulation studies	5
Procurement of various components	6
Survey of positioning methods and technologies; Positioning infrastructure; Occupancy estimation methods; Data collection, processing, visualization; Control system; Route planning and crowd modelling	7
Development of the framework and architecture for authentication and lightweight secure communication	8
Geospatial Data, Field Data Collection	9,10,12,13
Design of Data Structures	9,10,12,13
Integration with modelling / management tools	9,10,12,13
Algorithms of high precision data	11
Existing DL Models testing and Validation	14,15,16
Development and Unit testing over prior scenarios	17
Development of distributed computing testbed	18
Exploration of visualization techniques, Data mining and cleansing	19
Survey of existing technologies and Image Processing Algorithms for automated condition monitoring	20
Develop algorithms (toolkits) to capture conditions of road pavement infrastructure assets; Develop advanced road traffic management system; Testing and validation of algorithms; product release	21

Targets: Year 2: 0-6 Months

Target Goals	Contributing to Product Numbers
Establishment of laser locking (frequency stabilization) to stable reference cavities	1
Technology Development; HRD and skill generation	2
Simulation studies, fabrication and characterization of soil sensors, field testing, development of ICT platforms, development of nutrient delivery mechanisms; Sensor integration and fusion, process optimization by field trials, development of a controlled nutrient delivery mechanism	3
Prediction Algorithm Development using remote sensing data and other relevant information, Quality Assessment; Crop yield prediction, risk analysis, crop monitoring app development, Pilot study	4
Detector fabrication, characterization studies, designing of gain stages, Comparing the performance with PMTs, Developing UV detectors for other wavelengths	5
Procurement of various components; Development of Hydrodynamic Finishing system	6
Positioning infrastructure; Occupancy estimation methods; Data collection, processing, visualization; Control system; Route planning and crowd modelling	7
Development of protocols/algorithms and their performance analysis; Development of the prototype, implementation of the various proposed schemes and performance evaluation	8
Geospatial Data, Field Data Collection	9,10,12,13
Integration with modelling / management tools	9,10,12,13
Offline and real time simulation of the algorithms	11
Evolving with the SOAT DL model and Application	14,15,16
Deployment and field level testing for specific scenarios	17
Interfacing the testbed with big data sources and development of control theoretic models and autonomic controllers for service time management	18
Data mining and cleansing, Development of visualization platform	19
Conditioning monitoring algorithms on synthetic data	20
Testing and validation of algorithms; product release	21

Targets: Year 2: 7-12 Months

Target Goals	Contributing to Product Numbers
Develop a sub 1 Hz linewidth laser for clock spectroscopy at 729 nm	1
Technology Development; HRD and skill generation	2
Simulation studies, fabrication and characterization of soil sensors, field testing, development of ICT platforms, development of nutrient delivery mechanisms; Sensor integration and fusion, process optimization by field trials, development of the controlled nutrient delivery mechanism	3
Prediction Algorithm Development using remote sensing data and other relevant information, Quality Assessment; Crop yield prediction, risk analysis, crop monitoring app development, Pilot study	4
Detector fabrication, characterization studies, designing of gain stages, Comparing the performance with PMTs, Developing UV detectors for other wavelengths	5
Development of Hydrodynamic Finishing system	6
Positioning infrastructure; Occupancy estimation methods; Data collection, processing, visualization; Control system; Route planning and crowd modelling	7
Development of protocols/algorithms and their performance analysis; Development of the prototype, implementation of the various proposed schemes and performance evaluation	8
Geospatial Data, Field Data Collection	9,10,12,13
Integration with modelling / management tools	9,10,12,13
Create Dashboards	9,10,12,13
Offline and real time simulation of the algorithms	11
Performance Analysis of large real data and development to the product level	14,15,16
Deployment and field level testing for specific scenarios	17
Interfacing the testbed with big data sources and development of control theoretic models and autonomic controllers for service time management	18
Data mining and cleansing, Development of visualization platform	19
Testing and validation on field data	20
Testing and validation of algorithms; product release	21

Targets: Year 3: 0-6 Months

Target Goals	Contributing to Product Numbers
Perform Allan deviation measurements on clock laser stability	1
Technology Development; HRD and skill generation	2
Simulation studies, fabrication and characterization of soil sensors, field testing, development of ICT platforms, development of nutrient delivery mechanisms; Sensor integration and fusion, process optimization by field trials, development of controlled nutrient delivery mechanism; Field deployment and integration of the sensors with the delivery systems, soil map creation	3
Prediction Algorithm Development using remote sensing data and other relevant information, Quality Assessment; Crop yield prediction, risk analysis, crop monitoring app development, Pilot study	4
Developing UV detectors for other wavelengths, Testing	5
Checking of sub nano finishing capability and patenting. Then demonstration to various suitable industries and research laboratories	6
Occupancy estimation methods; Data collection, processing, visualization; Control system; Route planning and crowd modelling; End user application; Integration, testing, performance optimization	7
Development of protocols/algorithms and their performance analysis; Development of the prototype, implementation of the various proposed schemes and performance evaluation	8
Geospatial Data, Field Data Collection	9,10,12,13
Integration with modelling / management tools	9,10,12,13
Create Dashboards	9,10,12,13
Validate end to end product	9,10,12,13
Manufacturing prototype and testing	11
Compact model design for real-time applications & App creation	14,15,16
Self-sustained maintenance and source of human resources	17
Integrated testing of the testbed for the developed models of the computing testbed with the automation and autonomous systems	18
Development of visualization platform, Application of platform for disaster management	19
Pilot Deployments in a typical substation	20
Testing and validation of algorithms; product release	21

Targets: Year 3: 7-12 Months

Target Goals	Contributing to Product Numbers
Setup beat-note measurements with an optical frequency comb	1
Technology Development; HRD and skill generation	2
Simulation studies, fabrication and characterization of soil sensors, field testing, development of ICT platforms, development of nutrient delivery mechanisms; Sensor integration and fusion, process optimization by field trials, development of controlled nutrient delivery mechanism; Field deployment and integration of the sensors with the delivery systems, soil map creation	3
Prediction Algorithm Development using remote sensing data and other relevant information, Quality Assessment; Crop yield prediction, risk analysis, crop monitoring app development, Pilot study	4
Developing UV detectors for other wavelengths, Testing	5
Checking of sub nano finishing capability and patenting. Then demonstration to various suitable industries and research laboratories	6
Occupancy estimation methods; Data collection, processing, visualization; Control system; Route planning and crowd modelling; End user application; Integration, testing, performance optimization	7
Development of protocols/algorithms and their performance analysis; Development of the prototype, implementation of the various proposed schemes and performance evaluation	8
Geospatial Data, Field Data Collection	9,10,12,13
Create Dashboards	9,10,12,13
Validate end to end product	9,10,12,13
Beta release, training, manuals	9,10,12,13
Manufacturing prototype and testing	11
Real time demonstration	14,15,16
Self-sustained maintenance and source of human resources	17
Integrated testing of the testbed for the developed models of the computing testbed with the automation and autonomous systems	18
Development of visualization platform, Application of platform for disaster management	19
Pilot Deployments in a typical substation	20
Testing and validation of algorithms; product release	21

Targets: Year 4: 0-6 Months

Target Goals	Contributing to Product Numbers
Characterize the clock laser frequency in terms of first and second-order frequency shifts due to micromotion, laser intensity, ambient magnetic field, polarizability, black-body radiation, etc.; Perform Allan deviation measurements on the clock frequency	1
Technology Development; HRD and skill generation	2
Field deployment and integration of the sensors with the delivery systems, soil map creation; Integration of technology components and demonstration, and technology transfer	3
Prediction Algorithm Development using remote sensing data and other relevant information, Quality Assessment; Crop yield prediction, risk analysis, crop monitoring app development, Pilot study; Web-Framework frontend, backend development and App development, Repeat of Beta Version and study of market value; Release version of the product and commercialization	4
Assembly, testing	5
End user application; Integration, testing, performance optimization; Final report and manuals generation	7
Development of the prototype, implementation of the various proposed schemes and performance evaluation; Trial for evaluation and verification of the prototype in Indoor and outdoor scenarios	8
Geospatial Data, Field Data Collection	9,10,12,13
Beta release, training, manuals	9,10,12,13
Rollout to production and support	9,10,12,13
Pilot Deployments in a typical smart grid control application	11
To customize these product developments in further applications related to anomaly detection, precision Agriculture, monitoring with change detection in smart cities	14,15,16
Field deployment and continuous improvement of products	19

Targets: Year 4: 7-12 Months

Target Goals	Contributing to Product Numbers
Characterize the clock laser frequency in terms of first and second-order frequency shifts due to micromotion, laser intensity, ambient magnetic field, polarizability, black-body radiation, etc..; Perform Allan deviation measurements on the clock frequency	1
Technology Development; HRD and skill generation	2
Field deployment and integration of the sensors with the delivery systems, soil map creation; Integration of technology components and demonstration, and technology transfer	3
Prediction Algorithm Development using remote sensing data and other relevant information, Quality Assessment; Crop yield prediction, risk analysis, crop monitoring app development, Pilot study; Web-Framework frontend, backend development and App development, Repeat of Beta Version and study of market value; Release version of the product and commercialization	4
Assembly, testing	5
End user application; Integration, testing, performance optimization; Final report and manuals generation	7
Development of the prototype, implementation of the various proposed schemes and performance evaluation; Trial for evaluation and verification of the prototype in Indoor and outdoor scenarios	8
Geospatial Data, Field Data Collection	9,10,12,13
Rollout to production and support	9,10,12,13
Pilot Deployments in a typical smart grid control application	11
To customize these product developments in further applications related to anomaly detection, precision Agriculture, monitoring with change detection in smart cities	14,15,16
Field deployment and continuous improvement of products	19

Targets: Year 5: 0-6 Months

Target Goals	Contributing to Product Numbers
Characterize the clock laser frequency in terms of first and second-order frequency shifts due to micromotion, laser intensity, ambient magnetic field, polarizability, black-body radiation, etc..; Perform Allan deviation measurements on clock frequency; Perform error-budget calculations on the observed clock frequency	1
HRD and skill generation; Dissemination of results and commercialization of product/technology	2
Integration of technology components and demonstration, and technology transfer	3
Crop yield prediction, risk analysis, crop monitoring app development, Pilot study; Web-Framework frontend, backend development and App development, Repeat of Beta Version and study of market value; Release version of the product and commercialization	4
Integration and commissioning, technology transfer	5
Trial for evaluation and verification of the prototype in Indoor and outdoor scenarios	8

Targets: Year 5: 7-12 Months

Target Goals	Contributing to Product Numbers
Perform error-budget calculations on the observed clock frequency	1
HRD and skill generation; Dissemination of results and commercialization of product/technology	2
Integration of technology components and demonstration, and technology transfer	3
Crop yield prediction, risk analysis, crop monitoring app development, Pilot study; Web-Framework frontend, backend development and App development, Repeat of Beta Version and study of market value; Release version of the product and commercialization	4
Integration and commissioning, technology transfer	5
Trial for evaluation and verification of the prototype in Indoor and outdoor scenarios	8

10. Finance Breakup

This section provides the details of the financial expenditures for the establishment of INiF. The Hub's financial break-ups include human resources, travel, technology development, skill development, start-up & entrepreneurship, international collaborations, equipment, and CAPEX. The total budget proposed for the establishment of INiF is Rs. 100 Crores. The following subsections give the details of the financial breakups. Table 4 and Table 5 present the year-wise INiF expenditure for each break-up and estimated recurring and non-recurring expenses, respectively. The following subsections will give the details of the financial break-ups.

Table 4: Estimated year-wise expenditure for INiF

Head	Y1	Y2	Y3	Y4	Y5	Total (Crs)
Manpower (TIH) & HRD	4.00	4.50	5.00	5.50	6.00	25.00
Travel	0.25	0.40	0.50	0.40	0.30	1.85
Technology Development	2.00	3.50	5.75	2.00	0.50	13.75
Skill Development	0.50	0.60	0.80	0.60	0.50	3.00
Startup/ Entrepreneurship	0.50	4.50	5.00	1.50	0.40	11.90
International Collaborations	0.00	1.00	0.70	0.50	0.30	2.50
Equipment	0.00	18.00	11.00	0.00	0.00	29.00
CAPEX	0.00	10.00	2.00	1.00	0.00	13.00
Total	7.25	42.50	30.75	11.50	8.00	100.00

Table 5: Estimated Recurring and Non-Recurring year-wise expenditure for INiF

Budget Head/Year	Y1	Y2	Y3	Y4	Y5	Total (Crs)
Recurring	7.25	14.50	17.75	10.50	8.00	58.00
Non-recurring	0.00	28.00	13.00	1.00	0.00	42.00
Total	7.25	42.50	30.75	11.50	8.00	100.00

10.1 Manpower (HRD & TIH)

The workforce expenditure has two significant heads: i) INiF management to support the administration and monitoring of the TIH activities, including Chief Executive Officer, technical and administrative staff, and ii) Human Resources Development for the proposed technology development and products, including summer interns, undergraduate, graduate, doctoral and postdoctoral or faculty fellowships. Table 6 provides the funding requirements for the total manpower expenditure. In the Cost-Benefit Analysis section, the details of the year-wise human resources requirements for each product are detailed.

Table 6: Estimated Manpower Expenditure

S. No.	Manpower component	Cost (Crs)
1	TIH Staff (CEO, Managers, Accounting staff, administrative staff, office/lab assistants, project and technical staff)	9.46
2	Students (undergraduate, graduate, doctoral, summer interns, research assistants), postdoctoral fellows and faculty fellows	15.54
	Grand Total	25.00

10.2 Technology Development

One of the Hub's primary focuses is on technology development. The critical components of technology development are patents, publications, IPR, increasing PPT research base, Industry Standard Prototyping, field testing, data collection and ecosystem creation. The estimated expenditure on technology development is presented in Table 7.

Table 7: Estimated Expenditure for Technology Development

S.No	Technology Development	Cost (Crs)
1	Patents, Publications, IPR, Increase in CPS Research Base	6.00
2	Includes Industry Standard Prototyping costs + Field Testing + Data collection + Ecosystem creation	7.75
	Total	13.75

10.3 Skill Development, Start-up, and International Collaborations

Based on the guidelines of the NM-ICPS, the Hub's estimated budget for skill development, start-ups, and International collaboration is presented in Table *8*. The skill development includes workshops, user-oriented hands-on training programs, counsel, and support services for the start-ups. The INiF will require funding to foster the growth of start-ups and entrepreneurs for several proposed activities, such as (a) establishment of Technology Business Incubator (TBI), and (b) funding for start-ups and spin-off companies, grand challenges and competitions, PRAYAS, an Entrepreneur in Residence (EIR), Dedicated Innovation Accelerator (DIAL), Seed Support System (SSS). The international collaboration fund will be utilized for conducting international workshops and one international conference per year, travel and local hospitality expenses for foreign collaborators, and visits of students and project staff for international conferences.

Table 8: Estimated Expenditure for Skill Development, Start-up & Entrepreneurship, and International Collaborations

S. No	Head	Total (In Crs)
1	Skill Development	3.00
2	Startup/ Entrepreneurship	11.90
3	International Collaborations	2.50

10.4 Equipment for Research and Product Development

The INiF has identified nine key product frameworks (**Error! Reference source not found.**). The d evelopment of the products requires infrastructure, workforce, and facilities. The proposed frameworks need the latest equipment for testing, product development, and skill development. The details of the products and their estimated cost are presented in Table 9.

Table 9: Proposed product framework equipment details and their cost

S. No	Equipment	Cost (Crs)
1	Laser systems (for ionization, cooling and spectroscopy)	1.50
2	Photodetector QE measurement system, Photon counting electronics, Optical sources, Lithography, Optics (filters, telescope etc.), Consumables (Semiconducting substrates, Chemicals, Spare parts, miscellaneous), Fabrication charges	1.50
3	E-beam evaporator, Ellipsometer, PCB prototyping machine, Contact angle measurement unit, Electrical measurement units (SMU, function generators, power supplies, oscilloscopes), Boards, Microcontrollers and DAQs, Commercial sensors, drones for aerial imaging, Consumables	0.60
4	Diffraction based particle and droplet sizing device (Malvern Spraytech/PDPA system), Spray nozzle fabrication & flow controllers, Consumables	0.40
5	Polymer Micro and Nanoparticle generator and accessories, High precision polymer and fertilizer blenders along with accessories, In-vitro CRF degradation in various soil setup, Scratch tester	0.40

Table 9 (Continued): Proposed product framework equipment details and their cost

S. No	Equipment	Cost (Crs)
6	Cavity Reactor Fabrication, Laser systems with accessories, Microwave source with accessories, RF Generator source, kHz frequency generator, UV-VIS monochromator, Vibration isolation table, Vacuum System	1.50
7	Stand-alone SDR Type 1 (4 Nos), Standalone SDR Type 2 (5 Nos), SDR for indoor scenario (6 Nos); data logger (2 Nos); Computing unit for interfacing with SDR (5 Nos); specific sensor kits and raspberry pi; specific accessories for SDR, Antennas, Protection shields; FPGA Kintex, Zynq and Zed boards (11 Nos), Computing unit for interfacing FPGA (5 Nos), ARM boards (10 Nos), FPGA accessories (1 No), IC design software for the board	1.20
8	DGX A100 GPU server system with cooling rack; High-end GPU workstations;	1.50
9	LiDAR (Terrestrial and Aerial), Bathymetry	1.25
10	GPR, Thermal Imaging Camera	1.00
11	DGPS CORS + Field DGPS	0.75
12	Real-Time Simulators, Relays, Measurement Units, Sensors, clocks; Software Tools; Thermal Imaging Camera	1.50
13	Portable Water Quality Monitoring KIT + Milli-Q Water Purification Unit (Type -1 Water) + Onsite + lab)	0.15
14	Two Thermal Cameras	0.50
15	Vehicle and Image Processing Tools along with Software Development	0.60
16	Field Spectrometer, Drones and other accessories	0.65
17	Dedicated power Edge servers, Fog devices and networking accessories, Modular Production systems	0.70
18	Virtual Reality Systems (10 Nos) HTC/ Oculus or similar - Virtual reality hardware systems; Touchscreen Smart Displays (3/4 Nos) LG/ Samsung or similar - Touch-based input to augmented and virtual reality systems/visualization; Microsoft Hololens 2 (3 Nos) Microsoft - Immersive reality developer edition; Google Daydream View Headsets (5 Nos) Google - Android compatible VR glasses; Smartphones and Tablets (10 Nos) Samsung/Similar - Develop and deploy smartphone-based PoC devices; Two high-end GPU workstations	0.60
19	Motorized stage (3 Axis Servo); Hydrodynamic Polishing system with Granite Machine bed structure; Rotary and reciprocating attachments; Cutting tools	0.20
20	ARM-based Development boards, Sensors, Smartphones, Networking devices, LiDAR 360 camera and other Hardware prototyping facilities, etc.,	0.60
21	Computing Infrastructure	10.00
22	Software (skill development, research, and product developments)	1.90
	Total	**29.00**

10.5 Capital Expenditure

The CAPEX will be used to establish and maintain the infrastructure for INiF. The funds include requirements for renting, furnishing, office space creation, electrical works, and other CAPEX items. The year-wise details of the CAPEX expenditure are provided in Table 4.

10.6 Facilities and resources available with IITT that could be shared by the Hub

The Hub will be utilizing Host Institution facilities such as equipment, laboratories and workshops, computational facilities, and software for the development of the products. The in-kind support of IIT Tirupati in terms of the above facilities is about Rs. 10 crores. Table 10 provides the details about the host institute facilities shared with INiF for product developments.

Table 10: Facilities and Resources available with IITT

S.No	Name of the facility	Cost (Crs)
1	Institute Server(s) with NVIDIA Tesla GPUs and 1 TB RAM	1.00
2	High End Workstation Lab (with 30 NVIDIA 2080Ti GPUs)	1.00
3	Laser systems for doing calcium ion spectroscopy for atomic clocks or quantum computation or quantum technology purposes	2.00
4	Cavity ring-down spectrometer	0.24
5	Narrow linewidth (<100kHz) CW Laser system in the wavelength range (700-1025 nm & 350-500 nm & 250-255 nm) for precision spectroscopy	3.25
6	UV-VIS (200 nm-900nm) monochromator	0.38
7	Microwave source with waveguide coupler and water cooling system	0.35
8	RF source with variable impedance matching network	0.22
9	Tunable low-frequency high voltage signal generator	0.11
10	Vibration isolation optical table (6ftx5ft)	0.03
11	Stand-alone software-defined radio	0.53
12	FPGA boards for prototyping and proof-of-concept development	0.23
13	MATLAB Software	0.10
14	AUTOCAD Software	0.05
15	SOLIDWORKS Software	0.05
16	Cadence Software	0.20
17	COMSOL Multiphysics Software	0.10
18	Mathematica Software	0.05
19	ORCAD Software	0.03
20	SIMULIA ABAQUS Software	0.08
21	Ansys Software	0.07
22	GeoStudio Software	0.03
23	CSI Software	0.04
	Total	**10.14**

11. Cost-Benefit Analysis and DST Targets/Outcomes

The overall revenues projected from the products proposed in section 7 is Rs. 417 Crores over 10 years. Of this, INiF expects to capture 3-5% as licensing revenue. Another source of short-term revenue for the centre are various training programs, reports and databases, we will be creating and we expect to raise Rs. 3 Crores from these over the first five years of its operations. Apart from this, INiF will also hold equity in the spin-off companies based on the IP generated. Apart from the financial benefits captured here, several products like disaster management, water management, energy management and crop management will have significant societal benefits such as economic development, damage protection, saving lives and livelihood improvement of poor communities. Other economic benefits and social benefits such as the earnings of the manpower trained and its socio-economic value and impact of the advanced technologies on the evolution of the society and impact on the virtuous cycle of knowledge creation are not captured here. These outcomes for INiF and comparison with the targets set by DST are discussed in this section.

Table 11: Framework-wise expected HRD, publications/patents, startups and revenue generation

Prod. Frame work No.	UG	PG	PhD	PDF	Summer Interns	Publ. /IPR	IP/Patent s/Licensin g	Startups	Expected Revenue Generation (10 Yrs. in Crs)
1	13	5	2	0	32	3	1	2	25.00
2	13	5	2	0	32	3	1	2	25.00
3	27	10	2	1	64	3	4	2	50.00
4	13	5	6	1	32	10	2	6	5.00
5	78	30	6	0	124	3	4	6	106.00
6	13	5	2	0	32	6	0	2	37.00
7	27	10	4	1	68	5	4	4	36.00
8	13	5	2	0	32	5	0	2	100.00
9	13	5	6	0	96	6	4	6	33.00
Total	**210**	**80**	**32**	**3**	**512**	**44**	**20**	**32**	**417.00**

From IIT Tirupati, about 48 faculty from 9 Departments have shown their interest in participating in the hub activities. A total of 21 product ideas are spread across these 9 frameworks (**Error! Reference source not found.**) as a result of research challenges and product perspectives. The product details include Target beneficiaries, Unique selling points, Patents that could be filed, Market revenue and Industry participation. IIT Tirupati and TIH expect at least five-fold outcomes viz. human resource development (UG, PG, PhD, PDF and Summer Internships), Publications, Incubation Startups, Patents and overall valuation. Table *12* summarizes the expected targets as set by DST in its communication (D.O.No. DST/NM-ICPS/MGB/2018 dated: 30/07/2020) vis-à-vis what is projected. In Table 14, the targets and deliverables of the TIH over the span of five years is presented.

Table 12: DST Target vs Projected Target

S. No.	Activity	Target set by DST	Projected Target
1	**Technology Development**		
	(a) No of Technologies (IP, Licensing, Patents, etc.)	19	20
	(b) Technology Products	12	21
	(c) Publications, IPR, and other Intellectual activities	36	44
	(d) Increase in CPS Research Base	60	60
2	**Entrepreneurship Development**		
	(a) CPS-Technology Business Incubator (TBI)	1	1
	(b) CPS-Start-ups and Spin-off companies	32	32
	(c) CPS-GCC-Grand Challenges and competitions	1	1
	(d) CPS-Promotion and Acceleration of Young and Aspiring technology entrepreneurs (CPS-PRAYAS)	1	1
	(e) CPS-Entrepreneur in Residence (CPS-EIR)	19	19
	(f) CPS-Dedicated Innovation Accelerator (CPS-DIAL)	1	1
	(g) CPS-Seed Support System (CPS-SSS)	1	1
	(h) Job Creation	7500	7500
3	**Human Resource Development**		
	(a) Graduate Fellowships	210	210
	(b) Post Graduate Fellowships	39	80
	(c) Doctoral Fellowships	23	32
	(d) Postdoctoral Fellowships	3	3
	(e) Faculty Fellowships	0	2
	(f) Chair Professors	3	3
	(g) Skill Development	380	380
4	**International Collaboration**		
	(a) International Collaboration	1	3

Table 14: Deliverable and Targets (5 Year Plan)

S.No.	Target Area	Targets					
		1st Yr	2nd Yr	3rd Yr	4th Yr	5th Yr	Total
1.0	**Technology Development**						
(a)	No. of Technologies (IP, Licensing, Patents etc.)	-	-	3	7	10	20
(b)	Technology Products	-	1	4	6	10	21
(c)	Publications, IPR and other Intellectual activities	-	5	10	14	15	44
(d)	Increase in CPS Research Base	-	5	15	15	25	60
2.0	**Entrepreneurship Development**						
(a)	Technology Business Incubator (TBI)	1	-	-	-	-	1
(b)	Start-ups & Spin-off companies	-	1	6	10	15	32
(c)	GCC- Grand Challenges and Competitions	-	-	1	-	-	1
(d)	Promotion and Acceleration of Young and Aspiring technology entrepreneurs (PRAYAS)	-	-	1	-	-	1
(e)	CPS-Entrepreneur In Residence (EIR)	-	2	3	5	9	19
(f)	Dedicated Innovation Accelerator (DIAL)	-	-	-	1	-	1
(g)	CPS – Seed Support System (CPS-SSS)	-	-	-	1	-	1
(h)	Job Creation	-	-	1500	2500	3500	7500
3.0	**Human Resource Development**						
(a)	Graduate Fellowships	-	50	50	50	60	210
(b)	Post Graduate Fellowships	-	20	20	20	20	80
(c)	Doctoral Fellowships	-	-	-	16	16	32
(d)	Faculty Fellowships	-	1	1	-	-	2
(e)	Chair Professors	-	1	1	1	-	3
(f)	Skill Development	-	40	80	100	160	380
4.0	**International Collaboration**	-	1	1	1	-	3

11.1 Confidence in Achieving the projected Target

11.1.1 Technology Development

The projected targets related to items 1(a) and 1(c) of Table 12 are justified in Table 11. Section 7 of this report provides 21 product ideas with timelines and market potentials as is mentioned in 1(b) of Table 12. A list of 48 faculty from IIT Tirupati is given in Section 15. Also, the list of collaborators which includes 27 international collaborators of which 16 are committed and 58 Indian collaborators of which 35 committed already and will actively participate in INiF's activities are given in Section 16. Section 17 shows the list of industry partners from India and abroad, where 7 Foreign Industries and 42 Indian Industries will support INiF's activities, of which 26 Industries have already given their support letters and the remaining industry partnerships are ongoing on negotiations of terms and conditions. We plan to have at least 60 researchers mentored by INiF which could promise a strong research base in the next 5 years. Also, the Hub will be collaborating with a number of researchers, institutes and centres of excellence in PPT. Currently, we are is in the process of connecting with major institutes such as Anna University and SASTRA Deemed University under the hub and spoke model. This strong portfolio of projects and collaborations will create an ecosystem for nurturing start-ups and spin-offs in PPT.

11.1.2 Entrepreneurship Development

CPS- Technology Business Incubator (TBI): IIT Tirupati will establish the TBI once the funding for INiF is received. The TBI will organize various programs to promote entrepreneurship within the PPT community and train its members in starting and growing such advanced technology-based ventures.

CPS- Start-ups & Spin-off companies: All spin-offs from INiF will be incubated at the TBI. Furthermore, we expect that the thriving ecosystem that grows through the projects at INiF will help us to attract other start-ups from across the country. The TBI with a partner with The Global Accelerator for Innovation Network (The GAIN) to provide these startups and spin-offs with mentorship and access to the industrial and investor community in India and abroad. The GAIN will also support the TBI by connecting them with companies abroad to fulfil their supply chain needs and market expansion plans. Together, we expect to support the creation of at least 32 startups and spin-off companies.

CPS-GCC- Grand Challenges and Competitions: TIH PPT is planning to organize one grand challenge using the under-skill development fund.

INiF is committed to organize or facilitate the following entrepreneurship development as per the DST guidelines provided.

1. CPS-PRAYAS
2. CPS-EIR
3. CPS-DIAL
4. CPS-SSS

Job Creation: INiF will ensure to prepare further manpower through various training programs, skill development programs such as SSS, EIR, DIAL, PRAYAS and involving good number of UG, PG and research students in product developments to equip themselves to take up the PPT technology developments and contribute in the futuristic developments of PPT. This paves clear guidance and direction to the origin of spinoffs and startup companies in line with the proposed products and enables around 7500 in the first 5 years.

11.1.3 Human Resource Development

The human resource development listed in 3(a) to 3(e) of Table 13 are detailed in Table 12. IIT Tirupati and TIH become a base platform for human resource development. Involving a good proportion of UG (210), PG (80), PhD(32), PDF(3) and Summer Internships (512) students as listed in Table 12 brings out a large number of highly skilled technology developers and innovators in this PPT domain. As the proposed 21 product developments cover various technological and research themes of PPT it is expected that the skill development of these various manpower spans over the wide spectrum of PPT to evolve interdisciplinary and innovative product developments in future. The skill development targets will be achieved by various training programs, certificate programmes, hackathons, challenges/competitions and summer internships.

11.1.4 International Collaboration

Sections 16 and 17 provide more details about the international collaborators and industry partnership. Already, three companies have expressed their interest. We expect another 10 companies down the line. Further, we expect that at least three of these will grow into a large collaboration involving multiple experts from academia and industry.

12. Risk Analysis

Early stage technology development and commercialization that INiF will embark on carry technology, market and implementation risk. INiF will manage the technology risk through thorough evaluation of the projects during the selection phase and close monitoring of the selected projects on a regular basis and staging the funding. The implementation risk is managed by having the right mentors to guide the development and creating a pool of highly talented manpower through various skill development programs. INiF will also strive to ensure rapid decision-making in order to minimize implementation delays. The market risk is managed by creating an ecosystem of industry partners and close scrutiny of commercialization strategies. In addition, every failed project will provide INiF and the people involved in the project an opportunity to learn and improve the project support and management practices. It is also important to note that the collective learnings from both successful and failed projects will help build our knowledge base in PPT and improve our overall success rate. While these strategies do not completely eliminate the risk, they increase the odds of developing advanced solutions in PPT and creating direct and indirect social and economic impacts envisioned under this proposal.

Furthermore, INiF will be developing cutting edge technologies. Deployment of these solutions in the market will require compliance with existing and evolving standards and regulations. Any lack of clarity in the standards and regulation of these solutions in the market will also have a significant impact on the revenue generation potential of the projects. Since many of our solutions involve the development of hardware, availability of components and tariff structure relevant to imported components will also affect the rate of scale-up and market deployment.

13. Legal Framework

INiF will be set up as a Section 8 company under the Companies Act. Similarly, the TBI will be a Section 8 company. The relationship between IIT Tirupati, DST and INiF will be governed by an MoU. The various projects funded by INiF will involve commercial and financial contracts based on domestic and international laws. Additionally, INiF will be seeking protection of its Intellectual property under various national and international IP regimes. The strength of these laws and regimes and our ability to enforce them will have a significant impact on the revenue generation potential of the projects.

14. Environmental Factors

IIT Tirupati has 548 acres of land of which 18 acres is earmarked for the research park. IIT Tirupati will manage the TIH setup in this existing land. Since all work in this proposal requires academic, research and product development, with the help of the existing setup, we could establish TIH including the construction of remote sensing lab, building constructions for Section 8 company and other allied startups with minimal environmental impact. We do not require any environmental clearances concerning the land acquisition. The work will be carried out in an existing academic and research institution setting, and hence, there will be no environmental impact.

Environmental clearances are not involved as it is based on green technologies. Furthermore, forestry clearances are not required as there is no clearance of forest land or acquisitions are involved. Additionally, wildlife clearances are also not required as the project is being implemented at existing academic institutions and there is no direct or indirect impact on wildlife.

15. List of Faculty Participants

IIT Tirupati has a strong emerging group of faculty members working on propositions and developments of technology related to (i) Atomic Clock, (ii) Precision agriculture - instruments, manufacturing, mapping (iii) Precision manufacturing, (iv) Indoor positioning and its application and (v) Precision spectroscopy techniques. IIT Tirupati is also enriched with faculty having their research expertise in (i) Secure communication, (ii) Image processing of remote sensing data, (iii) Natural hazard assessment, disaster risk management and Infrastructure resources management, (iv) Energy management and Smarter and Sustainable city developments and (v) Data science and Visualization. Bringing research and development strength from multiple disciplines and nearly 50 % of the IIT Tirupati faculty involvement, IITTP aims to develop a state-of-the-art Technology Innovation Hub (TIH) in PPTs. The specific list of faculty participants in TIH activities is given below. As noted from the table below we have 48 IIT Tirupati faculty and a Startup & Entrepreneurship manager shall be acting as members in the TIH product developments and activities.

S. No.	Name	Designation	Department	Area of Expertise	Roles/ Responsibilities
1	Dr. Abhijit Ganguli	Associate Professor	Civil & Environmental Engineering	Structural Engineering, Nondestructive Evaluation	Member
2	Dr. Ananya Lahiri	Assistant Professor	Mathematics and Statistics	Statistics and Probability	Member
3	Dr. Arijit Sharma	Assistant Professor	Physics	Experimental AMOP	Member
4	Dr. B. Krishna Prapoorna	Associate Professor	Civil & Environmental Engineering	Transportation Engineering	Member
5	Dr. Balaji Subramanian	Assistant Professor	Mechanical Engineering	Experimental and computational fluid dynamics, wind energy, drones.	Member
6	Dr. Chandra Sekhar Bahinipati	Assistant Professor	Humanities and Social Science	Socio-economic vulnerability assessment	Member
7	Dr. G. Ramakrishna	Assistant Professor	Computer Science and Engineering	Graph Algorithms, Algorithmic Engineering, GPU Computing.	Member
8	Dr. Girish Kumar Rajan	Assistant Professor	Mechanical Engineering	Mathematical Modelling, Fluid Mechanics	Member

S. No.	Name	Designation	Department	Area of Expertise	Roles/ Responsibilities
9	Dr. Gorthi Subrahmanyam	Assistant Professor	Electrical Engineering	Signal Processing, Computer Vision, Image Processing, Medical Imaging	Member
10	Dr. A. Gowri	Assistant Professor	Civil & Environmental Engineering	Transportation Engineering	Member
11	Dr. Hiran Vedam	Senior Advisor, Innovation & Entrepreneurship	-	Technology Management, New Business Development, IP and Business Strategy, Start-up Financing	Member
12	Dr. Ishapathik D	Assistant Professor	Mathematics and Statistics	Statistical Modelling	Member
13	Dr. Iyer Ravi Prakash	Professor	Computer Science and Engineering	Multidisciplinary Systems Design & Optimization	Member
14	Dr. Jaynaryan T Tudu	Assistant Professor	Computer Science and Engineering	VLSI Systems	Member
15	Dr. Kalidas Yeturu	Assistant Professor	Computer Science and Engineering	Machine Learning Algorithms, Applications and Big Data Technologies	Member
16	Dr. Madan Mohan Avulapati	Assistant Professor	Mechanical Engineering	Spray and Combustion	Member
17	Dr. M. Nabil	Assistant Professor	Chemical Engineering	Process Systems Engineering	Member
18	Dr. Mamilla Ravi Sankar	Associate Professor	Mechanical Engineering	Smart Manufacturing	Member
19	Dr. N. N. Murty	Associate Professor	Electrical Engineering	Solid-state devices, Sensors	Member
20	Dr. Oinam Romanbabu Meetei	Assistant Professor	Civil & Environmental Engineering	Seismic rehabilitation and retrofitting of concrete and steel structures, Risk Assessment	Member
21	Dr. P. S. SaiKrishna	Assistant Professor	Electrical Engineering	Control Systems/Robotics/Autonomic Computing	Member
22	Dr. Panchatcharam Mariappan	Assistant Professor	Mathematics and Statistics	Mathematical Modelling, Computational Fluid Dynamics,	Member

S. No.	Name	Designation	Department	Area of Expertise	Roles/ Responsibilities
23	Dr. Parthajit Mohapatra	Assistant Professor	Electrical Engineering	Information theory, physical layer secrecy and wireless communication	Member
24	Dr. Prasanna Venkatesh Sampath	Assistant Professor	Civil & Environmental Engineering	Groundwater Engineering	Member
25	Dr. Prashanth Vooka	Assistant Professor	Electrical Engineering	Embedded Systems, Data Acquisition, Interface Circuits for Sensors	Member
26	Dr. Rama Krishna Sai Gorthi	Associate Professor	Electrical Engineering	Image Processing, Computer Vision, Machine Learning, Deep Learning.	Member
27	Dr. Reetesh Kumar Gangwar	Assistant Professor	Physics	Spectroscopy, Plasma Physics, Atomic and Molecular Physics	Member
28	Dr. Roshan Srivastav	Assistant Professor	Civil & Environmental Engineering	Hydroclimatology, Flood Risk Assessment, GIS & Remote Sensing, Water Resources Systems	Member
29	Dr. Shihabudheen M. Maliyekkal	Assistant Professor	Civil & Environmental Engineering	Water Quality, Material Science	Member
30	Dr. K. N. Satyanarayana	Director and Professor	Civil & Environmental Engineering	Disaster management, Infrastructure Planning	Member
31	Dr. Sridhar Chimalakonda	Assistant Professor	Computer Science & Engineering	Software Engineering Social Media Analytics Visualization User Interfaces	Member
32	Dr. Vaneet Kashyap	Assistant Professor	Humanities and Social Science	Human Resources Management/Organizational Behavior	Member
33	Dr. Venkata Ramana Badarla	Associate Professor	Computer Science and Engineering	Wireless Networks, Cloud Computing, IoT, ICT and its applications to Precision Agriculture and Smart Infrastructure	Member

S. No.	Name	Designation	Department	Area of Expertise	Roles/ Responsibilities
34	Dr. Viju Nair	Assistant Professor	Electrical Engineering	Power Electronics	Member
35	Dr. Vignesh V	Assistant Professor	Electrical Engineering	Smart Power Grids, Data Driven Automated Fault Diagnosis of Power System Assets	Member
36	Dr. Vikramkumar Pudi	Assistant Professor	Electrical Engineering	Digital VLSI	Member
37	Dr. Ajay Kumar	Assistant Professor	Mechanical Engineering	Advanced Casting and forming	Member
38	Dr. N. Venkaiah	Associate Professor	Mechanical Engineering	Advanced Manufacturing Processes	Member
39	Dr. Rajib Biwas	Assistant Professor	Chemistry	Molecular Modeling	Member
40	Dr. Subba Reddy	Assistant Professor	Mechanical Engineering	Advanced Composite Materials, Polymers	Member
41	Dr. Sunil Kumar	Associate Professor	Chemical Engineering	Microfluidics and Granular flow, Process Scale-up	Member
42	Dr. Sasidhar Gumma	Professor	Chemical Engineering	Adsorption and Metal-Organic Frameworks	Member
43	Dr. Koteswara Rao	Assistant Professor	Physics	Material science and Magnetic Materials	Member
44	Dr. Narendra Singh	Assistant Professor	Chemical Engineering	Surface Engineering and Nano Materials	Member
45	Dr. D. V. Kiran	Assistant Professor	Mechanical Engineering	Smart Manufacturing, Precision Additive Manufacturing, Welding	Member
46	Dr. Sri Ram	Assistant Professor	Mechanical Engineering	Vibrations	Member
47	Dr. Suresh Jain	Professor	Civil Engineering	Pollution	Member
48	Dr. Saranya Kshatriya	Assistant Professor	HSS	Stock Market, Risk Management Analysis	Member

16. National/International Collaborations

Proposed TIH actives and product developments are being supported by a large number of National and International collaborators. (i) Faculty groups from top international universities such as University of Purdue, USA, Weizmann Institute of Science, Israel, University of Waterloo, Canada, Toronto, Canada, Arizona State University, USA etc., Korea Institute of Industrial Technology, South Korea, INRIA/IRISA, France ; (ii) faculty groups from IISc, many of the other IITs, IISERs and other primer institutes in India; (iii) the scientist from top Government R&D labs such as ISRO, ICAR, DRDO, NARL and (iv) few connecting catalyst organizations such as The GAIN have shown keen interest in the collaborative development of the products and also for the involvement in TIH activities. The explicit list of 85 collaborators in these national and international institutes of repute are given in the table below.

S. No	Collaborator	Designation	Institute	Domain	Status
1	Dr. Nandini Rajamani	Assistant Professor, Biology	Indian Institute of Science Education and Research Tirupati	Ecology of Species	Committed
2	Dr. V. V. Robin	Assistant Professor, Biology	Indian Institute of Science Education and Research Tirupati	Ecology, behavioural ecology, biogeography and evolutionary biology	Committed
3	Dr. P. C. Nayak	Assistant Professor, Deltaic Regional Centre	National Institute of Hydrology	Watershed management, hydrologic modelling, climate change on water resources, drought analysis, flood forecasting	Committed
4	Dr Anand T. N. C.	Associate Professor, Mechanical Engineering	IIT Palakkad	Multiphase flow and sprays	Committed
5	Dr. Rebecca Ramhmachhuani	Assistant Professor, Civil Engineering	Mizoram University	Seismic hazards analysis, Soil dynamics and Engineering seismology	Committed
6	Prof. Sridharakumar Narasimhan	Professor, Chemical Engineering	Indian Institute of Technology Madras	Optimization, Water networks, Process control, sensor networks	Committed

S. No	Collaborator	Designation	Institute	Domain	Status
7	Dr. Umesh Kadhane	Associate Professor and Head, Department of Physics	Indian Institute of Space Science & Technology	Experimental and theoretical atomic and molecular physics, X-ray emission spectroscopy, Mass spectrometry of molecular ions, giant resonances, Biomolecules, cluster ions	Committed
8	Prof. Ravikrishna R.V.	Professor, Mechanical Engineering	IISc Bangalore	Sprays and Combustion Diagnostics	Committed
9	Dr. Kavita Sutar	Lecturer, Mathematics	Chennai Mathematical Institute	Commutative algebra, Representation theory, Representations of quivers and Combinatorics	Committed
10	Dr. Ramkrishna Pasumarthy	Associate Professor, Electrical Engineering	Indian Institute of Technology Madras	Modelling and Control of Complex Physical Systems	Committed
11	Dr. Diganta M	Professor	ISI Kolkata	Sampling Theory, Statistics,	Committed
12	Dr. Rituparna Sen	Assistant Professor	ISI Kolkata	Markov Process, Statistics	Committed
13	Dr. Nirav Bhatt	Assistant Professor, Biotechnology	Indian Institute of Technology Madras	Reaction networks, Bioprocess control	Committed
14	Dr. J. Ramkumar	Professor	IIT Kanpur	Micro and Nano Manufacturing	Committed
15	Dr. Subhadeep De	Associate Professor, Physics	IISER Pune	Optical Physics	Committed
16	Dr. Subhasis Panja	Senior Scientist	NPL	Time and Frequency Standard	Committed
17	Mr. Vivek Saxena	Chief Executive Officer	The GAIN	Catalyst for funding startups **Partners with MeitY,** GoI to conduct their MSH (MeitY startup hub) program **Sector:** Innovation and entrepreneur development, promoting IP creation and implementation	Committed

S. No	Collaborator	Designation	Institute	Domain	Status
18	Dr. M. S. Giridhar	Scientist	LEOS Unit, ISRO	Experimental AMO, Spectroscopy	Committed
19	Dr. Vasudharani Devanathan	Assistant Professor	IISER Tirupati	Cell adhesion, neurodegeneration	Committed
20	Prof. Alika Khare	Professor	IIT Guwahati	Laser spectroscopy, laser-plasma interaction, nonlinear optics	Committed
21	Dr. L. N. Rao		IISc Bangalore	Plasma Technology	Committed
22	Prof. Rajesh Srivastava	Professor	IIT Roorkee	Atomic and Molecular Physics	Committed
23	Ravi Shankar T	Scientist	GD, LULC, ISRO-NRCS	Satellite image processing	Committed
24	Dhiroj Kumar B	Scientist	ISRO-NRCS	Land use, Land cover mapping	Committed
25	Dr. Ramiya	Assistant Professor, ESS	IIST	Satellite & Hyperspectral Image Processing	Committed
26	Dr. P V Vinod	Scientist	ISRO, RRSC-S, Bangalore	Remote sensing applications & development	Committed
27	Litu Rout	Scientist	ISRO	Deep learning for Satellite Image Processing	Committed
28	Dr. Y. Bhavani Kumar	Scientist	National Atmospheric Research Laboratory	Remote sensing	Committed
29	Dr. S Manthira Moorthi	Scientist	SAC Ahmedabad, ISRO	Satellite Data Processing	Committed
30	Dr. Manish Asthana	Assistant Professor, HSS	IIT Roorkee	Cognitive Psychology, Cognitive Science	Committed
31	Dr. V. Katiyar	Professor, Chemical Engineering	IIT Guwahati	Bio-Medical Materials	Committed
32	Dr. Shibdas Banerjee	Assistant Professor	IISER Tirupati	Mass-spectrometry	Committed
33	Dr. Suniljha	Professor, Mechanical Engineering	IIT Delhi	Micro and Nano Manufacturing	Committed
34	Dr. B. Sivaiah	Assistant Professor, School of Minerals, Metallurgical and Material Science	IIT Bhubaneswar	Advanced Nano Materials	Committed

S. No	Collaborator	Designation	Institute	Domain	Status
36	Dr. Ramesh Singh	Professor, Mechanical Engineering	IIT Bombay	Ultra Precision Manufacturing	Committed
37	Dr. Serji Amirkhanian	Professor Civil Engineering	The University of Alabama	Sustainable cities.	Committed
38	Dr. Diwakar Krishnamurthy	Associate Professor Electrical and Computer Engineering	The University of Calgary	Performance evaluation of distributed computing system	Committed
39	Prof. Etienne Memin	Director Fluminance team	Inria Technological Development Commission	Remote-sensing, Image Processing, Data Assimilation.	Committed
40	Prof. Linga Reddy	Associate Professor, Head of the Applied Research Group, Department of Information & Communication Technology	University of Agder	Communication and Signal Processing.	Committed
41	Dr. Amar Vutha	Asst. Professor and Canada Research Chair, Physics	University of Toronto	Experimental Atomic Molecular and Optical Physics	Committed
42	Dr. Anurag K Srivastava	Asso. Professor and Director Smart Grid Demonstration and Research Investigation Lab, The School of Electrical Engineering and Computer Science	Washington State University	Smart Grid	Committed
43	Dr. Oded Heber	Scientist	Weizmann Institute of Science	Atomic and Molecular Physics	Committed
44	Prof. Tony Q S Quek	Professor, Information Systems Technology and Design	Singapore University of Technology and Design	Wireless communications and networks, network intelligence, big data processing, URLLC, and IoT.	Committed

S.No	Collaborator	Designation	Institute	Domain	Status
45	Prof. Dmitry Budker	Professor Antimatter Group	UC Berkley, CA, USA and Helmholtz-Institut Mainz, Germany	Experimental AMO, Spectroscopy	Committed
46	Dr. Sivanandh Budarapu	Associate Professor of Psychiatry & Fellow	Sri Venkateswara Institute of Medical Sciences & Royal Australia and New Zealand College of Psychiatry (RANZCP)	Psychology	Committed
47	Dr. Saurav Goel	Asst. Professor, Precision Engineering	Cranfield University	Ultra Precision Manufacturing	Committed
48	Dr. Kamil Kaloush	Professor School of Sustainable Engineering and the Built Environment	Arizona State University, USA	Smart cities and sustainable infrastructure, asset management	Committed
49	Dr. Satish Bhukkapatnam	Professor Industrial and Systems Engineering	Texas A&M University,	Seismic retrofitting and rehabilitation of structures.	Committed
50	Dr. Jason Hyeonpil Cheon	Senior researcher	Korea Institute of Industrial Technology, South Korea	Smart hybrid two wire arc precision additive manufacturing	Committed
51	Dr. Hosin "David" Lee	Professor. Civil and Environmental Engineering	Seamans Center for the Engineering Arts and Sciences, Engineering Arts and Sciences,	Civil Engineering	Committed
52	Dr. Samuel Labi	Professor Civil Engineering	Purdue University, USA	Smart cities and vehicle automation, statistics, econometrics	Committed
53	Dr. T Narayana Rao	Scientist	NARL	Remote sensing	Probable

S.No	Collaborator	Designation	Institute	Domain	Status
54	Prof. G Mugesh	Professor Inorganic and Physical Chemistry	Indian Institute of Science	Bioinorganic Chemistry, Chemical Biology	Probable
55	Prof. Bharadwaj Amrutur	Professor Electronics and Communication	Indian Institute of Science	VLSI and Autonomous system	Probable
56	Dr. Umakant Rapol	Associate Professor Physics	IISER Pune	Experimental Atomic, Molecular and Optical Physics	Probable
57	Dr. Amitabha Bagchi	Asso. Professor Computer Science and Engineering	IIT Delhi	Probability and networks, Data algorithms and analytics	Probable
58	Dr. D Manjunath	Professor Electrical Engineering	IIT Bombay	General area of networking, stochastic systems, performance modelling	Probable
59	Dr. Rupashree Baral	Asso. Professor Management Studies	IIT Madras	Human Resource Management/Organizati onal Behavior	Probable
60	Prof. Sundar	Professor Mathematics	IIT Madras	Mathematical Modelling and Numerical PDEs	Probable
61	Dr. Sourish Das	Associate Professor	Chennai Mathematical Institute	Statistics and Data Science	Probable
62	Dr. Nimisha	Scientist	NGRI Hyderabad	Geoscience, Seismic imaging	Probable
63	Prof. Sadiq Rangwala	Professor Light and Matter Physics	Raman Research Institute	Experimental atomic molecular and optical physics	Probable
64	Dr. Venky Krishnan	Assistant Professor Mathematics	TIFR CAM	Inverse Problems & Computational Epidemiology	Probable
65	Dr. Rama Rao N	Asso. Professor Earth & Space Science	IIST Trivandrum	Remote Sensing	Probable
66	Prof. Prakash Jagadeesan	Professor Instrumentation Engineering	Anna University	State estimation, Bayesian methods	Probable
67	Dr. Shibendu Shankar Ray	Director	NCFC	Remote Sensing	Probable
68	Dr. B. Basu	Professor, MRC	IISc Bangalore	Advanced Materials for Biomedical Applications	Probable
69	Dr. Major Singh	Director	ICAR Onion and Garlic Research Centre	Vegetable production	Probable

S. No	Collaborator	Designation	Institute	Domain	Status
70	Dr. Ramasubramanian	Principal Scientist	ICAR-ISARI	Crop Forecasting	Probable
71	Dr. Alagusundarm	Scientist	ICAR	Natural Resource Management	Probable
72	Prof. Venkatesh babu	Associate Professor Computational and Data Sciences	Indian Institute of Science	Computer Vision & Deep Learning	Probable
73	Dr. Ardhendu Behera	Sr. Lecturer Computer Science	Edge Hill University	Gesture and Behaviour Recognition, Human-Robot Interaction (HRI)	Probable
74	Dr. Swagat Kumar	Lecturer Computer Science	Edge Hill University	Robotics, Computer Vision and Machine Learning	Probable
75	Prof. Yonghuai Liu	Professor, Computer Science	Edge Hill University	3D Computer Vision, Image Processing, Pattern Recognition	Probable
76	Prof. Humberto Varum	Professor Civil Engineering	University of Porto	Seismic retrofitting and rehabilitation of structures.	Probable
77	Dr. Mei Nagappan	Assistant Professor David R. Cheriton School of Computer Science	University of Waterloo	Software Engineering, Software Analytics, Mining Software Repositories.	Probable
78	Prof. Jens Schmidt	Junior Professor Mathematics	TU Ilmenau	Algorithms, Discrete Optimization	Probable
79	Prof. Biao Huang	Professor Chemical & Materials Engineering	University of Alberta	Process Control, Automation, Data Analysis	Probable
80	Dr. Jemin Lee	Associate Professor Information and communication engineering	Daegu Gyeongbuk Institute of Science and Technology	Security Techniques for Emerging Communication Networks, Intelligent Communication Techniques for 5G/Beyond 5G.	Probable
81	Dr. Ashok Srinivasan	Professor, Computer Science	University of West Florida	High-Performance Computing	Probable
82	Dr. Shiv Gopal Kapoor	Professor	University of Illinois, UC	Micro-Nano Manufacturing	Probable

S. No	Collaborator	Designation	Institute	Domain	Status
83	Dr. Sourav Das	Lecturer	James Cook University, Cairns	Statistics and Data Science	Probable
84	Dr. K. Rajurkar	Professor, School of Minerals, Metallurgical and Material Science	University of Nebraska, Lincoln	Advanced Nano Materials	Probable
85	Dr. Nikolaos Pappas	Asso. Professor Department of Science and Technology	Linköping University	Network-Level Cooperative Networks, Wireless Energy Harvesting Networks, Stability Analysis, Queueing Theory, Age of Information, Caching	Probable

17. Industry Partnerships

The success of the INiF relies on industry partnerships in the field of PPT. The primary goal of the Hub is to promote ‘Make in India’, ‘Skill India’, and ‘AatmaNirbharBharat Abhiyan’ in PPT. Initially, the Hub has identified 49 industry partners in PPT to support the fundamental research and translate proofs-of-concept to products. The industry partners for the development of nine product frameworks are classified as (i) user-oriented industries/organizations (ii) service-oriented industries/ organizations; (iii) Manufacturing industries; (iv) Software; and (v) Implementation. In areas of PPT, we have ongoing collaborations with the LEOS Unit, ISRO and NARL. Recently several collaborations have been established with organizations/industries such as Survey of India, State Survey Agencies, NRSC, NIDM, NDMA, NIH Roorkee, National GRID, Hexagon Technologies, Planet Labs, Singapore University of Technology and Design, TU Ilmenau, Germany, and the University of Toronto. Going forward, the TIH expects to have significant collaboration with TIHs in Sensors at IIT Madras, Data analysis at IIIT Hyderabad, agriculture and water at IIT Ropar, autonomous navigation at IIT Hyderabad and machine learning at IIT Kharagpur. The following table provides the list of the ongoing, committed and probable industry partners.

S. No	Name	Specific Area	Type	Status
1	National Atmospheric Research Laboratory (NARL)	Remote Sensing, LIDAR, RADAR	Service-Oriented, Implementation	Committed
2	National Remote Sensing Centre (NRSC)	Remote Sensing Data, Open Data, Capacity Building	Service-Oriented	Committed
3	LEOS Unit, ISRO, Peenya, Bengaluru	Atomic clocks	Service-Oriented	Committed
4	kCube Consultancy Services Pvt Ltd. Chennai	Precision Agriculture	Implementation	Committed
5	Hexagon, Intergraph SG&I India Pvt Ltd	Remote Sensing	Service-Oriented, Implementation, Software	Committed
6	Renuka Bio Farms LLP	Precision farming	Implementation	Committed
7	TestRight Nanosystems Pvt. LTD.	Optical sensor, Spectrometers /Spectrophotometers	Service-Oriented	Committed
8	Zuari Agro Chemicals Limited (ZACL), Gurgaon, Haryana	Precision Farming	Implementation	Committed
9	Xilinx India Pvt Ltd.	R&D, GPS sensors, Atomic clocks and precision timing devices	Service-Oriented, Implementation	Committed
10	Datakrew Pvt Ltd, India	IoT, AI & data security	Implementation	Committed
11	Incredible AM Pvt Ltd.	Precision manufacturing of medical implants	Implementation	Committed
12	Fronius India Pvt Ltd.	Power source manufacturers for welding and wire arc additive manufacturing	Manufacturing Industry	Committed
13	Lincoln Electric India Pvt Ltd.	Power source manufacturers for the welding and wire arc additive manufacturing	Manufacturing Industry	Committed
14	Advanced Photonics, Mumbai	Spectroscopic Sensors, spectroscopic educational kit for UG/PG level students	Service-Oriented	Committed
15	ATOS Instruments Marketing Services	Marketing of spectroscopic sensor-based products	Service-Oriented	Committed
16	Sandvic Components, New Delhi	Spectrometers, Sensors	Service-Oriented	Committed
17	New Age Instruments & Materials Pvt. Ltd., Gurgaon - 122001, Haryana, INDIA	Spectrometers, Sensors, atomic clocks, FPGA boards	Service-Oriented	Committed
18	NIH, Roorkee	Disaster Management and Natural Resource Management	User-Oriented	Committed

S. No	Name	Specific Area	Type	Status
19	3rdi, Hyderabad	Built Infrastructure	Service-Oriented, Software	Committed
20	Nirvapate	Precision Agriculture, Organic Farming	Implementation	Committed
21	CMTI, Bangalore	Precision Manufacturing	Manufacturing Industry	Committed
22	Amara Hospital	Biomedical Project	Service-Oriented	Committed
23	Consulpav International	Noninvasive technologies	Implementation	Committed
24	Silence Laboratories, Singapore	Cyber-security company with a focus on seamless authentication frameworks and secret key distribution	Service-Oriented	Committed
25	NUMA Innovation Ltd	Model development, Simulation, Validation and Product design of PPT	Manufacturing Industry	Committed
26	Survey of India	Remote Sensing, LIDAR, Advanced Surveying	User-Oriented Organization	Ongoing
27	Indian Space Research Organization (ISRO)	Atomic Clocks, InSAR	Service-Oriented, Implementation	Ongoing
28	National Institute of Disaster Management (NIDM)	Capacity Building	Implementation	Ongoing
29	ESRI, Delhi	Disaster Management, Natural Resource Management and Smart Cities	Service-Oriented	Ongoing
30	NIDM, Delhi	Disaster Management	Service-Oriented	Ongoing
31	ARCI, Hyderabad	Precision Manufacturing	Service-Oriented	Ongoing
32	DRDL, Hyderabad	Precision Manufacturing	Service-Oriented, Implementation	Ongoing
33	RCI, Hyderabad	Precision Manufacturing	Manufacturing Industry	Ongoing
34	GTRE, Bangalore	Precision Manufacturing	Manufacturing Industry	Ongoing
35	Honeywell	Precision Agriculture	Service-Oriented	Ongoing
36	Kaiinos Technologies	Built Infrastructure mapping	Service-Oriented, Implementation	Ongoing
37	Planet.org	Disaster Management, Natural Resource Management	Service-Oriented	Ongoing
38	Flax and Teal. Belfast, UK	Disaster Management and Open Source Simulation	Service-Oriented, Software	Ongoing
39	Facebook	Disaster Dashboard	Service-Oriented	Ongoing
40	BEL-CRL	Security & Crypto Systems, and Radio Communications	Service-Oriented	Probable
41	Synergies Casting Ltd	Precision Manufacturing	Service-Oriented	Probable
42	AECOM	Asset Management, Smart City	Service-Oriented, Implementation	Probable

S. No	Name	Specific Area	Type	Status
43	APSPDCL	Power Grid, Smart Cities	Service-Oriented, Implementation	Probable
44	Murata Electronics (India) Private Limited	GPS	Service-Oriented, Implementation	Probable
45	Aarvee Associates	Built Infrastructure and Geospatial Services	Service-Oriented, Implementation	Probable
46	Mojo Networks	Networks, products and services	Service-Oriented, Implementation	Probable
47	CogniPhi	Computer Vision/Visualization Tools	Service-Oriented, Implementation	Probable
48	Lekha Wireless	Wireless Communication products and services	Service-Oriented, Implementation	Probable
49	Schweitzer Engineering Laboratories Pullman WA, USA	Precision Controllers for Energy Grids	Service-Oriented	Probable

18. Conclusion

A key outcome of **IIT Tirupati Navavishkar i-Hub Foundation** (INiF) is to make India self-reliant in PPT by developing indigenous cutting edge technologies and skilled manpower in this area through the proposed products and initiatives. These will enable India to integrate the geospatial information from various resource management applications and develop national strategies, policies and related implementation frameworks and platforms. The activities of INiF shall suitably amplify and augment the needs and aspirations of the nation reflected through "AatmaNirbhar Bharat" and the Make-in-India campaign. The strategy developed in this DPR will strengthen the precision and position technology ecosystem of the country and take steps to nurture the (i) Technology Development, (ii) Centers of Excellence, (iii) HRD & Skill Development, (iv) Innovation, Entrepreneurship & Start-up ecosystem, and (v) International Collaboration. By implementing the project management strategies discussed here, we expect to significantly enhance the odds of achieving the objectives for the centre within the stipulated period.

By implementing the project management strategies discussed here, we expect to significantly enhance the odds of achieving the objectives for the centre within the stipulated period. INiF expects to create a sustainable model for its financing through internal revenue generation, and by securing sponsored research and implementation projects. Key internal revenue sources for INiF are the licensing revenue generated from commercializing the technologies developed through INiF, the equity owned in the start-ups and spin-offs incubated at the TBI and fees collected for various training programs discussed above. In addition, INiF will actively secure sponsored research projects from government and industry partners. INiF will also position itself as an implementation partner for the deployment of PPT related solutions by funding agencies like the World Bank, UN agencies and Central/State governments.

Within this period, INiF will become the most sought-after resource for technology, data and manpower for PPT in the country. Its knowledge repository on PPT will be the most accessed resource for everyone seeking information and knowledge in these areas. It will be a single point of contact for connecting international and national experts in PPT. INiF will also become a key resource and collaborator for national and international companies for technologies and manpower related to remote sensing, GIS and GPS. As reflected in the proposed products TIH also work very closely with the government Indian R&D organizations to scale up the proposed PPT developments as nationwide resources and products and bring in the rich value of local relevance to address the potential issues in the development of India. Further, the best Indian start-ups in PPT will identify INiF as the place where they started and want to continue engaging.

More immediately, INiF will develop several products outlined in Section 7 that either has orders of magnitude better performance or cost advantage than the state-of-the-art or apply the existing technologies to solve India’s urgent problems. These and other initiatives by INiF towards enhancing the country’s capabilities in this area and will create an ecosystem for successful deployment of modern Positioning and Precision Technologies (PPT) solutions and create economic and social impact.