



ENGINEERS WITH  
SOCIAL RESPONSIBILITY

# RESEARCH AND DEVELOPMENT @ DA-IICT





# From the desk of THE DIRECTOR

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**Prof. K. S. Dasgupta**  
Director, DA-IICT

The Institute is committed towards developing and maintaining high standards in both research and academics, as we strongly believe that outstanding research is a pre-requisite for providing quality and holistic education.

Research-led education enhances the research productivity which depends on quality of research workforce and number of research publications. Research productivity is a step towards innovation and creativity. In other words, research eco-system needs quality research work force and research infrastructure. Hence, flow of research fund is very essential for establishment of research infrastructure.

The Institute encourages faculty members to participate in interdisciplinary cutting-edge research by providing a conducive research environment. The Institute is happy to apprise that 29 sponsored research and 7 consultancy projects of worth 11.69

crores were awarded to DA-IICT since 2017. The sponsored research agencies include premier R&D Institutes – ISRO-DoS, GUJCOST-GoG, DST-SERB, etc. The sponsored research covers a broad spectrum of research domain –AI & ML, Communication & Signal Processing, Electronics, Robotics and VLSI, Information retrieval, Science and Mathematics.

The sponsored research awarded to any institute is a reflection of the credentials of the faculty members and the vibrancy of research eco-system of that Institute.

I am extremely delighted that the Coffee Table Book compiled by the researchers is being released to showcase the complexities of the sponsored research problems.

## From the desk of **THE DEAN**

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**Prof. Maniklal Das**  
Dean AP, DA-IICT

DA-IICT is a place where academic programmes meet research-driven teaching and learning. The institute is equipped with experienced faculty, quality students and state of the art ICT infrastructure. Our jubilant student fraternity, highly qualified faculty, interdisciplinary curricula, and vibrant campus ambience are tightly interwoven to provide the highest standards of academic excellence and all-round development of its students. The strength of our academic programs lies in the interdisciplinary teaching-learning process backed by a strong research-driven training. Various research groups mentored by faculty with the support of research scholars and projects funded by national and international agencies motivate undergraduate and postgraduate students to pursue projects/thesis in their area of interest, in turn, publish scholarly articles in national and international forums.

## From the desk of **THE DEAN (R&D)**

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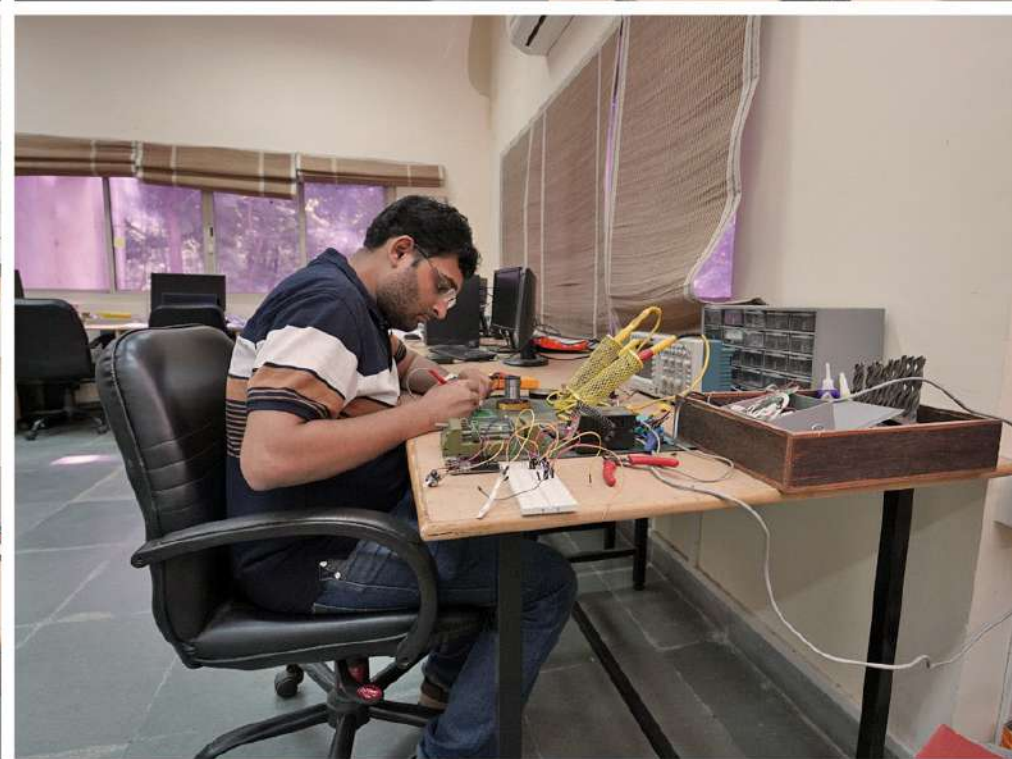


**Prof. Manjunath V. Joshi**  
Dean R&D, DA-IICT

DA-IICT is committed towards developing and maintaining the highest standards in both teaching and research. Engineering with Humanities and Social Sciences at DA-IICT provides a best environment that fosters inter-disciplinary research in cutting edge areas. A number of research labs mostly funded by the research grants from outside agencies are engaged in cutting-edge research in specialized fields. These labs are run by the faculty members working in the relevant fields. The students across all programmes often work on research projects offered by these labs. Brief research plans of various projects are summarized in this booklet. Faculty members are encouraged to publish in reputed conferences that have high visibility and attendance by the academic community. A faculty member can seek financial support of INR 3.0 lakhs for every block of three years to attend international conferences/symposiums, training and research programs for professional development,

take up membership of professional Societies etc. To promote innovation and entrepreneurship culture among DA-IICT community, DA-IICT Centre for Entrepreneurship and Innovation (DCEI) was established in the year 2011 which has resulted in several incubates. DCEI is supported by DeitY, Government of India and Government of Gujarat. Collaboration with leading universities and industry provides us the motivation for conducting meaningful research. I am privileged to be part of DA-IICT that thrives to get the best minds of our country and abroad to build world class engineers and researchers. All this success is due to the dedication of my colleagues towards academic activities by bringing their experience into high quality teaching and research. We express our thanks to sponsoring agencies for their encouragement by funding our research. We, at DA-IICT are committed to hard work in taking the Institute to the next level.

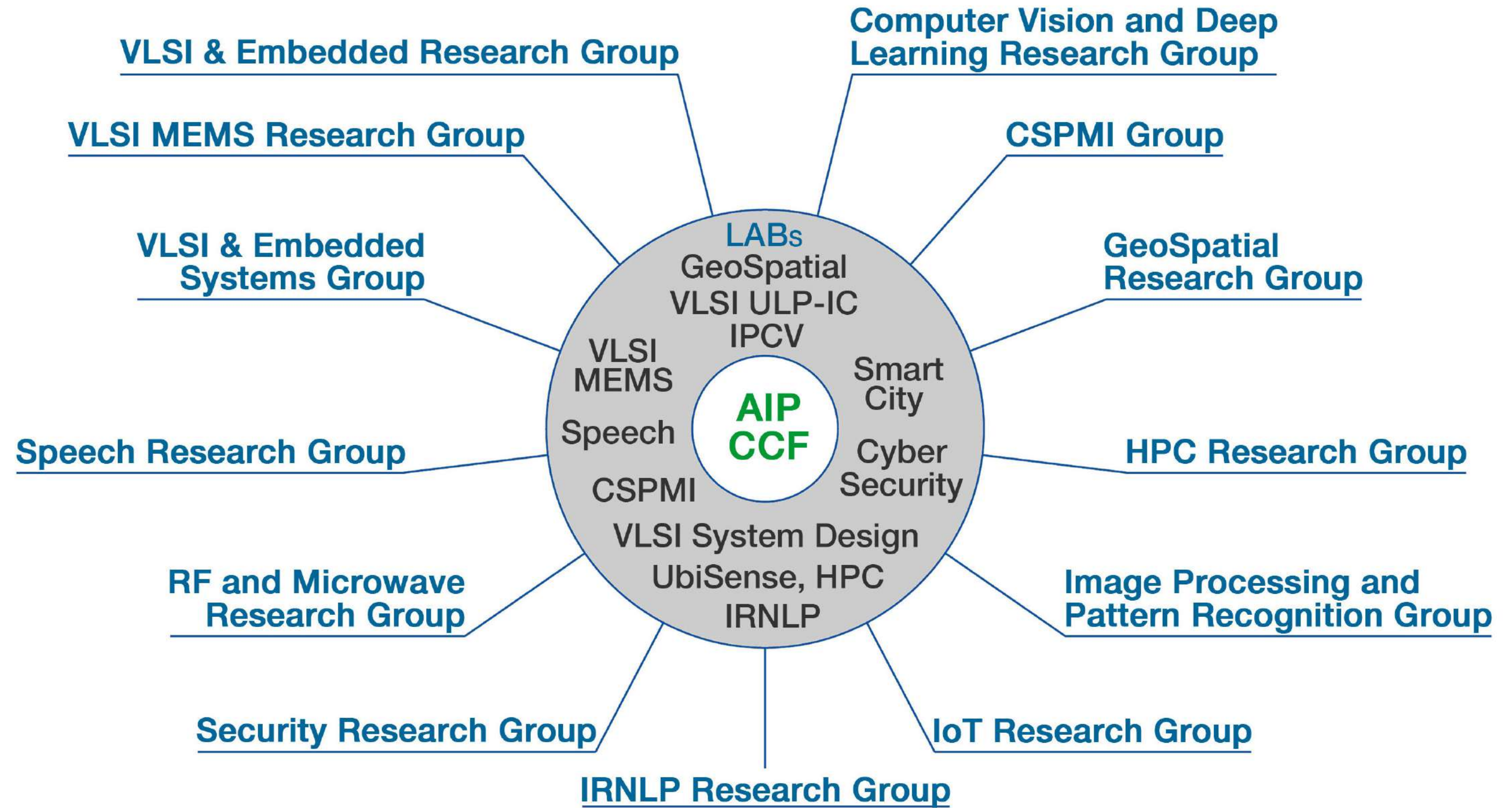
# Research Ecosystem



## Sponsored Research Labs

Besides the above academic programmes, a number of research labs mostly funded by the research grants from outside agencies are engaged in cutting-edge research in specialized fields. Various Research Groups use the sponsored research labs as well as centralized computational facilities of the Institute to carry out advanced research in different technical/scientific areas.

The research activities of these labs are led by the faculty members working in the relevant fields. The students across all programmes often work on research projects offered by these labs. In the following, the list of research labs, its activities, and the faculty member/members associated with it are furnished. A faculty member interested in the research activities of the lab may join.



AIP : Anchor Institute Programme  
 CCF : Centralized Computational Facility  
 IPCV : Image Processing and Computer Vision  
 HPC : High-performance Computing  
 VLSI : Very Large Scale Integration

IRNLP : Information Retrieval and Natural Language Processing  
 UbiSense : Ubiquitous Sensing Lab  
 CSPMI : Communication, Signal Processing & Machine Intelligence  
 IPPR : Image Processing and Pattern Recognition  
 ULP-IC : Ultra-Low Power Integrated Circuit



# A Forensic Tool for Land Revenue Documents Forgery Detection



PI: Priyanka Singh

Co-PI: Nilay Mistry

Number of JRFs: One

Funding Agency: GUJCOST

Duration of the Project: 2 Years

Status of the Project: Ongoing

Number of MTech/PhD: Nil

Sanctioned Funding: 10,45,000/-

Start Date: 09-04-2021

End Date: 31-03-2023

The Grant Number: SP-21/GUJCOST/PSS/FTLRD

## Research Problem Statement:

Most forensic techniques are concerned with authenticating the contents of a document, linking the document to a device or class of devices, or extracting forensically useful information from the document. Another aspect of forensics is the identification of previously identified content, particularly in the face of simple document modifications. Such so-called robust hashing techniques can be highly effective at finding forged documents, tampered land revenue documents, authenticating the seal or signatures present on the legal papers.

The growing use of end-to-end encryption on commercial platforms makes identification of such material significantly more challenging. We describe a robust hashing algorithm that is both robust to simple document manipulations and that can operate on an encrypted document, without the need or even ability to decipher the underlying encrypted documents.

A forensic tool based on this algorithm can be made available as the outcome of the proposed project which the Gujarat State Government officials can use to keep a track of the authenticity of the critical land revenue documents. In case of a dispute, this forensic tool can be used to validate the authenticity of the document and resolve the issue.

Accuracy(True Positive Rate) of similar and different images as a function of the threshold on L1-norm between two hashes. The two curves intersect each other (cross-over point) at 91.4% accuracy.

## Objectives & Proposed Approach:

The goal of this research is to develop a reliable system that can ascertain the authenticity of the documents that are critical to a decision-making. The objective of the current study is to:

1. Study the feasibility of extraction of various discriminative features from the document.
2. Identification of potential features among these that can contribute to a distinct signature.
3. Stability of the distinct signature to unintentional attacks that might happen just because of the system maintenance.
4. Possibility of transformation of the proposed approach on the encrypted documents and enable extraction of the same signature from the encrypted documents as it is for its plaintext counterpart.
5. Very low false alarm rate as we are dealing with decision-making judgements.
6. Time-efficient so that it can be applied to dealing with real-time scenarios.
7. Proposing a secure protocol for the entire verification process.

## Research Publication:

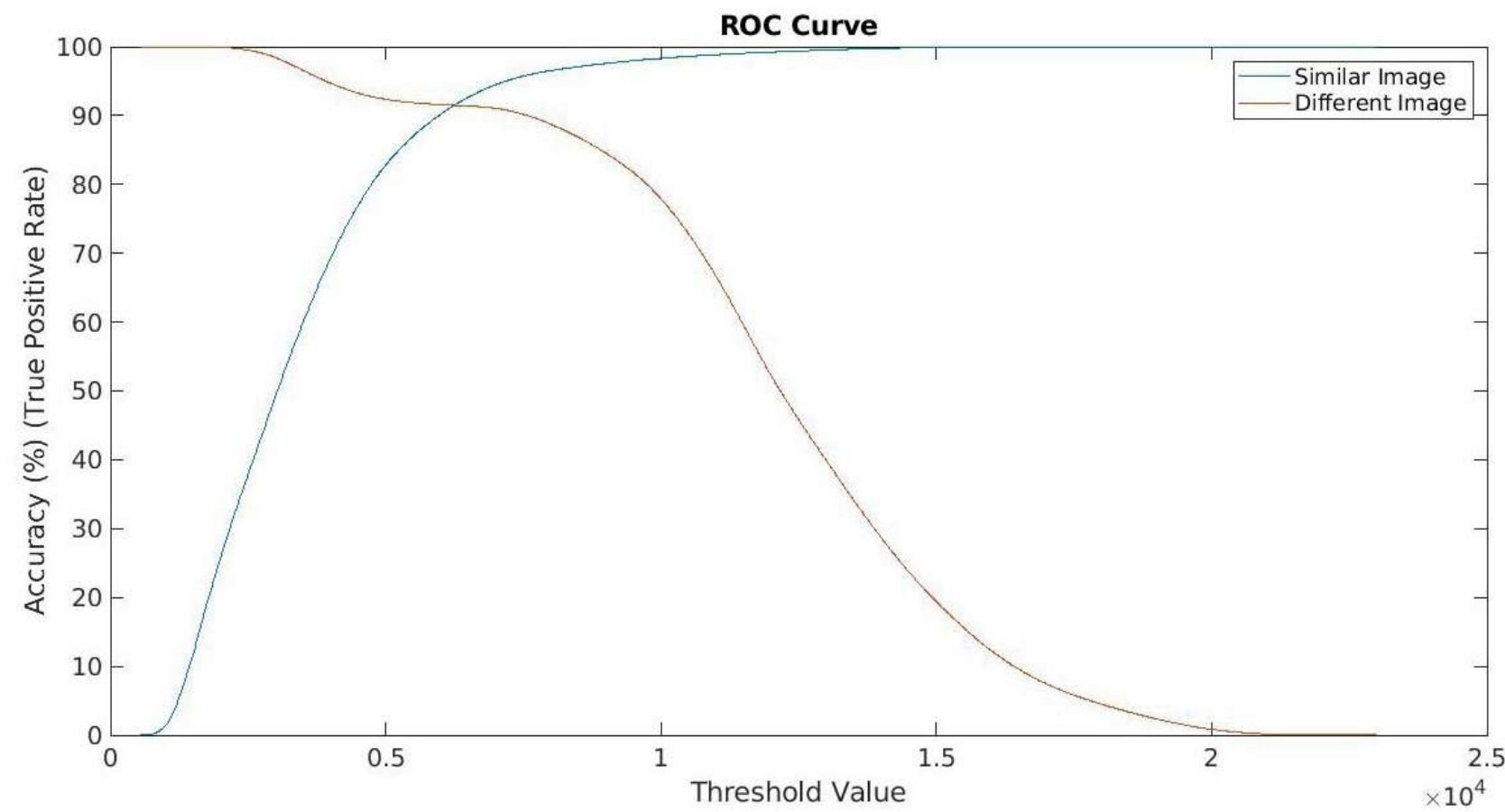
1. A forensic tool for document forgery detection (poster paper)
2. Verify what you see: A secure hash based framework for authentication of digital document images (Under Revision)



## Deliverables:

This research will deliver an easy-to-use forensic tool to help the state government officials authenticate the crucial land revenue documents. The project proposes a secure way of archiving the original documents in encrypted form along with their corresponding unique signatures. These signatures are equally extractable from the plaintext version of the documents as well and thus have the advantage of back compatibility with the

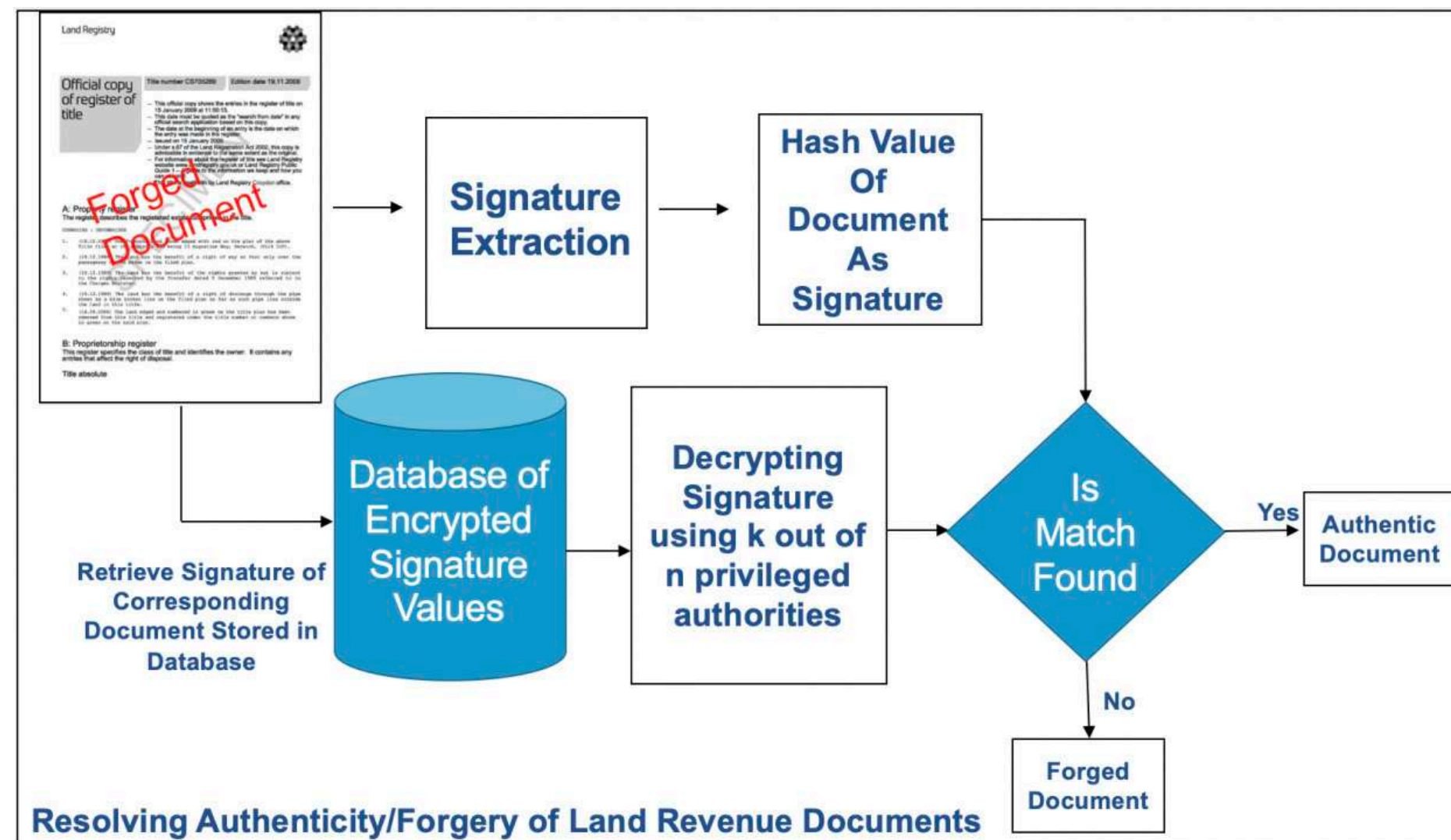
already existing database systems. In order to resolve a dispute, the authority can compute the signature from the forged document (in case of manipulation) and check with the archived signature in the database for the rightful document. If case of a mismatch, it confirms that the document has been manipulated.



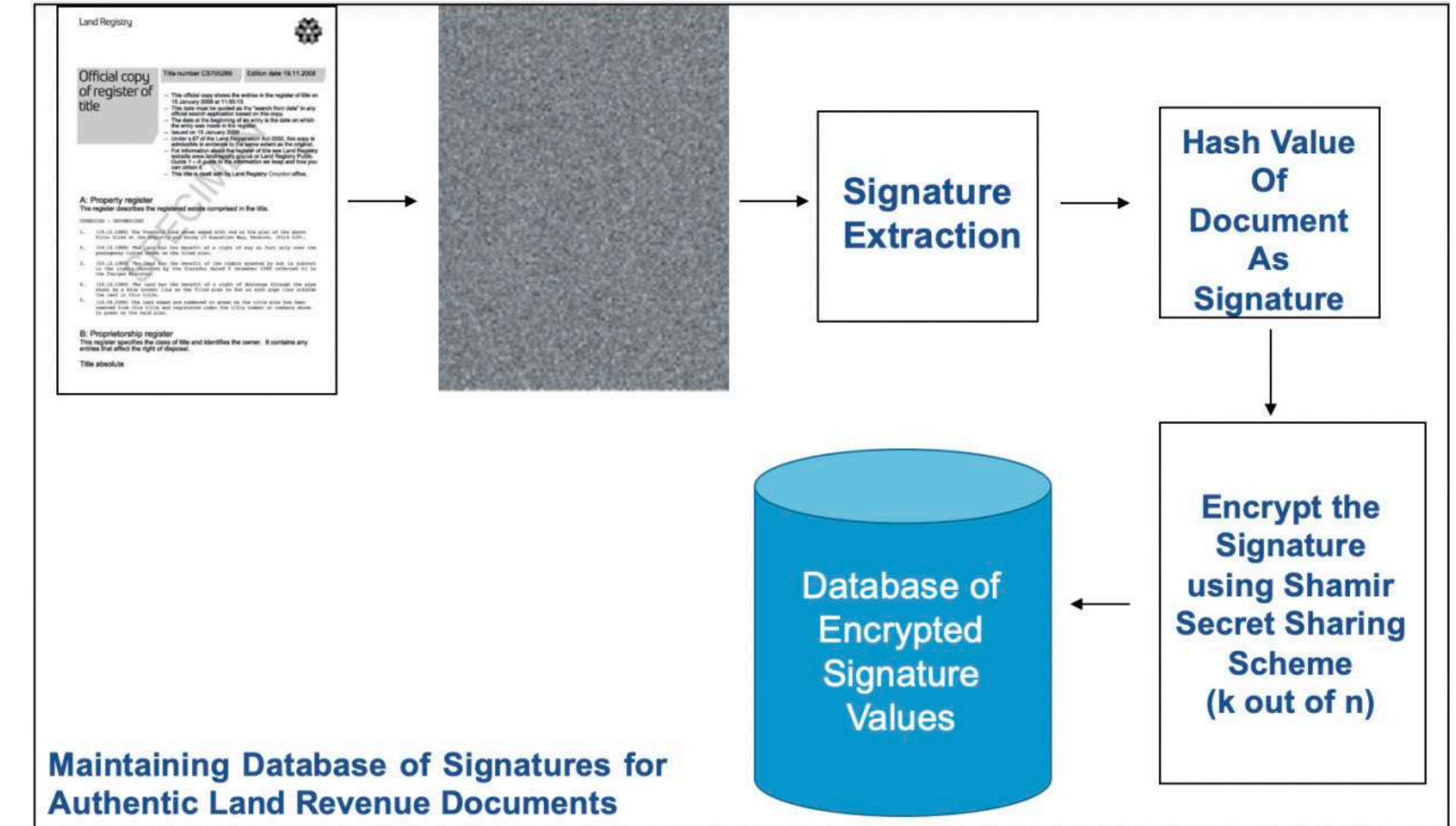
## Results:

The performance of the proposed framework is validated using 5575 document images. Hash values are extracted for all the document images using the robust image hashing technique proposed by Singh et al. Based on the experiments, the number of intensity bins is set as 2 as there is not much intensity variation in the document images. Thereafter, pairwise distance is computed for all possible combinations of the document images. These distances contribute to the “Different Image” set.

The Receiver Operating Characteristic (ROC) curve is shown depicting the accuracy of correctly classifying “similar” (original and its manipulations) and “different” (different images) images as a function of the L1-norm threshold. A document hash must have relatively small distances between the hash value of the original document and its manipulation, and large distances between different document images. The point where the two curves intersect is also known as cross-over point is at 91.4% accuracy.



Authenticity/Forgery Detection for Land Revenue Documents



Recording Signatures for Authentic Documents



# Development of Geomagnetism based Indoor Navigation System



PI: Kalyan Sasidhar

Co-PI: Bhaskar Chaudhury

Duration of the Project: 2 Years

Status of the Project: Ongoing

Start Date: 29-10-2020

End Date: 29-11-2022

Number of JRFs: Two

Funding Agency: DST, NRDMS

Number of MTech/PhD: Two

Sanctioned Funding: 27,41,332/-

The Grant Number: NRDMS/UG/NetworkingProject/e-13/2019(C) P-1

## Research Problem Statement:

With the advent of Global Positioning Systems (GPS), outdoor navigation has been made easier by GPS enabled devices, structured road maps, numerous landmarks, consistent numbering of street addresses, cues (famous buildings, restaurants, intersections), and signs. The same technology cannot function indoors due to multipath reflection and signal blockage due to buildings, resulting in signal attenuation. Because of this inherent problem of GPS, the design of indoor navigation systems has not received an equal share of attention. The problem can be defined as how to provide indoor location services using only a smartphone and without the need for additional infrastructure.

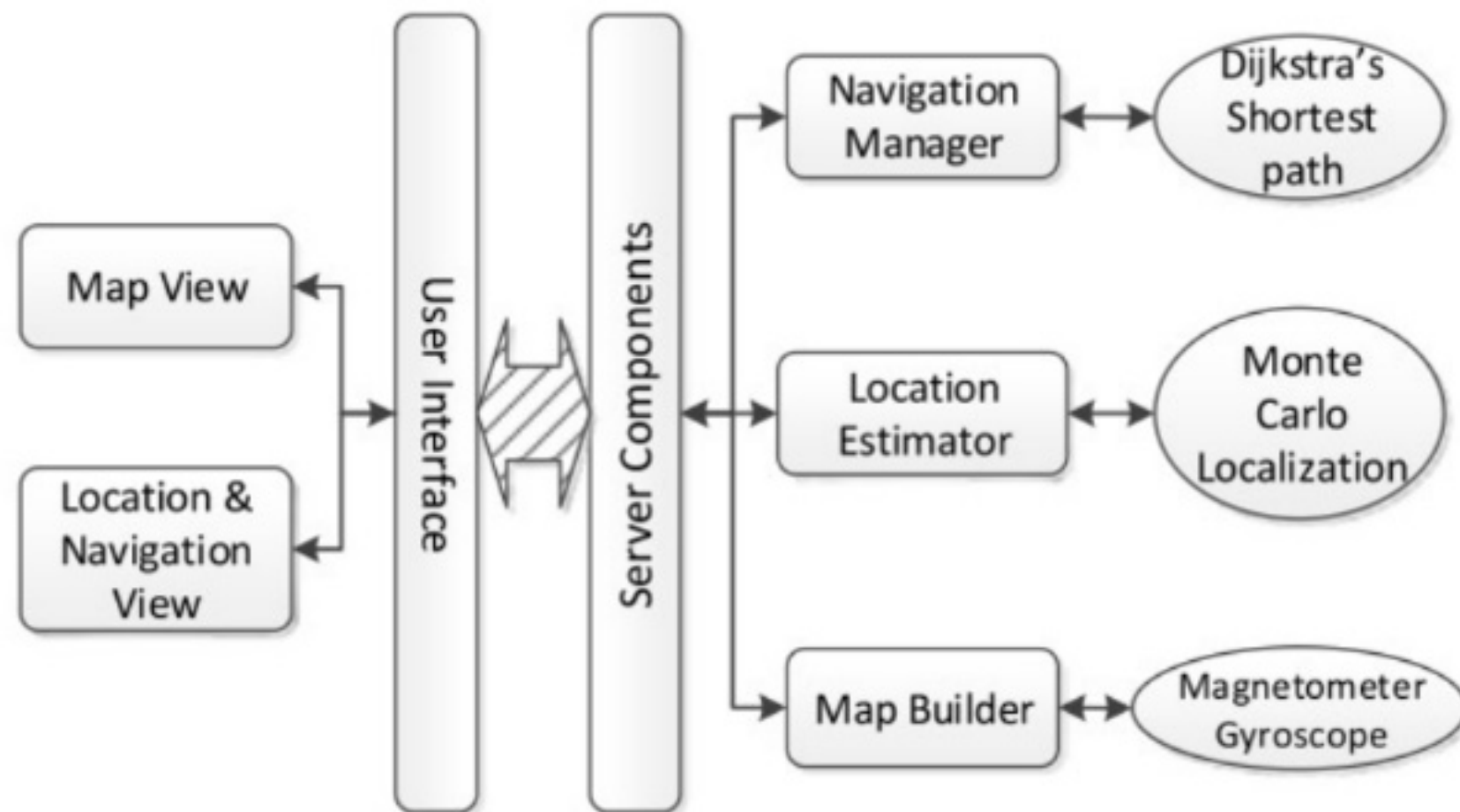
## Objectives & Proposed Approach:

This research proposes a novel idea of indoor localization and navigation, by exploiting the indoor geomagnetic field caused by different static ferromagnetic objects such as pillars, doors and elevators. By measuring the geomagnetism using a smartphone's embedded magnetic field sensor, this work proposes a system for identifying landmarks, developing a building information model and implementing an indoor localization and navigation system as a complete end-end solution without the need for any additional infrastructure.

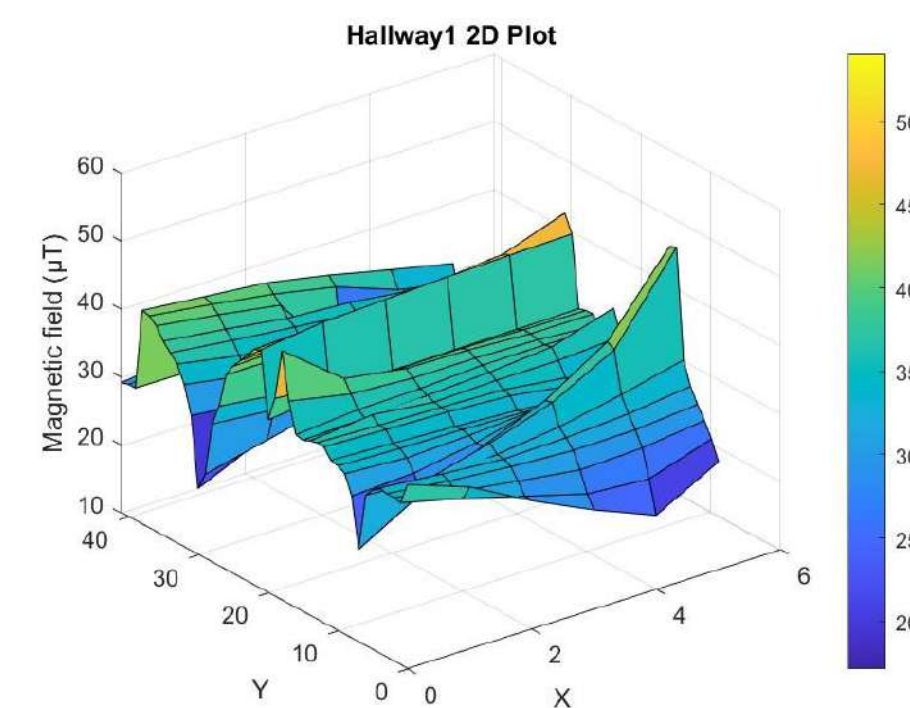
## Deliverables:

A well defined building map created through our solvers

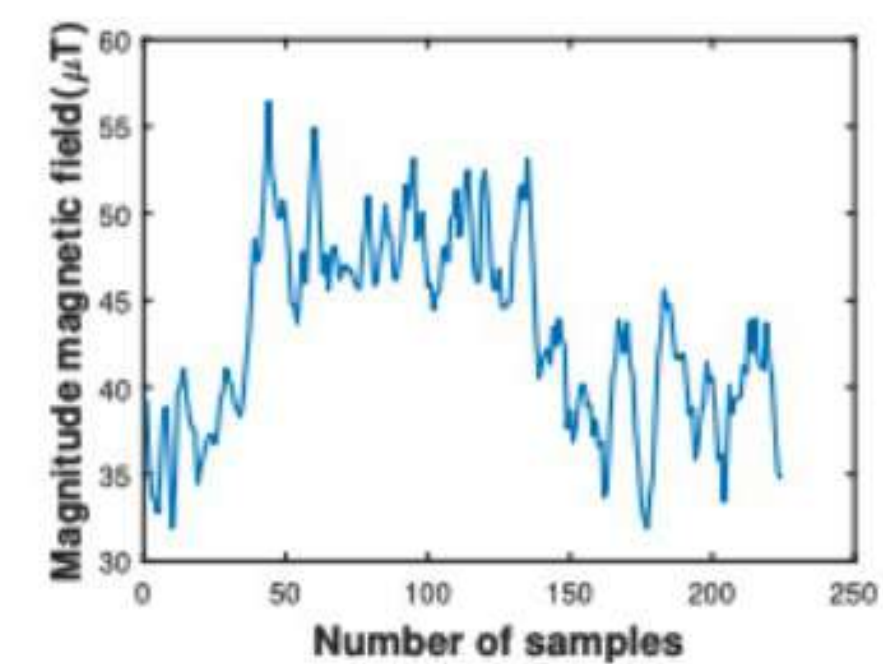
1. A first phase data collected around buildings
2. A mobile app installed on users
3. Performance analysis results



The architecture consists of smartphone clients and a server. Each client provides a user interface for collecting data, as well as visualizing the constructed map, the current (estimated) location, and the navigation routes. The server is a cloud service; it consists of modules that build floor maps, estimate locations, and deliver real-time navigation.



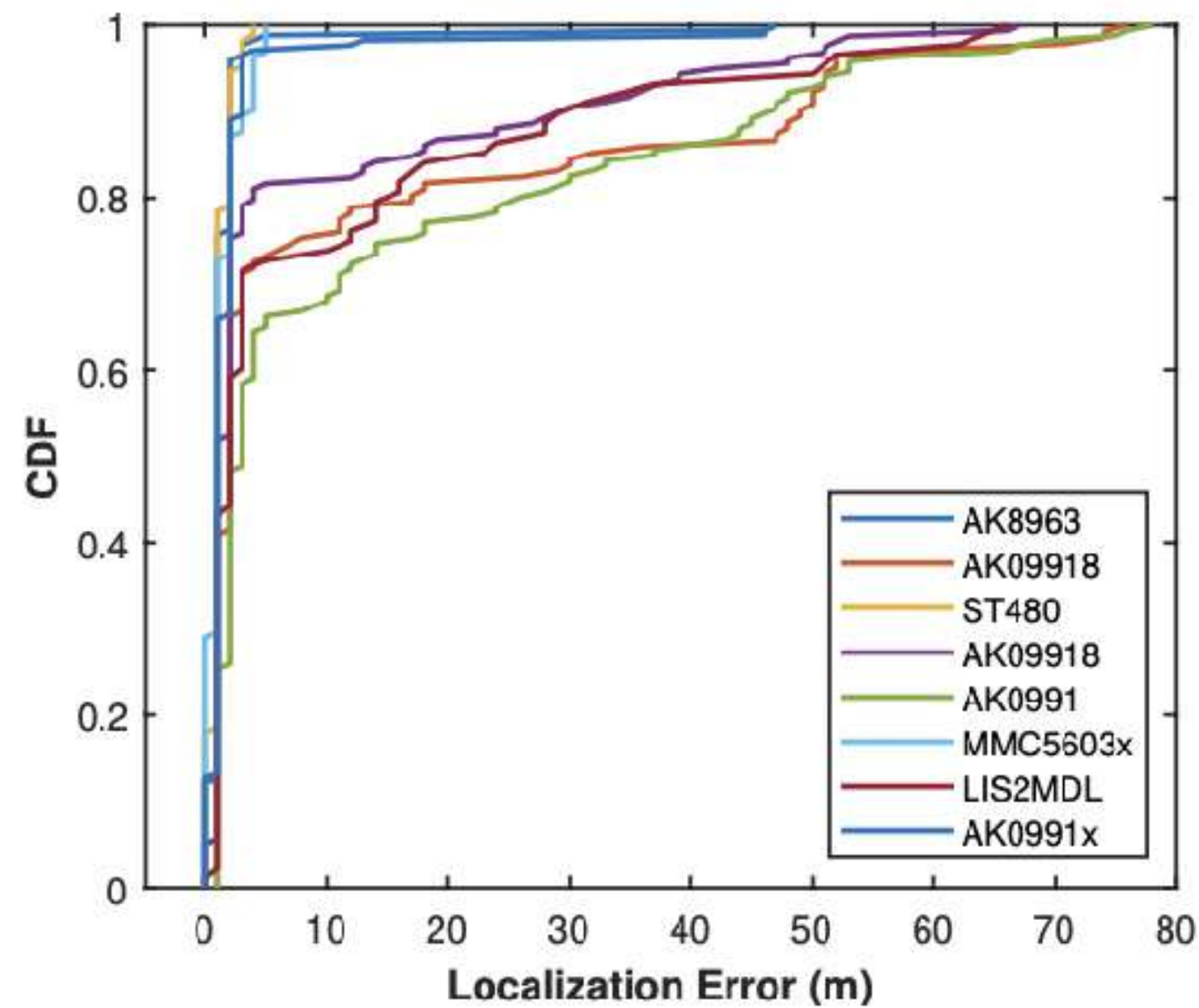
(I)



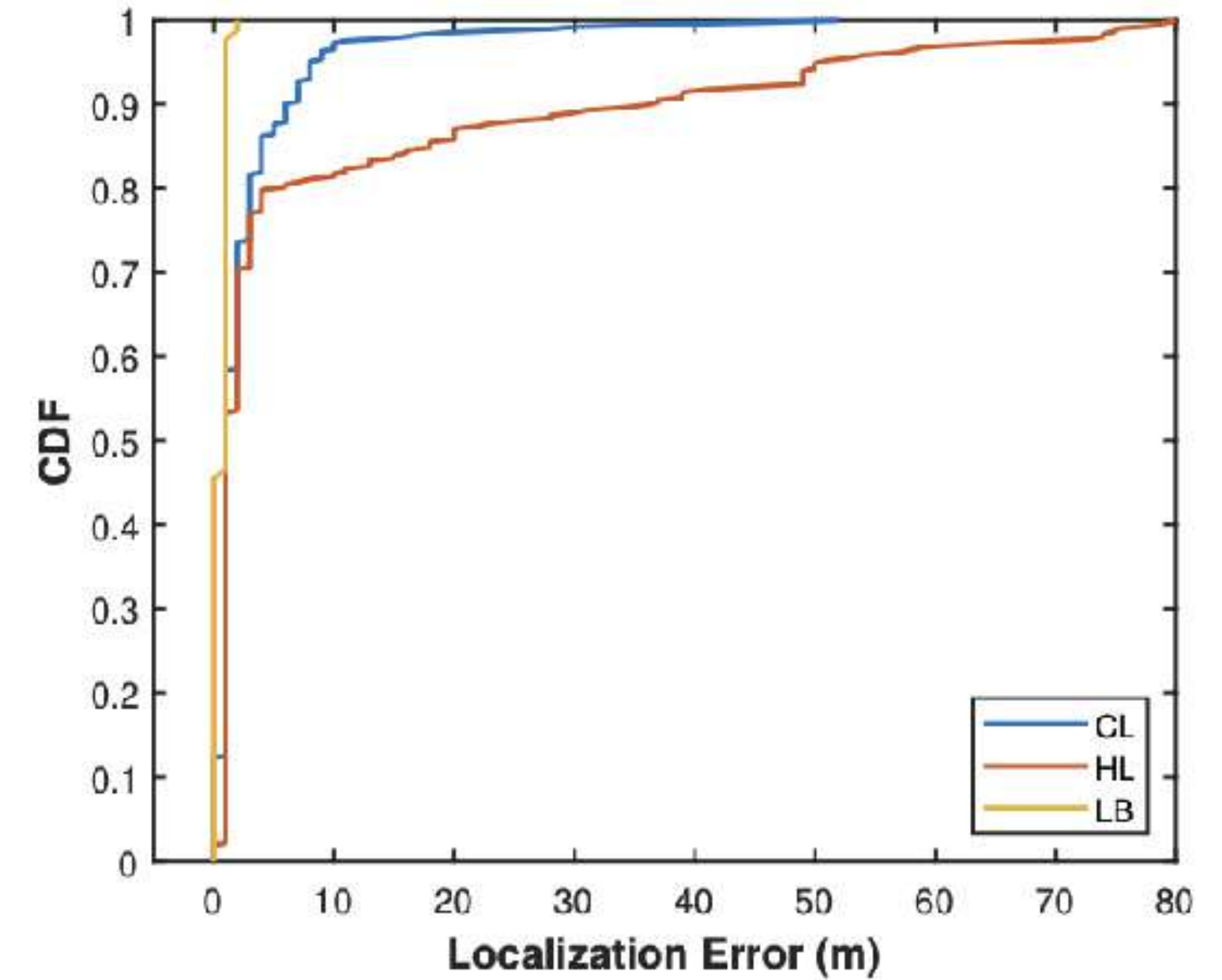
(ii)



(iii)



The signature in (i) is a 1 dimensional signal that captures the Earth's and Ferromagnetic field strengths corresponding to the pillars across the hallway shown below in (iii). The 2D plot (ii) shows the field strengths taken on X and Y coordinates of the same hallway



For the hallway in CL and LB building, we obtained errors of less than 5-6m 90% of the time in contrast to HL which was 6-8m for the HL building hallway

Heterogeneity in the sensor models does have an impact. From the CDF, we can see that the AK09918 model resulted in estimation error of 10m, 80% of time. Whereas the AK8963, st480 and mmc5603 models gave errors of less than 10m most of the time



# SAR Polarimetric Image Classification using Wishart Mixture Model and Convolutional Neural Networks



PI: Srimanta Mandal

Co-PI: Tapas Kumar Maiti

Number of JRFs: Two

Funding Agency: ISRO

Duration of the Project: 3 Years

Status of the Project: Ongoing

Number of MTech/PhD: Nil

Sanctioned Funding: 25,33,000/-

Start Date: 10-08-2020

End Date: 09-08-2023

The Grant Number: ISRO/RES/3/858/19-20

## Research Problem Statement:

The terrain captured by Polarimetric SAR imaging contains different ground covers such as urban regions, waterbody, and different types of crops. Classification of polarimetric SAR images is one of the important applications in remote sensing where each pixel of the image gets assigned to one of the classes. The Wishart classifier is a well-known statistical method for classification tasks. The Wishart Classifier works well for the homogeneous regions but not for the heterogeneous regions. The project aimed to improve the classification accuracy using the Wishart Mixture Model and Convolutional Neural Network where the terrain under consideration is heterogeneous in nature.

## Objectives & Proposed Approach:

The main objective of this work is to discriminate crop varieties spanned over heterogeneous agriculture land using polarimetric SAR images for agriculture monitoring and assessment. Covariance matrix of SAR data is assumed to follow complex Wishart distribution for major classification tasks. This is true for homogenous terrains but for heterogeneous regions, the accuracy of classification improves by assuming the data to follow a mixture model of Wishart distributions. Hence, Wishart mixture model has been employed with an expectation-maximization algorithm for parameter estimation. Further, a conditional random field based algorithm has been developed for incorporating spatial and contextual information. Instead of relying on hand-crafted feature for classification, automatic feature learning capability of convolutional neural network (CNN) has been explored. The squeeze and excitation network further helps to improve the classification accuracy by suppressing the speckle noise. We also would like to combine the advantages of classical methods and CNN-based method for better classification.

## Deliverables:

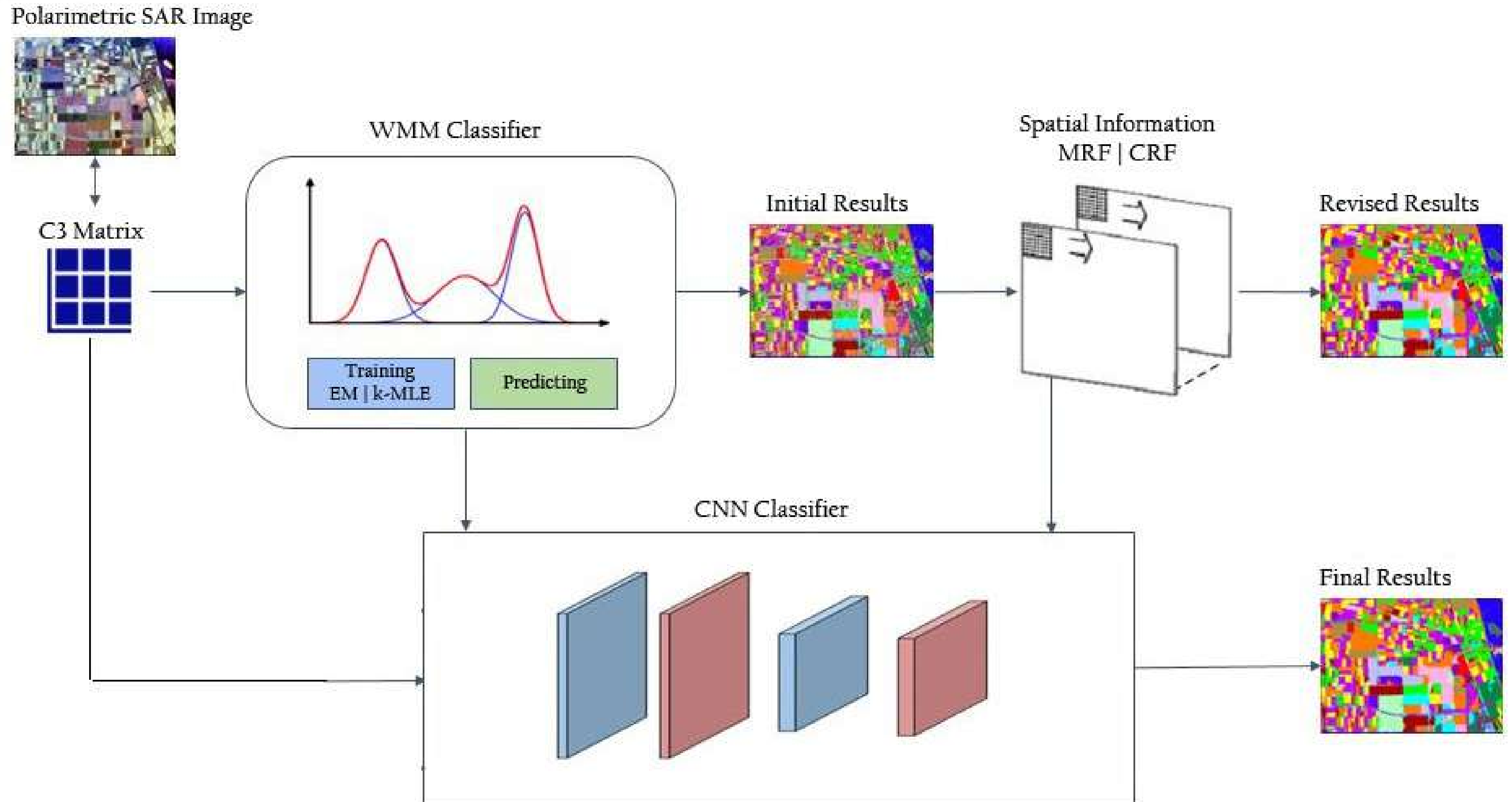
- 1) A well-written ATBD (Algorithm Theoretical Basis Document) detailing the theory and implementation of Wishart Mixture Model with parameter estimation.
- 2) Validation of models for crop classification.
- 3) A software module written in Python (well annotated) with accompanying user manual.
- 4) A well-written ATBD (Algorithm Theoretical Basis Document) detailing the theory and implementation of convolutional neural networks (FCN) for SAR polarimetry
- 5) Research papers publication in international refereed journals/conferences.

Class Label	Speckle Filtered Data	Unfiltered Data			
	WMM Classifier	Without Data Augmentation		With Data Augmentation	
	Global K-Means	Without Skip Connections	With Skip Connections	Without Skip Connections	With Skip Connections
Water	99.21	100.00	88.14	100.00	91.89
Forest	91.95	100.00	100.00	99.07	100.00
Lucerne	96.82	100.00	90.91	100.00	97.78
Grasses	92.50	77.78	88.24	98.99	97.03
Peas	97.61	100.00	95.45	100.00	99.17
Barley	97.18	66.67	69.57	96.10	92.31
BareSoil	96.66	100.00	57.14	97.30	82.35
Beet	94.73	100.00	97.56	99.39	100.00
Wheat2	87.20	100.00	97.96	96.24	93.62
Wheat3	95.45	100.00	100.00	97.61	99.66
Stembeans	97.19	100.00	95.24	100.00	100.00
Rapeseed	87.46	95.83	97.14	95.17	92.72
Wheat	93.58	97.44	98.18	99.18	97.96
Buildings	80.80	0	0	100.00	100.00
Potatoes	90.61	100.00	98.51	98.70	100.00
OA	<b>93.72</b>	<b>97.12</b>	<b>94.39</b>	<b>98.53</b>	<b>97.25</b>

Table: Comparison results on Flevoland 15 before and after data augmentation

## Research Publication:

- 1) N. Chaudhari, S. K. Mitra, S. Mandal, S. Chirakkal, D. Putrevu, and A. Misra, "Edge-Preserving classification of polarimetric SAR images using Wishart distribution and conditional random field," International Journal of Remote Sensing, vol. 43, no.6, pp.2134-2155, 2022.
- 2) N. Chaudhari, S. K. Mitra, S. Mandal, S. Chirakkal, D. Putrevu, and A. Misra, "Polarimetric SAR Classification: Fast Learning with k-Maximum Likelihood Estimator", in the Sixth IAPR International Conference on Computer Vision & Image Processing (CVIP2021) , 2021, Communications in Computer and Information Science, vol 1567. Springer, Cham, pp. 281-293.
- 3) N. Chaudhari, S. K. Mitra, S. Chirakkal, S. Mandal, D. Putrevu, and A. Misra, "Discrimination of multi-crop scenarios with polarimetric SAR data using Wishart mixture model," Journal of Applied Remote Sensing, Vol. 15, no.3, pp. 1-21, Aug. 2021.



The flow diagram of the proposed methodology



# Study of Privacy, Accountability and Ownership in IoT



**INRA**  
SCIENCE & IMPACT

Funding Agency: IFCPAR/CEFIPRA (Indo-French bilateral project) under DST-INRIA-CNRS Targeted Programme

Grant No. DST-CNRS 2015-03

Duration: 2016-2019

Collaborating Universities: DA-IICT, Gandhinagar, India and University Clermont Auvergne, France

Principle Investigators

Dr. Manik Lal Das (DA-IICT); Dr. Lafourcade Pascal (University Clermont Auvergne)

Co-Principle Investigators

Dr. Anish Mathuria (DA-IICT); Dr. Gerard Chalhoub (University Clermont Auvergne)

## Research Problem Statement:

The objective of this project is aimed at conducting extensive research in the security and privacy issues in IoT based on collaborative research through the exchanging visits between French researchers and Indian researchers, supervision of scholars and development of software/hardware modules by their domain expertise for continuing further research in the area.

One of the main goals of the project is to develop secure protocols. The project teams have devised a new primitive, Private Polynomial Evaluation, and validated the primitive with a formal security model, termed as Indistinguishable Chosen-Function Attack, which is a novel contribution to the scientific community by this project. The project has contributed towards privacy-preserving aspects of data processing and node-capture scenario in IoT applications. Data de-duplication and ownership issues in IoT applications have also been explored substantially. The technical merits of the research works have been anticipated in the form of publications appeared in referred journals and in peer-reviewed conferences in the area of security and privacy.

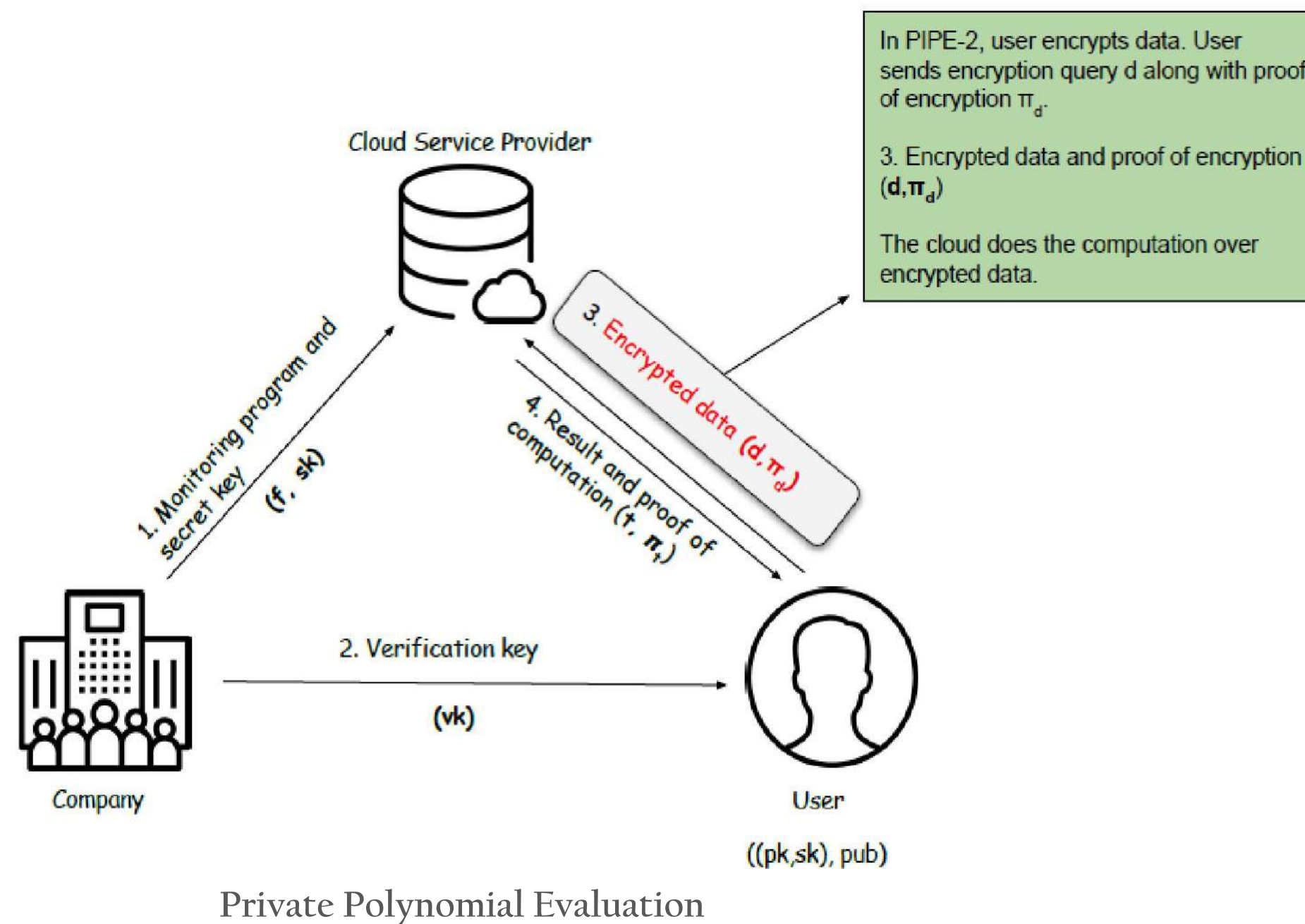
## Selected Research Publication:

- 1) Payal Chaudhari and Manik Lal Das. Privacy Preserving Searchable Encryption with Fine-grained Access Control. IEEE Transactions on Cloud Computing, 9(2): 753-762, 2021.
- 2) Sarita Agrawal, Manik Lal Das, and Javier Lopez. Detection of Node Capture Attack in Wireless Sensor Networks. IEEE Systems Journal, 13(1):238-247, 2018.
- 3) Hardik Gajera, Manik Lal Das. Privc: Privacy Preserving Verifiable Computation. In Proc. of COMSNETS, 298-305, 2020.
- 4) Xavier Bultel, Manik Lal Das, Hardik Gajera, David Gerault, Matthieu Giraud, and Pascal Lafourcade. Private Polynomial Evaluation. In Proc. of International Conference on Provable Security (ProvSec 2017), LNCS 10592, Springer, 487-506, China, 2017.
- 5) Hardik Gajera, Shruti Naik and Manik Lal Das. On the security of “Verifiable Privacy-preserving Monitoring for Cloud-assisted mHealth Systems”. In Proc. of the International Conference on Information Systems Security (ICISS 2016), LNCS 10063, Springer, 324-335, India, 2016.

## Objectives & Proposed Approach:

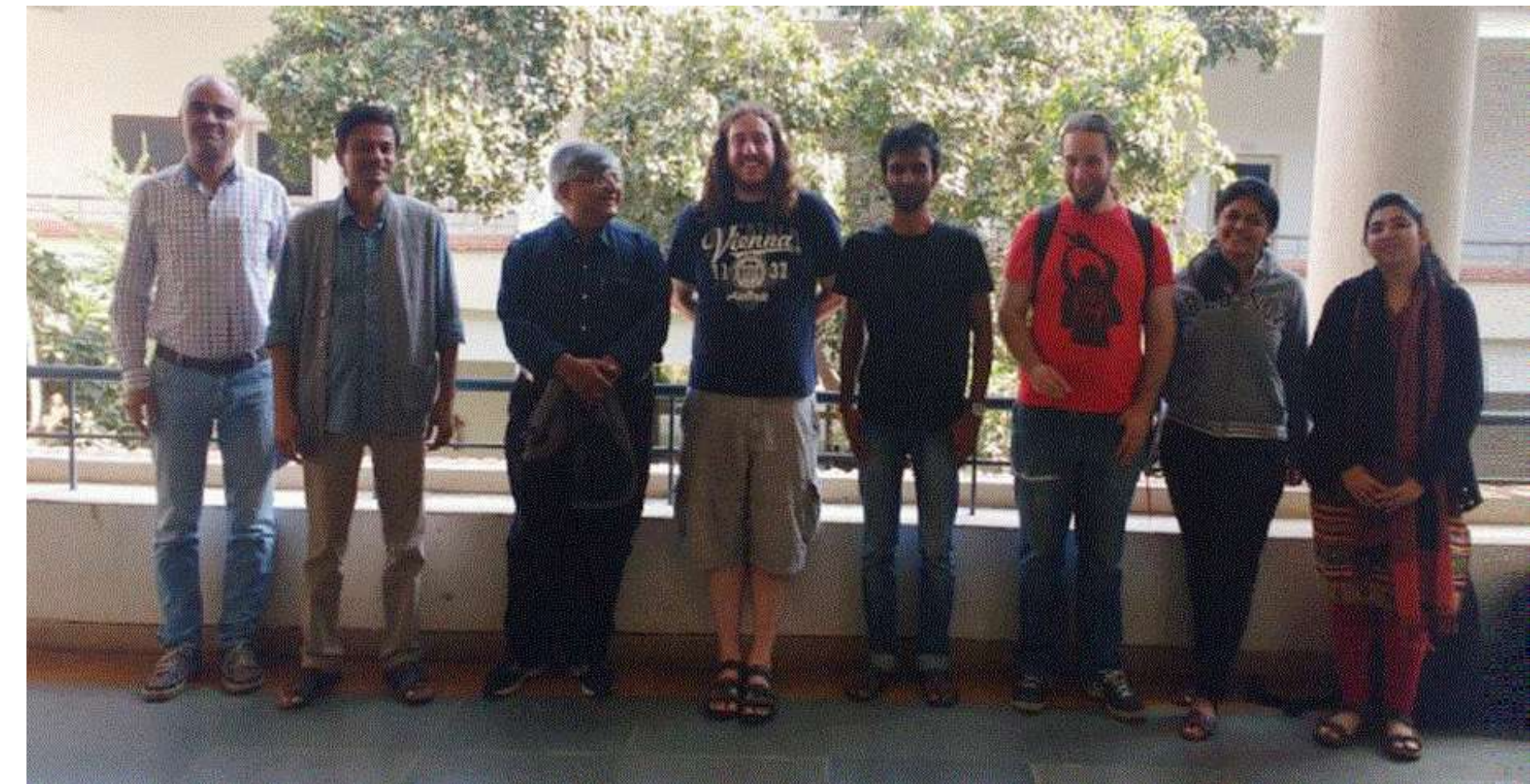
Multiple exchange visits have been carried out between Indian researchers and French researchers, which help not only in enhancing technical knowledge among researchers, but also has established a long lasting association between these research groups. The research problem of the project work has immensely encouraged students for doing their thesis and project work under this project. As outcome, two PhD theses and a few master and undergraduate thesis/projects have been supervised under this project.

These students have also got an opportunity for their knowledge sharing with French researchers. The results of the project will be of immediate use for the further development of IoT applications, not only by the institutions involved in the project, but also by other researchers in the scientific community.



## Theses/dissertations resulted from the project:

- 1) Privacy and Accountability in Cloud Computation and Storage (PhD thesis by Hardik Gajera).
- 2) Design and Analysis of Schemes for Privacy Preserving Cloud Storage Services (PhD thesis by Payal Chaudhari).
- 3) Privacy Preserving Identity Verification and Verifiable Computation for HealthCare System (MTech thesis by Shruti Naik).
- 4) Remote Car Locking System (MTech thesis by Jinita Patel).



From Left:

Naveen Kumar, Manik Lal Das, Anish Mathuria, Pascal Lafourcade, Hardik Gajera, David Gerault, Shruti Naik, Nidhi Desai



# KAVACH-Futuristic Flexible electronics based Communication System for Monitoring Soldier's condition during warfare



PI: Rutu Parekh

Duration of the Project: 2 Years

Start Date: 06-05-2022

Co-PI: Vinay Palaparthi

Status of the Project: Ongoing

End Date: 05-05-2024

Number of JRFs: One

Number of MTech/PhD: Nil

The Grant Number: GUJCOST/STI/2021-22/3880

Funding Agency: DST, GUJCOST

Sanctioned Funding: 16,90,000/-

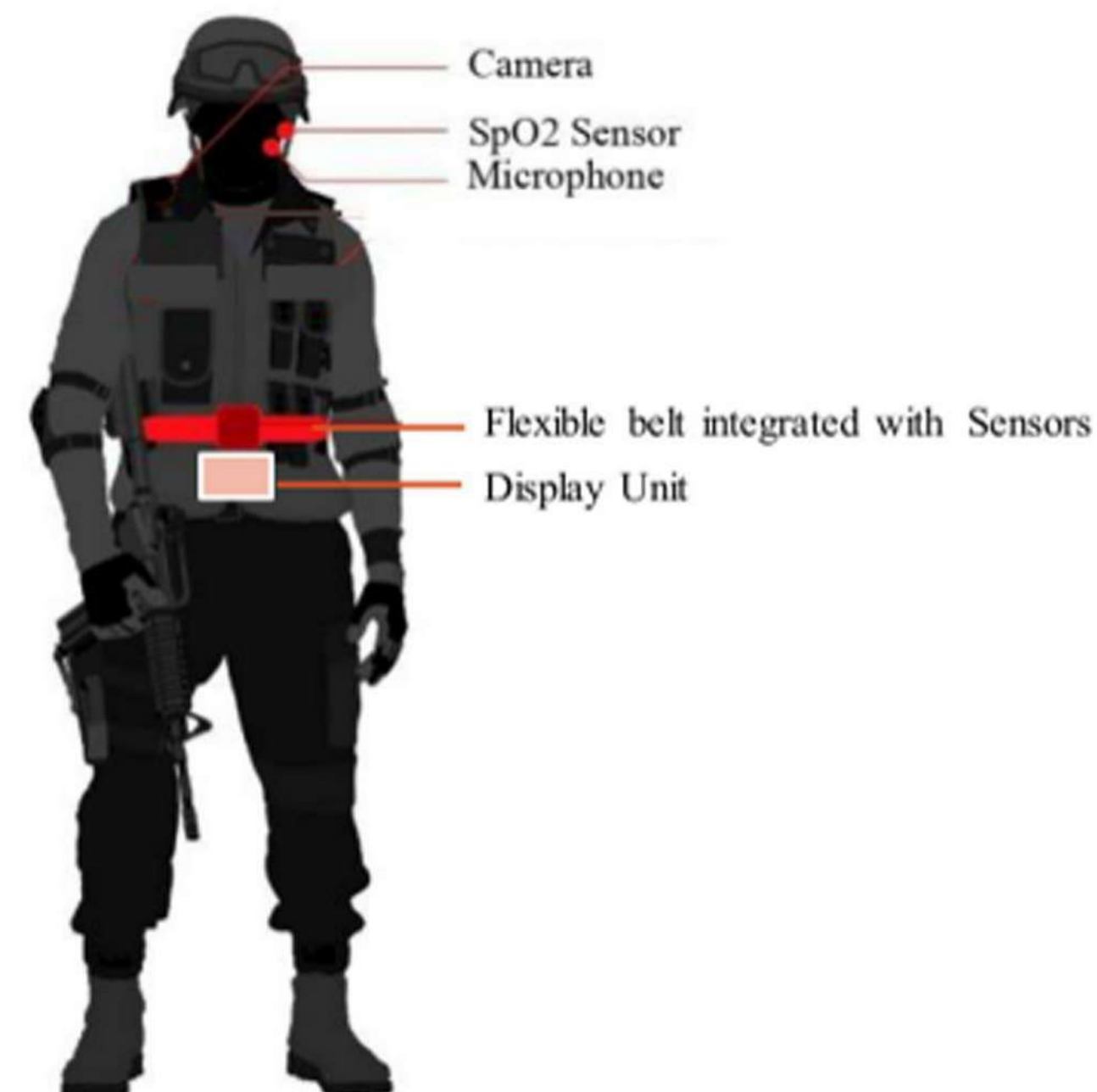
## Research Problem Statement:

During military operations, there is a controlling base station which monitors the overall activities of many troops and keeps a track of them primarily through communication with RF devices such as walkie-talkie and communication sets. Due to the heavy time lag in obtaining immediate information about any kind of casualty, the group leader cannot swiftly take effective decisions such as providing backup cover, sending additional manpower to the affected area, providing immediate backup from the base station etc., thus dwindling the overall fighting efficacy of the troop. The pictorial representation of ground situation is shown in figure below. It can be seen that there is no communication or firsthand information between the groups in case of any casualty of soldier. Effective first information of the activities happening in the area of operation plays an important role in taking decision and planning for further actions. Better communication and providing the first-hand information would rally round the following advantages :-

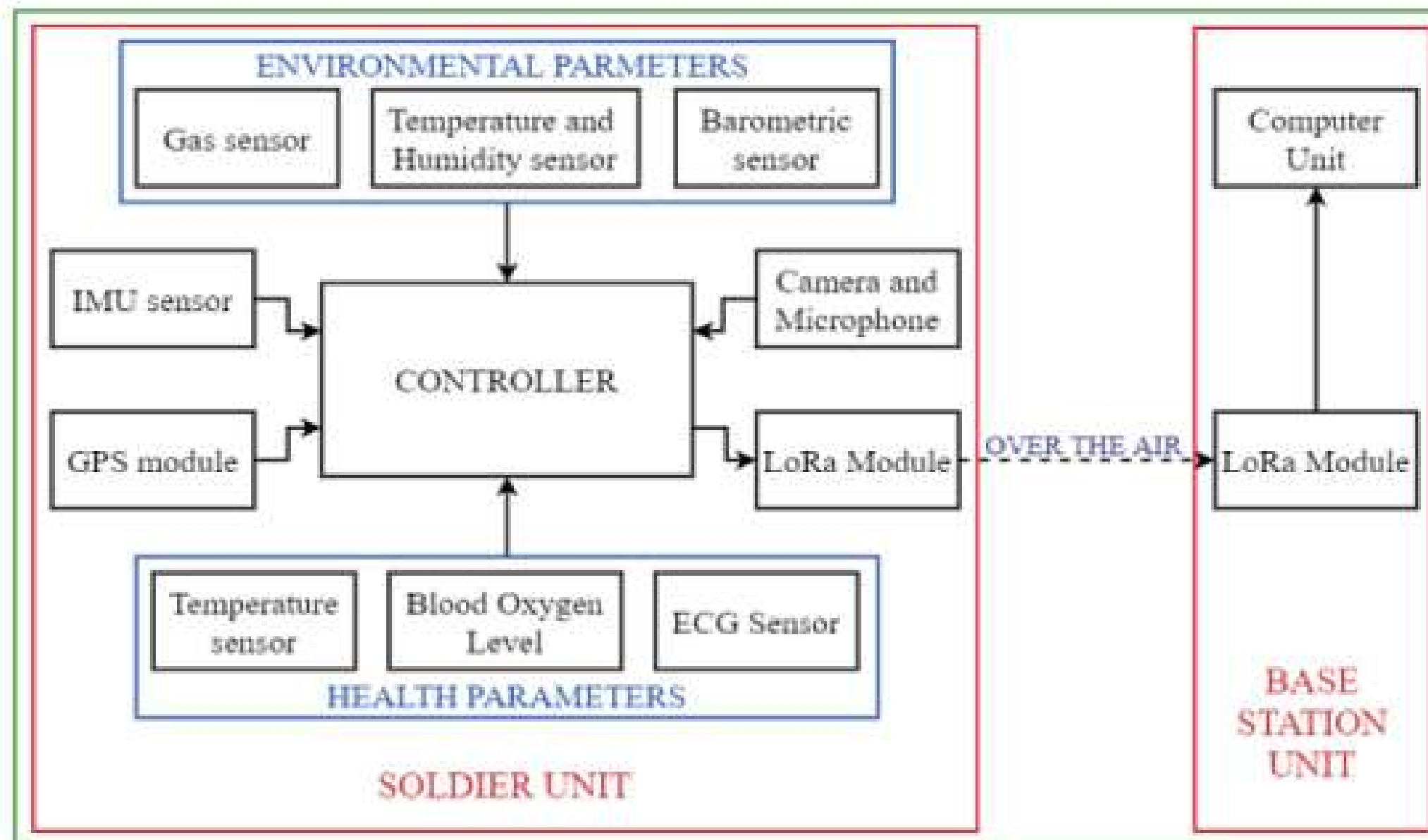
- 1) Respond much faster to the changing situations.
- 2) Tactical management and Strategic marshalling of resources to the troops by the base station.
- 3) Maintaining a higher degree of cohesiveness and coordination of the troops during any sort of operation.
- 4) Obtaining information about any sort of casualty in the group of soldiers deployed for an operation would help in provisioning of immediate medical cover

## Objectives & Proposed Approach:

To overcome these constraints and achieve the above goals, we propose a system to analyze the health and environmental conditions of the soldier, enabling the base station to make informed decisions in-time. This system consists of two units viz., soldier's unit which can be integrated into the soldier's clothing and a base station unit. Soldier's unit collects the environmental and health related data using different sensors and modules. The controller processes these data to extract useful information. This is then transmitted wirelessly to the base station which is few km away.







Block diagram proposed system

**Deliverables:**

Embedded flexible electronics to monitor mental, physical as well as environmental parameters for individual as well as the troop of soldiers, establish communication between all, and report it to the control room.



Group of Soldiers Patrolling



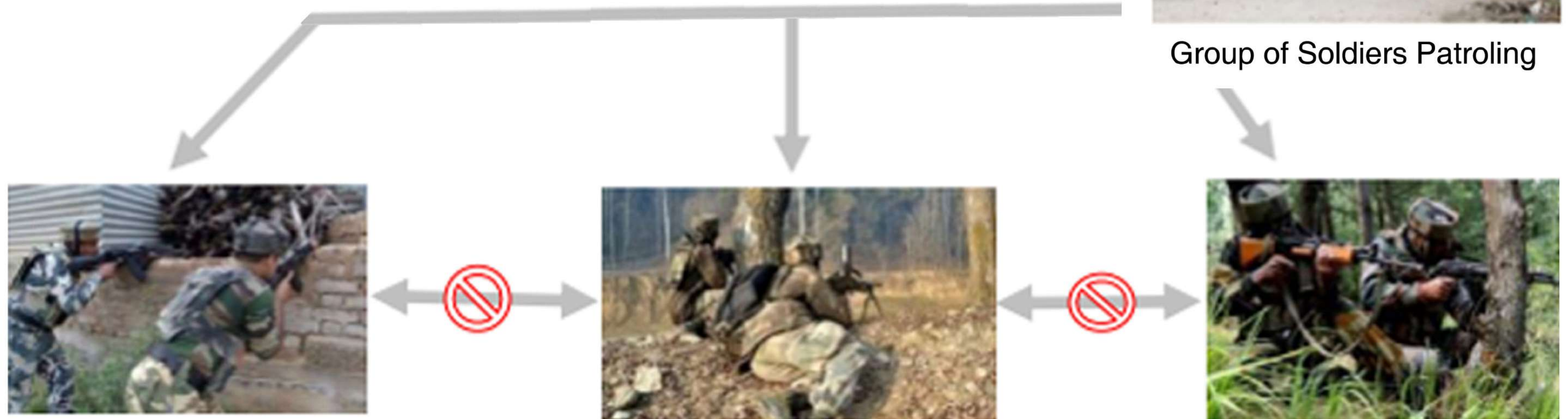
Sub Group 1



Sub Group 2



Sub Group 3





# Prototyping Dog Jacket for Real-Time Rescue Operation Inspired by Robotics Technology



PI: Tapas Kumar Maiti

Co-PI: Bhaskar Chaudhury

Number of JRFs: One

Funding Agency: DST, GUJCOST

Duration of the Project: 3 Years

Status of the Project: Ongoing

Number of MTech/PhD: Nil

Sanctioned Funding: 19,83,200/-

Start Date: 01-06-2022

End Date: 31-05-2025

The Grant Number: GUJCOST/STIR&D/22-23/904

## Research Problem Statement:

Indian society has been affected by several natural disasters that have occurred frequently over the last several decades, such as tsunami 2004, earthquake in Gujarat in 2001, bridge collapse in Kolkata in 2017, 65 landslides in Kerala in 2019, annual floods and tunnel collapses, etc. It has been claimed that several tens of thousands of people have lost their lives due to natural disasters. The state, Gujarat is located in the “Himalayan Collision Zone”-where Indo-Australian tectonic plate slides under Eurasian plate-causing active fault lines beneath. Earthquake risk is very high in this state which has suffered 9 major earthquakes in the past 200 years in 1819, 1845, 1847, 1848, 1864, 1903, 1938, 1956 & 2001. Under-construction bridge collapsed in Surat in 2014. Two people died and five people are feared trapped in the wreckage. Recently, in Pragatinagar in Kheda district’s Nadiad area, Gujarat, four people died after three-storey building collapsed in August 2019.

The building collapse is caused by heavy rains in the area. Many people are trapped under the debris of the building. At initial stage four to five people have been rescued. Such scenarios in the future can be handled much more efficiently with the use of the rescue dog embedded with proposed jacket. Proposed prototyping dog jacket can be used for search operation to track the people for such unforeseen rescue operation scenarios inside the collapsed building/bridges.

## Objectives & Proposed Approach:

The project aims to prototype a dog jacket with the combination of sensor system, data transfer and analysis technologies for searching operation in a disaster zone. Figure 1 shows a schematic representation of involved technologies, considered in the proposed project. The major tasks of the proposed project are:

### Tasks:

- 1) Prototyping Dog Jacket with Sensors
- 2) Data transfer and analysis for disaster mitigation
- 3) Demonstration
- 4) Scientific publications, patents, and explore feasibility of commercialization of the technology

## Typical Disaster Scenario

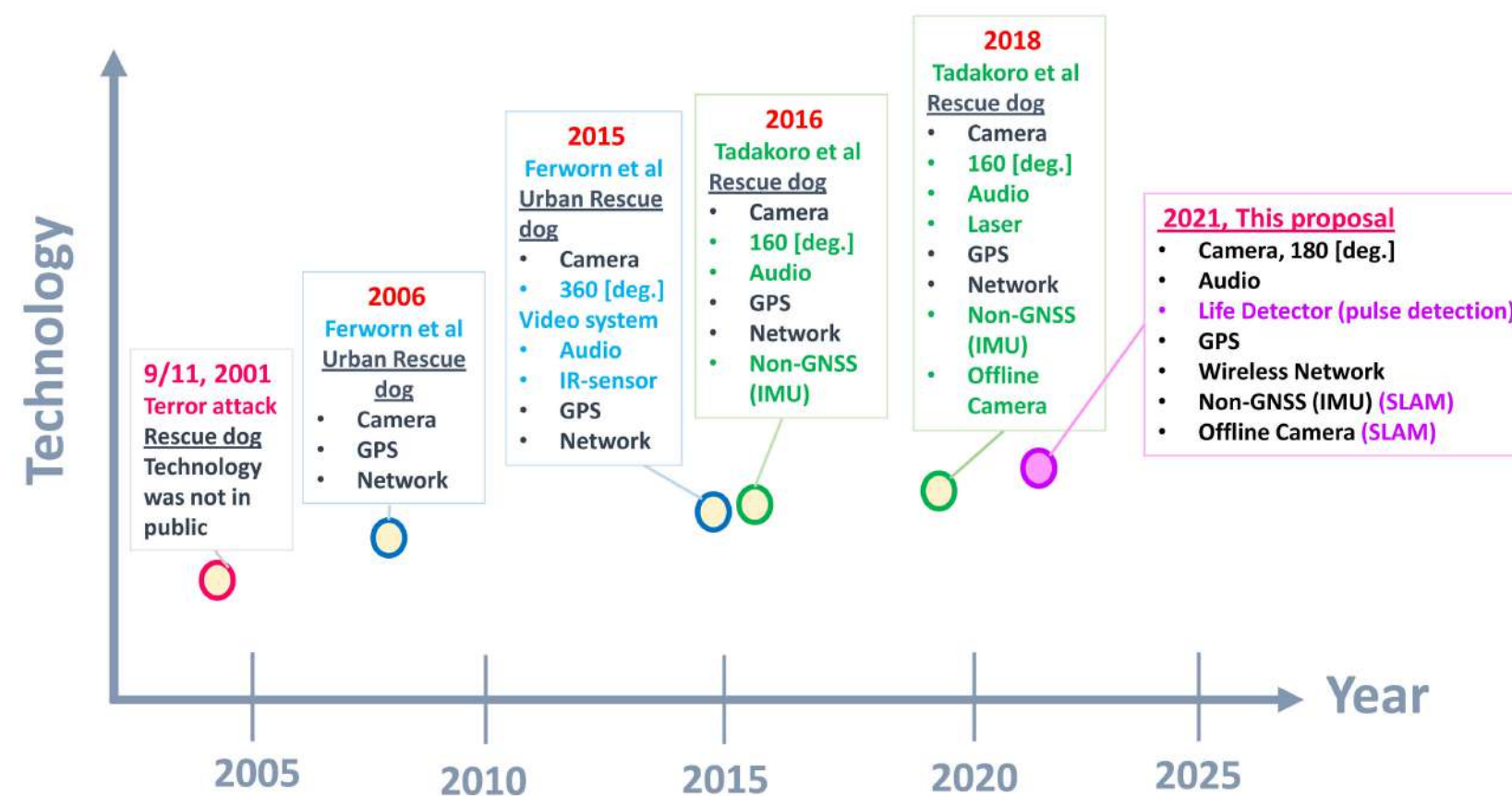


## Deliverables:

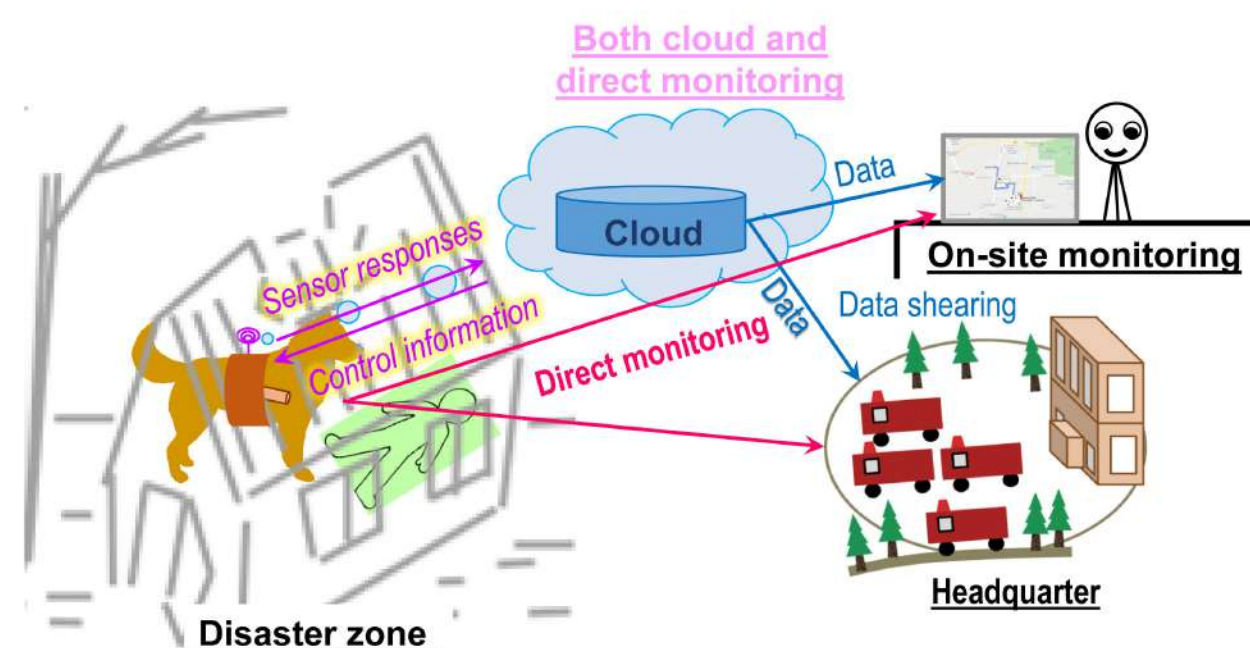
Sensor-system based prototype dog jackets will be developed for search and rescue operation in disaster zone which may be results from building and bridge collapses. Prototype will be make available to research community and also for training purse in Gujarat as well as in other region in India.

Outcome of the project will boost robot technology in the disaster management sector, will be used for rescue operation within one hour after disaster incident which will decrease the death rate of human and animals. It can be used for training and educational purposes, will be commercialize for rescue industries.

## Current Status

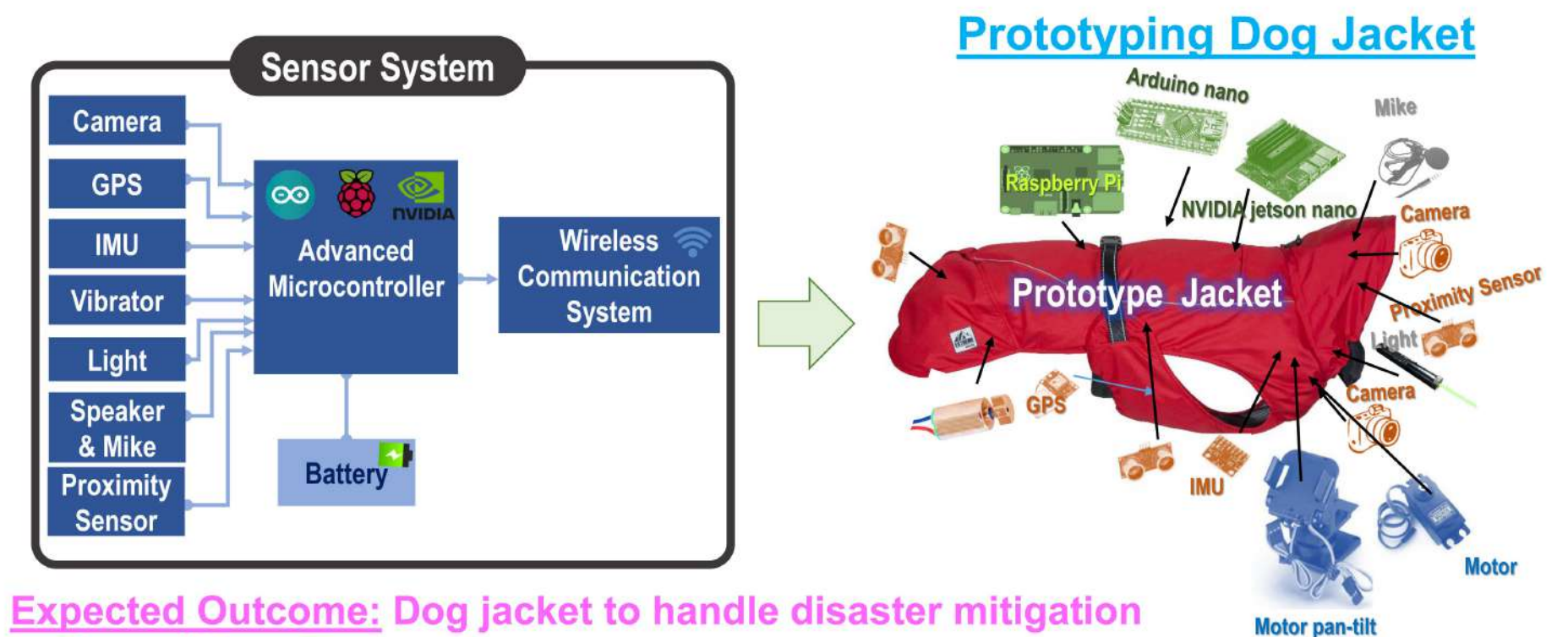


## Novelty of the Proposal



Overview of an entire system consists of prototype dog, cloud service, and visualization system.

## Materials and Method



Expected Outcome: Dog jacket to handle disaster mitigation in three different scenarios.

Fig. 2. (a) Sensor system layout and (b) Smart sensor based Dog jacket prototype. The dog jacket will be equipped with sensors and a wireless communication system.

## Major Tasks

- 1) Prototyping Dog Jacket with Sensors and Actuators
- 2) Cloud based framework for data collection and storage
- 3) Development of GUI for data analysis
- 4) On-Site Demonstration
- 5) Scientific publications, patents and explore feasibility of Commercialization

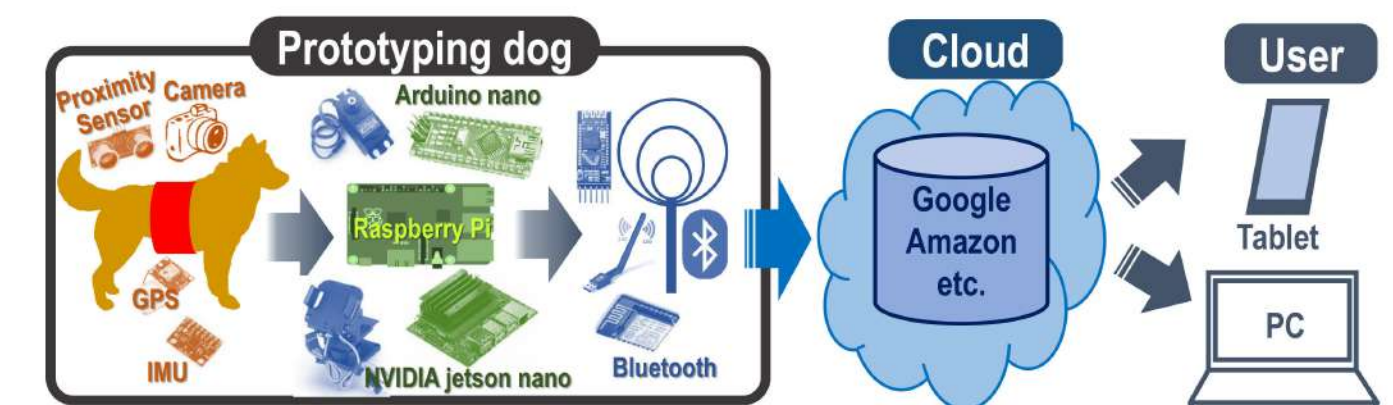


Fig. 1. Illustrates the integration of sensor system based dog jacket and user interface technology for data analysis.



# Development of microwave absorber (Carbonyl Iron filled Silicon Rubber Sheets) in 1 to 8 GHz range



PI: Deepak Ghodgaonkar

Co-PI: Sanjeev Gupta

Number of JRFs: One

Funding Agency: ISRO

Duration of the Project: 4 Years

Status of the Project: Completed

Number of MTech/PhD: One

Sanctioned Funding: 22,89,000/-

Start Date: 01-08-2017

End Date: 31-07-2021

The Grant Number: ISRO/RES/3/742/18-19

## Research Problem Statement:

Carbonyl Iron Silicon Rubber (CISR) Sheets were developed for Microwave Absorber Applications in 1 to 8 GHz range.

Two-layer Microwave Absorber in and 2.5 to 8.2 GHz range and Single-Layer Quarter Wavelength Absorber in 1.7 to 2.6 GHz range Design procedure and fabrication process (exact composition and process recipe) of CISR Sheets.

Test and Measurement Procedure for Characterization of CISR Sheets.

## Deliverables:

Operating frequency is 1 to 8.2 GHz with reflection better than -10 dB. The base materials should be iron filled silicone rubber with hardness of 73 (Shore A)



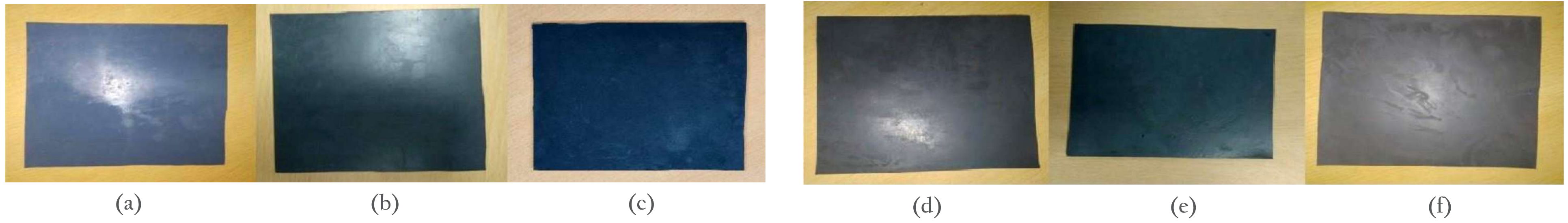
Photograph of toroidal shape sleeve CISR

## Objectives & Proposed Approach:

Two layer broadband microwave absorber (7.35 mm of silicone rubber as first layer and 1.4 mm of 50% of CI powder in CISR sheet by volume as second layer) provides reflectivity better than -10 dB in the frequency range of 2.5 to 8.2 GHz.

## Research Publication:

- 1) Rahul Vashisth, Deepak Ghodgaonkar and Sanjeev Gupta, "Broadband Microwave Absorber using Pixelated FSS Embedded in CISR Sheets in Frequency Range of 3.95 to 8.2 GHz" Journal of Electromagnetic Waves and Applications, Vol. 35, No. 17, 2021, pp. 2349-2367.
- 2) Rahul Vashisth, Deepak Ghodgaonkar and Sanjeev Gupta, "Design and fabrication of broadband microwave absorber using CISR sheets in 2.5 to 8.2 GHz range," Presented at Wireless, Antenna and Microwave Symposium (WAMS), June 5 to 8, 2022.
- 3) Rahul Vashisth, Deepak Ghodgaonkar and Sanjeev Gupta, "Complex Permittivity and Complex Permeability Measurements of CISR sheets for Microwave Absorber Applications," 2018 IEEE International RF and Microwave Conference (RFM), 17 to 19 December 2018, Penang, Malaysia.
- 4) Rahul Vashisth, Deepak Ghodgaonkar and Sanjeev Gupta, "Design and Fabrication of Broadband Microwave Absorber using CISR Sheets Embedded with FSS," 2018 IEEE MTT-S International Microwave and RF Conference (IMaRC), 28 to 30 November 2018, Kolkata, India.



Photograph of Fabricated CISR sheets (a) 0% (b) 10% (c) 20% (d) 30% (e) 40% (f) 50% of CI in CISR sheets by volume.



Photograph of WR-187 RDWG system for 3.95 to 5.85 Ghz frequency rang



# Dynamical Sampling and Representation of Frames via Iterated Operator Systems



PI: Nabin Kumar Sahu

Duration of the Project: 3 Years

Start Date: 12-01-2021

Co-PI: Nil

Status of the Project: Ongoing

End Date: 11-01-2024

Number of JRFs: Two

Number of MTech/PhD: Nil

The Grant Number: CRG/2020/003170

Funding Agency: SERB, DST

Sanctioned Funding: 16,16,032/-

## Research Problem Statement:

In many practical situations a signal  $f$  varies with time and its evolution obey certain rules. The dynamical sampling problem is to recover the signal  $f$  from the spatial samples. A frame is in general, a measurement set or spanning set. The main objective of this project is to study those frames those are dynamically generated by the iterative action of an operator.

- 1) Study of dynamical frames in tensor product spaces.
- 2) Study of weaving frames which are dynamically generated.
- 3) Characterize those dynamical frames which are two distance sets or  $K$ -distance sets.

## Deliverables:

At the completion of this project

- 1) We should be able to derive theoretical results that can be useful in dynamical sampling.
- 2) We construct enough examples to validate our theoretical results.
- 3) The use of tensor product on higher dimensional space will help in simplifying the problem into lower dimensional space. Hence we look for possible applications of dynamical sampling problems using tensor products.

## Proposed Approach:

- 1) For the first problem, we use the tensor decomposition to bring down the problem from higher dimension to lower dimension.
- 2) For the second problem, suppose we are given two frames, both of them are dynamically generated, then any weaving is also a frame. The newly generated frame by the weaving can also be dynamically generated. We characterize the generating operator and the generating set.
- 3) Two distance frames are those spherical frames where the distance between the frame vectors are either  $a$  or  $b$ . We characterize those operators or matrices which generate this type of frames. We characterize them in terms of their Gram matrix.

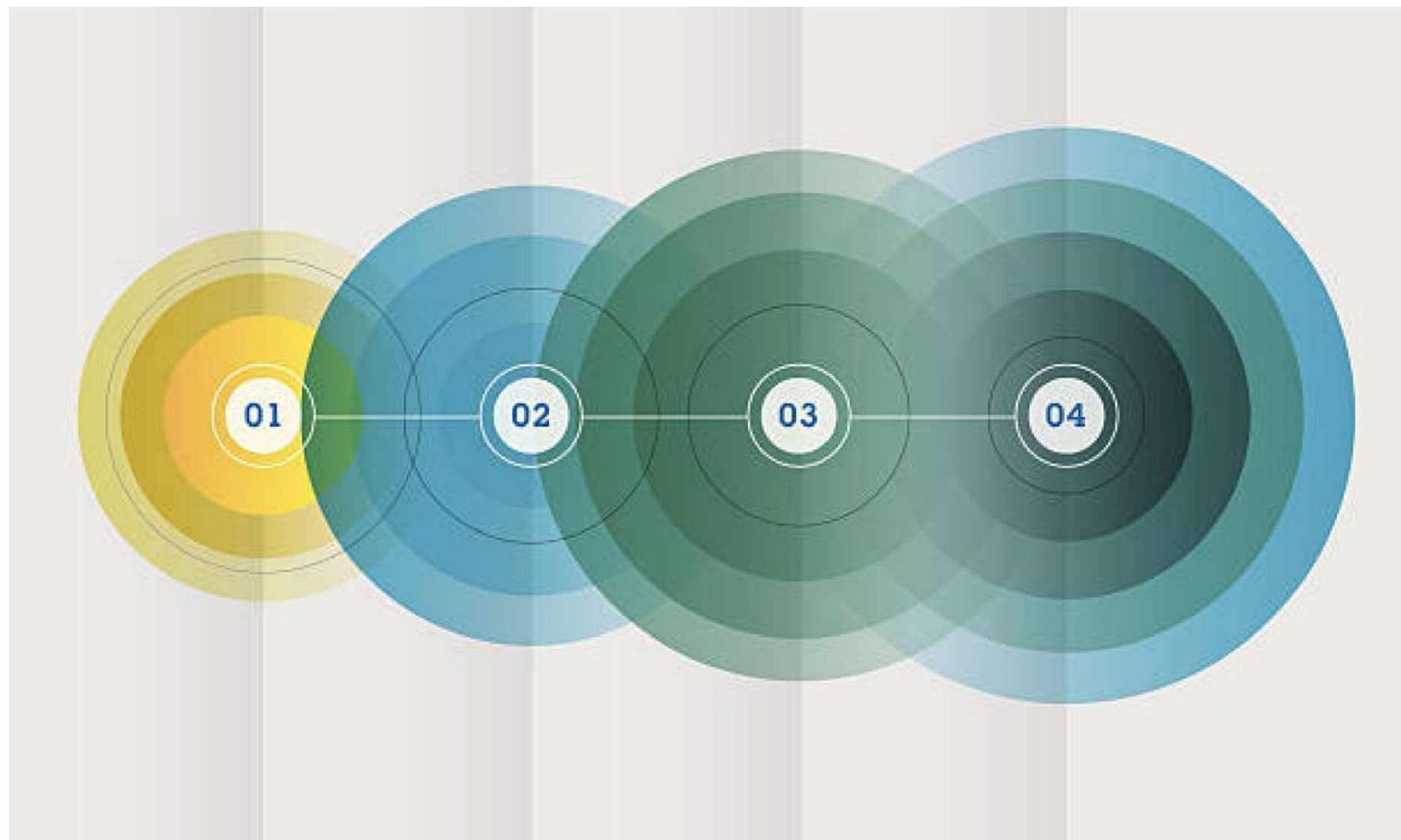


Time evolving wave

**Problem 1.** If  $\{f_i\}$  is a frame for the Hilbert space  $H_1$  with generating operator  $A$ , and  $\{g_j\}$  is a frame for the Hilbert space  $H_2$  with generating operator  $B$ . Then whether  $\{f_i \otimes g_j\}$  is a frame for  $H_1 \otimes H_2$ ? What will be the generating matrix? Whether its dual can be dynamically generated? What will be its representation?

**Results obtained:**

- Yes,  $\{f_i \otimes g_j\}$  is a frame for  $H_1 \otimes H_2$ .
- The generating operator is  $A \otimes B$ .
- In this case one single element  $f_1 \otimes g_1$  can not generate the frame  $\{f_i \otimes g_j\}$  using the operator  $A \otimes B$ , instead we have to take a set of elements  $\{f_1 \otimes g_j\}_{j \in J} \cup \{g_1 \otimes f_i\}_{i \in I}$ .
- If the frame operator for  $\{f_i\}$  is  $S_1$  and the frame operator for  $\{g_j\}$  is  $S_2$ , then the frame operator for  $\{f_i \otimes g_j\}$  is  $S_1 \otimes S_2$ .
- The standard dual of  $\{f_i \otimes g_j\}$  is  $\{(S_1 \otimes S_2)^{-1}(f_i \otimes g_j)\}$ .
- The standard dual can be generated by the operator  $(S_1^{-1}AS_1) \otimes (S_2^{-1}BS_2)$ .



Dynamical representaiton

**Example 0.1.** Let  $\{f_i\}_{i=1}^3 = \{(1, 0, 0), (1, -1, 1), (1, -2, 1)\}$  and  $\{g_j\}_{j=1}^3 = \{(1, 0, -1), (0, 1, 2), (0, -1, -1)\}$  be two frames in  $\mathbb{R}^3$  with their generating matrix  $A$  and  $B$ , respectively, where

$$A = \begin{pmatrix} 1 & 1 & 1 \\ -1 & 0 & -1 \\ 1 & 0 & 0 \end{pmatrix} \quad B = \begin{pmatrix} 1 & -2 & 1 \\ 2 & -3 & 1 \\ 3 & -3 & 1 \end{pmatrix}.$$

Then,  $\{f_i \otimes g_j\}$  is given by

$$\{f_i \otimes g_j\} = \begin{pmatrix} f_1 \otimes g_1 & f_1 \otimes g_2 & f_1 \otimes g_3 \\ f_2 \otimes g_1 & f_2 \otimes g_2 & f_2 \otimes g_3 \\ f_3 \otimes g_1 & f_3 \otimes g_2 & f_3 \otimes g_3 \end{pmatrix}$$

where,

$$f_1 \otimes g_1 = \begin{pmatrix} 1 & 0 & -1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}, f_1 \otimes g_2 = \begin{pmatrix} 0 & 1 & 2 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}, f_1 \otimes g_3 = \begin{pmatrix} 0 & -1 & -1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

$$f_2 \otimes g_1 = \begin{pmatrix} 1 & 0 & -1 \\ -1 & 0 & 1 \\ 1 & 0 & -1 \end{pmatrix}, f_2 \otimes g_2 = \begin{pmatrix} 0 & 1 & 2 \\ 0 & -1 & -2 \\ 0 & 1 & 2 \end{pmatrix}, f_2 \otimes g_3 = \begin{pmatrix} 0 & -1 & -1 \\ 0 & 1 & 1 \\ 0 & -1 & 1 \end{pmatrix}$$

$$f_3 \otimes g_1 = \begin{pmatrix} 1 & 0 & -1 \\ -2 & 0 & 2 \\ 1 & 0 & -1 \end{pmatrix}, f_3 \otimes g_2 = \begin{pmatrix} 0 & 1 & 2 \\ 0 & -2 & -4 \\ 0 & 1 & 2 \end{pmatrix}, f_3 \otimes g_3 = \begin{pmatrix} 0 & -1 & -1 \\ 0 & 2 & 2 \\ 0 & -1 & -1 \end{pmatrix}$$

On operating  $A \otimes B$  on  $f_1 \otimes g_1$  we get  $f_2 \otimes g_2$ . That is  $(A \otimes B)(f_1 \otimes g_1) = A(f_1 \otimes g_1)B^T = f_2 \otimes g_2$ . Again, on operating  $A \otimes B$  on  $f_2 \otimes g_2$ , we get  $f_3 \otimes g_3$ , that is  $(A \otimes B)(f_2 \otimes g_2) = A(f_2 \otimes g_2)B^T = f_3 \otimes g_3$ .

Thus,  $\{f_1 \otimes g_1, A(f_1 \otimes g_1), A^2(f_1 \otimes g_1)\}$  generate the diagonal elements.

Similarly, on operating  $A \otimes B$  on  $f_1 \otimes g_2$  and  $f_2 \otimes g_1$ , we get  $f_2 \otimes g_3$  and  $f_3 \otimes g_2$ , respectively.

We can see this as follows:

$(A \otimes B)(f_1 \otimes g_2) = A(f_1 \otimes g_2)B^T = f_2 \otimes g_3$  and  $(A \otimes B)(f_2 \otimes g_1) = A(f_2 \otimes g_1)B^T = f_3 \otimes g_2$ .

Therefore,  $\{f_1 \otimes g_j : j = 1, 2, 3 \text{ and } f_i \otimes g_1 : i = 2, 3\}$  will generate the frame  $\{f_i \otimes g_j\}$  in  $\mathbb{R}^3 \otimes \mathbb{R}^3$ .



# Design & Implementation of Visibility Improvement Model for Haze Removal in Images Acquired from Real-time CCTV Camera



PI: Manish Khare

Co-PI: Bakul Gohel

Number of JRFs: Nil

Funding Agency: GUJCOST

Duration of the Project: 2 Years

Status of the Project: Ongoing

Number of MTech/PhD: Three

Sanctioned Funding: 19,25,000/-

Start Date: 02-04-2021

End Date: 31-03-2023

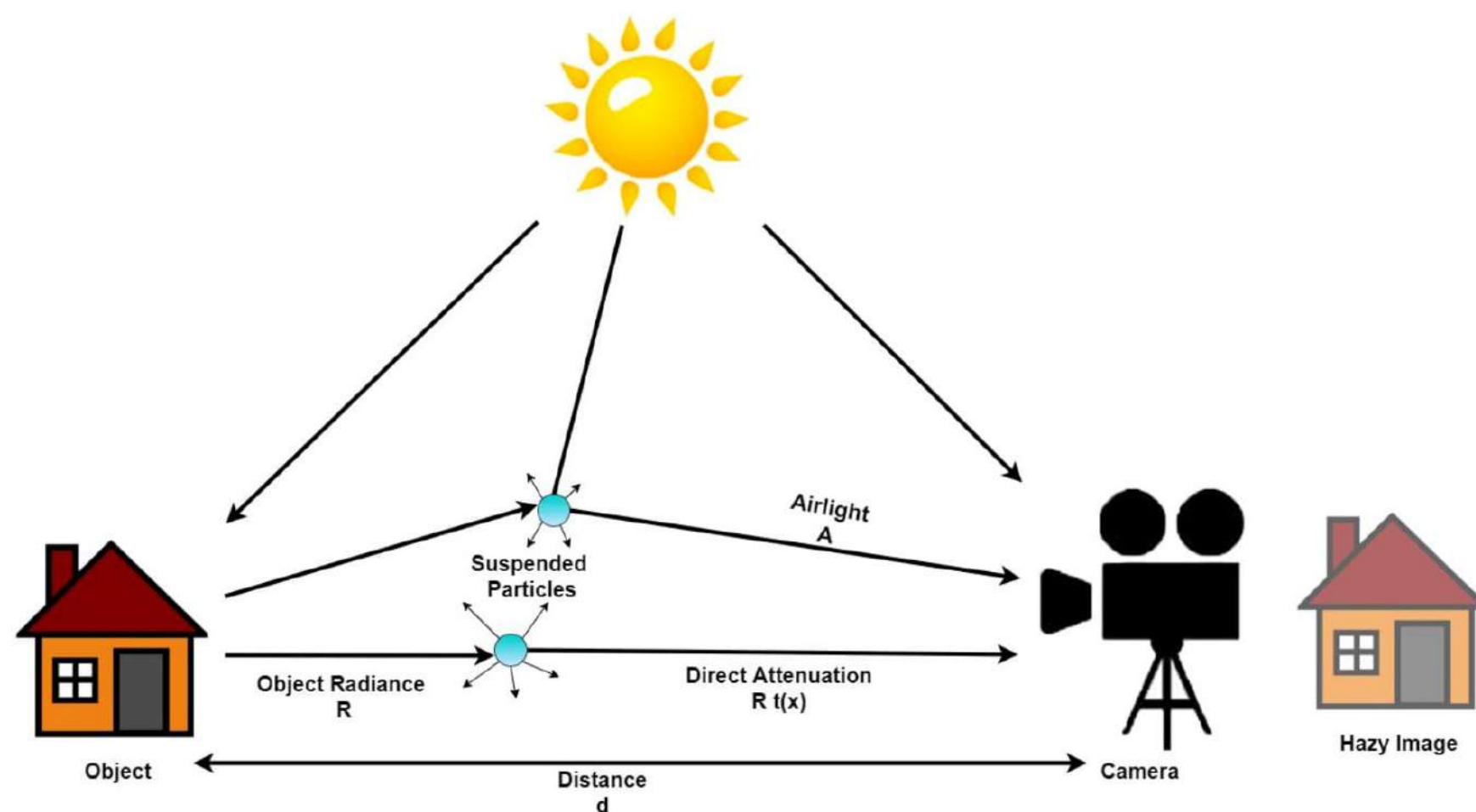
The Grant Number: 2273

## Research Problem Statement:

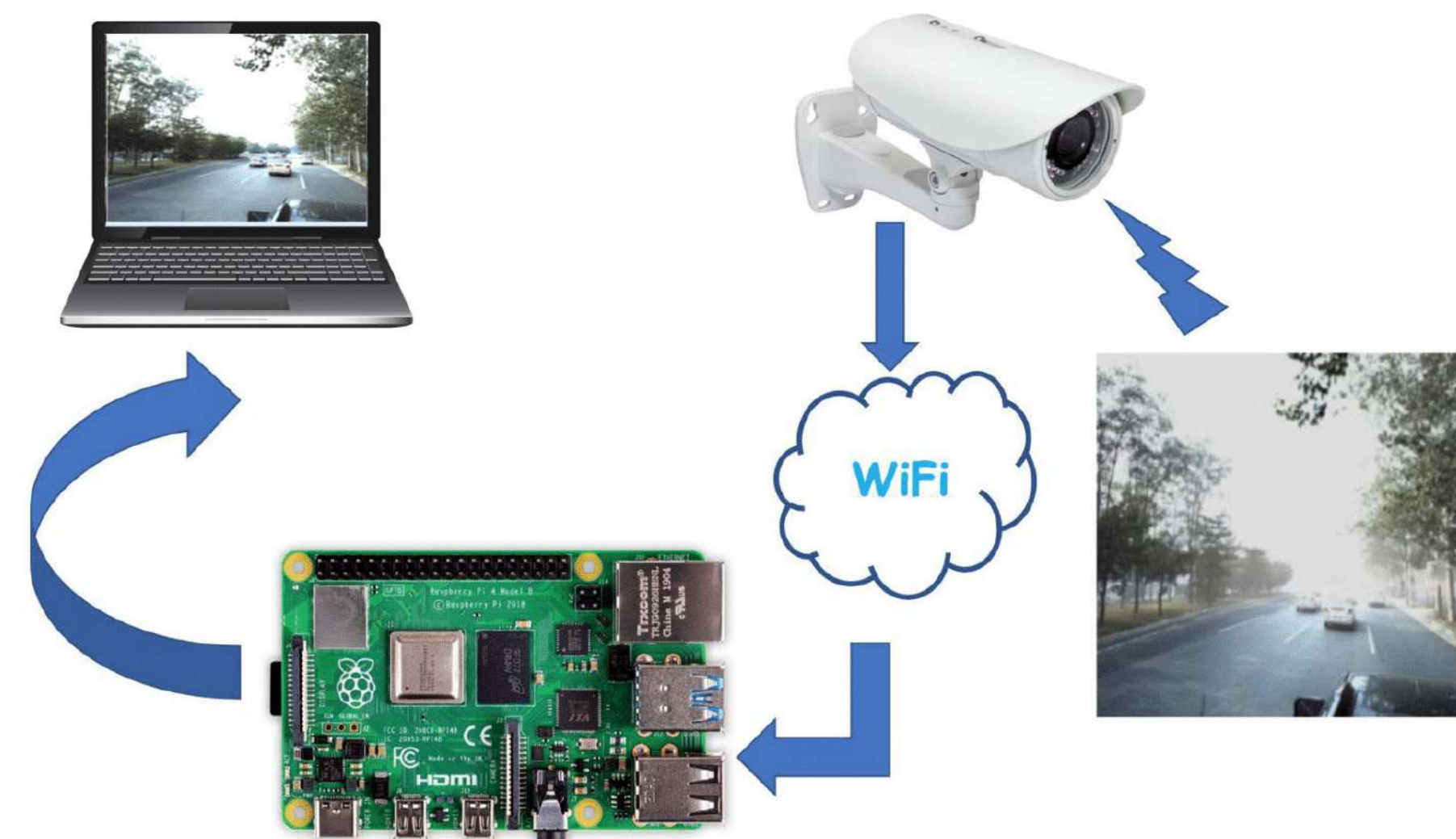
All types of cameras, such as digital cameras, surveillance cameras, and car mounted cameras, have been applied in many aspects of life, with the advances in technology and improvement of living. However, bad weather (fog, haze, dust, rain, and snow, etc.) will reduce the performance of outdoor cameras, and make them hard to keep stable visibility. For surveillance cameras and car cameras, the images will be blurred under the situations of heavy fog, dust, and air pollution. Other areas of interest are disaster management, unlawful activities like terrorist attacks, providing security cover in high alert areas, make rescue support available for people met with accident. To solve such problems, we are proposing a visibility improvement model for removing fog from real time images acquired from CCTV camera.

## Objectives & Proposed Approach:

Study and understand the image de hazing model. Propose a new dehazing model that can overcome the existing problems. Develop a Deep Learning based model for image dehazing. Experimental verification of the results using real image datasets obtained via CCTV camera

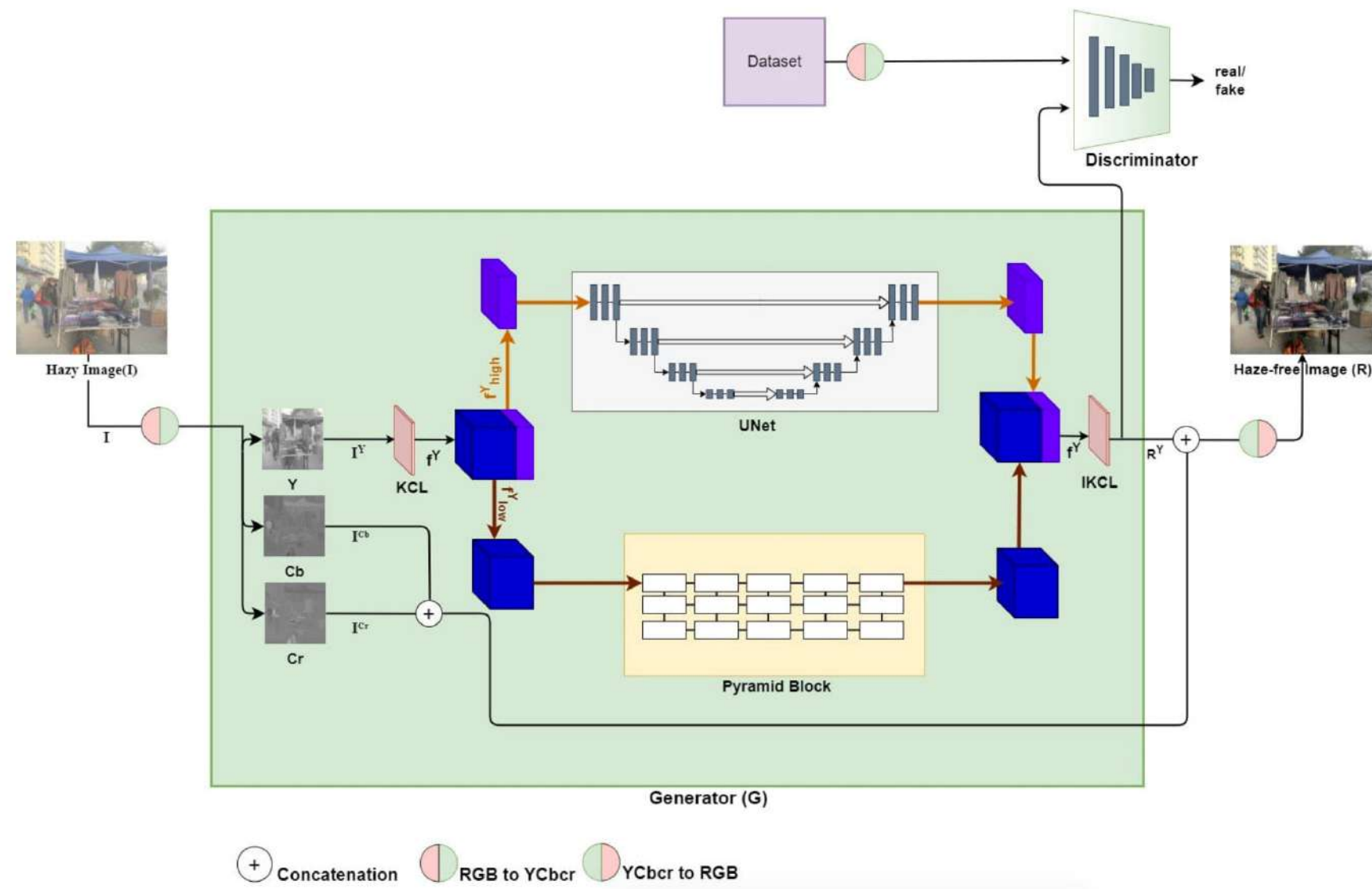


Haze Formation Model



Hardware for Traffic Surveillance





Qualitative Comparison for Various Methods on SOTS-Outdoor Dataset



Qualitative Comparison for Various Methods on Real-World Dataset

**TABLE I**  
 QUANTITATIVE ANALYSIS SHOWING PSNR/SSIM SCORES (HIGHER THE BETTER) FOR SOTS(OUTDOOR AND INDOOR) AND HSTS

	DCP	CAP	BCCR	NLD	DehazeNet	DCPDN	AOD-NET	MSCNN	GFN	Deep Energy	OTGAN
SOTS(Outdoor)	17.55/0.798	22.28/0.912	15.48/0.782	18.05/0.803	22.74/0.856	19.68/0.882	21.34/0.924	19.55/0.864	21.48/0.837	24.08/0.933	<b>25.28/0.935</b>
SOTS(Indoor)	20.14/0.871	19.06/0.835	16.87/0.789	17.28/0.748	21.14/0.846	15.77/0.817	19.37/0.850	17.12/0.804	<b>22.33/0.879</b>	19.25/0.832	21.12/0.873
HSTS	17.21/0.799	21.53/0.866	15.09/0.737	17.63/0.792	24.48/0.916	20.40/0.883	21.57/0.921	18.28/0.842	22.93/0.873	24.44/ <b>0.933</b>	<b>25.42/0.929</b>



# UCMA: A Toolset to Automatically Analyse Functional Requirements Specified in the Use Cases



PI: Saurabh Tiwari

Co-PI: Nil

Number of JRFs: One

Funding Agency: SERB, DST

Duration of the Project: 2 Years

Status of the Project: Completed

Number of MTech/PhD: One

Sanctioned Funding: 7,56,790/-

Start Date: 01-03-2017

End Date: 28-02-2019

The Grant Number: ECR/2016/001347

## Research Problem Statement:

USE CASES are one of the popular means for capturing the functional requirements of a software system. Being documented using some natural language, issues such as incompleteness, inconsistency, incorrectness, redundancy and ambiguity are inevitably introduced in the specification.

This project aims to develop a toolset to analyze automatically the functional requirements specified in the use cases.

UCMA (Use Case Modeler and Analyzer), a toolset for automatically analyze the quality of use case specification in terms of the well-known quality metrics such as completeness, correctness, consistency, and redundancy.

UCMA employs Natural Language Processing (NLP), a restricted form of use case specifications, and implementation of the well-known authoring guidelines, which would help the analyst to document problem specification in use cases using the proposed annotations.

- 1) The tool also supports the automated generation of Use Case Maps (UCMs).
- 2) Estimation of the effort required to implement the functional requirements using Use Case Point (UCP) based effort estimation method.

## Deliverables:

There are several open source and commercial tools available that help to automatically transform use case specification in behavioral and analysis models, but no tool is available which guide you in specifying the use cases in an appropriate format. UCMA is a unique tool because it incorporates an ideal template which provides a complete use case metamodel for representing all elements proposed in the literature to incorporate both structural and behavioral aspects.

- 1) The identified ideal use case template is implemented as a tool called UCMA which provides a degree of completeness and accuracy needed to ensure consistency between the problem specifications and use case textual descriptions, without constraining readability and understandability.
- 2) UCMA help to evaluate the quality of use case specification by automatically deriving the quality metrics, and also facilitate to improve the quality further by highlighting suggestive actions.
- 3) Automated estimation of the effort and size, and automated generation of UCMs for early detection of features in terms of casual scenarios bound to underlying abstract components.

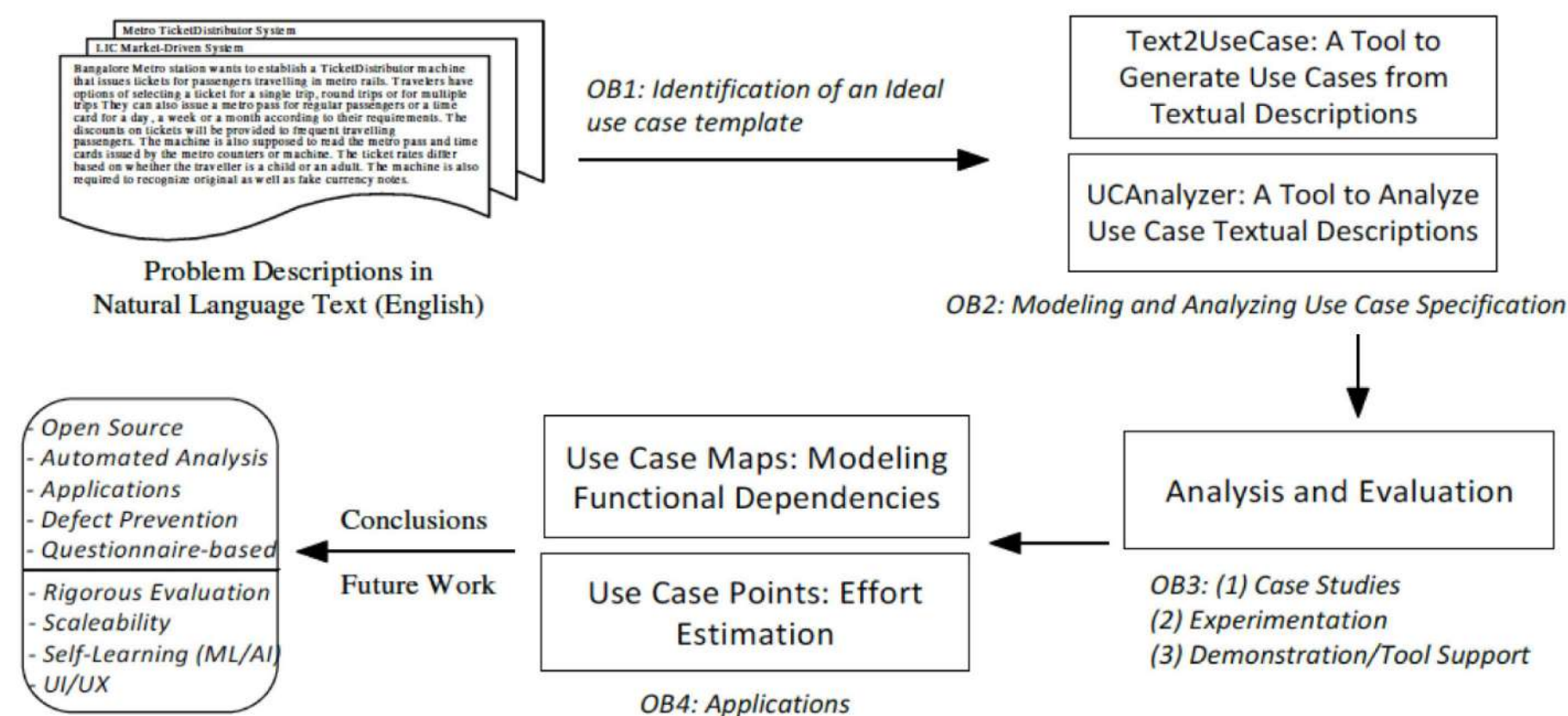
## Output from the Project:

- UCAnalyzer: A Tool to Analyse Use Case Textual Descriptions ([UCAnalyzer](#)) [[Demo](#)]
- Text2UseCase: A Tool to Develop Use Case Scenarios from Textual Specifications ([Text2UseCase](#)) [[Demo](#)]
- UC2Map: A Tool to Model functional Dependencies of Use Cases in Maps ([Git](#) and [AMS](#)) [[Demo](#)]

## Objectives & Proposed Approach:

- 1) Empirically investigate the usability of various use case templates in order to identify an ideal use case template along with their authoring rules and guidelines, and implement the ideal use case template and the specification authoring guidelines in UCMA.
- 2) Propose an approach for analysing the use case specification using some Natural Language Processing (NLP) technique for accessing the quality of specification in terms of their completeness, correctness, consistency and redundancy, and also suitable actions for improvements.
- 3) Assess the quality of use case specification developed using UCMA by comparing them with academic and industry-level use cases.
- 4) Automated generation of the Use Case Maps (UCMs) to specify functional dependencies and implementation of the use case-based effort estimation technique, Use Case Point (UCP) to estimate software cost, effort and size.
- 5) Integration of UCMA with IBM Doors, development of various project related documents and report generation.

## Block Diagram



## Research Publication:

- 1) Saurabh Tiwari and Atul Gupta, "Use Case Specifications: How Complete are they?", Journal of Software: Evolution and Process, Volume 32, January 2020, Pages 1-23, <https://doi.org/10.1002/smr.2218>
- 2) Saurabh Tiwari and Atul Gupta, "Investigating comprehension and learnability aspects of use cases for software specification problems", Information and Software Technology, Volume 91, November 2017, Pages 22-43, <https://doi.org/10.1016/j.infsof.2017.06.003>
- 3) Saurabh Tiwari, Santosh Singh Rathore, Shreya Sagar, and Yash Mirani, Identifying Use Case Elements from Textual Specification: A Preliminary Study, In 28th IEEE International Requirements Engineering Conference (RE 2020), pp 410-411, Zurich, Switzerland, August 31-September 4, 2020.
- 4) Saurabh Tiwari, Rishab Arora, and Ashray Bharambe, UC2Map: Automatic Translation of Use Case Maps from Specification, In 35th ACM-SIGAPP Symposium on Applied Computing, SAC 2020, pp 1650-1653, Brno, the Czech Republic, March 30-April 3, 2020
- 5) Saurabh Tiwari, Deepti Ameta, and Asim Banerjee, An Approach to Identify Use Case Scenarios from Textual Requirements Specification, In 12th Innovations in Software Engineering Conference (ISEC 2019), 14-16 February, ACM, Article No. 5, 2019.
- 6) Chirag Usdadiya, Saurabh Tiwari, and Asim Banerjee, An Empirical Study on Assessing the Quality of Use Case Metrics, In 12th Innovations in Software Engineering Conference (ISEC 2019), 14-16 February, ACM, Article No. 6, 2019.
- 7) Saurabh Tiwari and Mayank Laddha, "UCAnalyzer: A Tool to Analyze Use Case Textual Descriptions". In 25th IEEE International Requirements Engineering Conference, IEEE Computer Society, RE2017, pp 448-449, Lisbon, Portugal, 2017.





# An empirical analysis on Deriving Test Cases from Natural Language text using MBT approach



PI: Saurabh Tiwari

Co-PI: Nil

Duration of the Project: 3 Years

Status of the Project: Ongoing

Start Date: 01-05-2022

End Date: 30-04-2025

Number of JRFs: One

Funding Agency: SAC-ISRO

Number of MTech/PhD: Two

Sanctioned Funding: 20,78,280/-

The Grant Number: ISRO/RES/3/897/21-22

## Research Problem Statement:

Model-Based Testing (MBT) is the process of generating test cases from specification models representing system requirements and the desired functionality. The generated test cases are then executed on the system under test to obtain a pass or fail verdict.

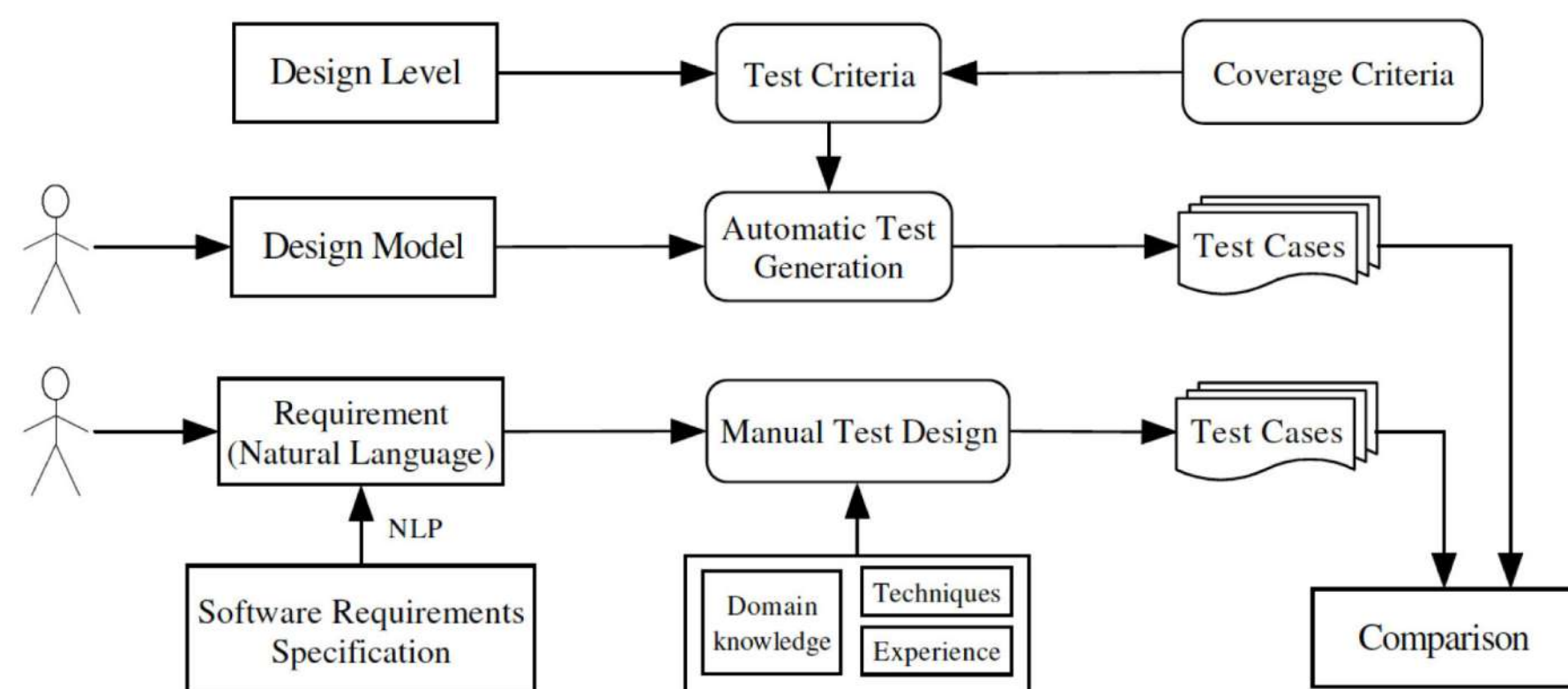
The Different MBT techniques have been developed and applied in different contexts, however, their applicability in the real-world software systems domain is a point of investigation. The Consequently, there is a need to investigate the use of MBT and the evidence on how modeling and test generation can improve the current way of creating test cases based on natural language (NL) requirements. The input to the MBT approaches is specification models and these models are generated from the requirements specification. Hence, there is a need for checking/verification of the requirements using methods like model checking and formal verification. After the verification of the requirements, the review reports can be generated that can be taken as input to the MBT approach for test case generation and evaluation.

## Objectives & Proposed Approach:

The main area of the focus of the project is based on the following research questions

- 1) **RQ1:** How can we prevent inconsistencies and incompleteness from propagating into the requirements and how to improve their quality?
- 2) **RQ2:** How can we model the testable behavior of the requirements specified in the NL textual format?
- 3) **RQ3:** How can automated test cases be generated from a behavior/functional model for the software functions?
- 4) **RQ4:** How to assess the quality of test cases generated using the MBT approach in terms of covered test goals and the number of test cases?

Answering these research questions (a.k.a. project objectives) help to analyze and evaluate the applicability of MBT approaches and will streamline the process of deriving test cases from the software requirements specification (SRS).



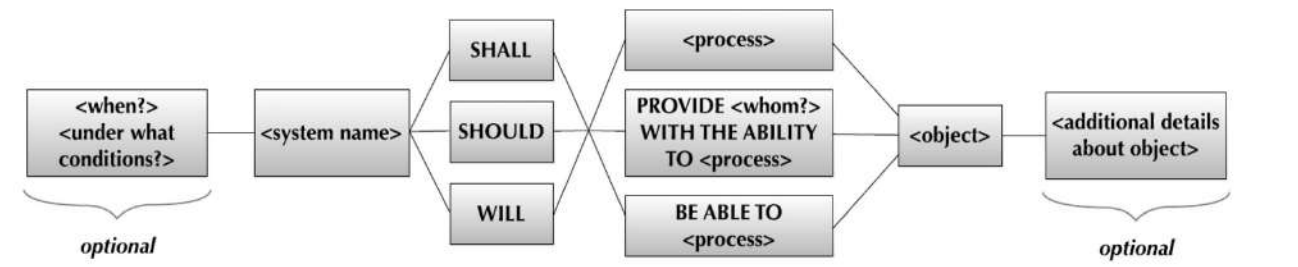
Overview of the proposed approach

## Deliverables:

- 1) Verification of requirements specification
- 2) Modeling approach
- 3) Development of a prototype

The successful completion of the project help to determine whether the use of MBT techniques facilitates efficient testing mechanism, and hence the test and requirements verification process can be streamlined better.

## Examples on RUPP's Template



R1 : The software feature shall generate Level-0, Level-1, Level-2 data products from raw data, OAT file and trigger.

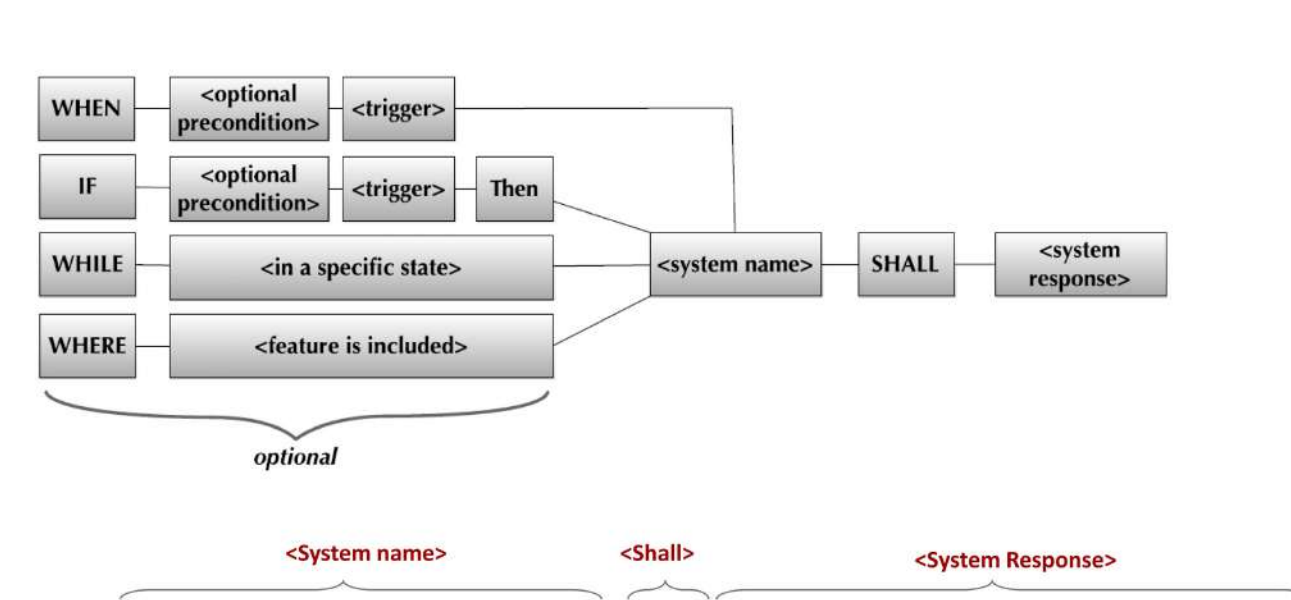
<Additional details about the object>  
 <Actor> <Will be able to> <Object>

R2 : The user will be able to monitor the currently running and waiting product queue through scheduler logs/error logs.

<Additional details about the object>

R3 : Error will be generated if configuration file/OAT file is not present in the configuration area, software will exit with defined error codes. [Non-Conformance]

## EARS Template Structure



R1 : ADIF\_OAT Data extraction module shall be able to extract data from the database.

R3 : The software feature shall generate Level-0, Level-1, Level-2 data products from raw data, OAT file and trigger. It will use all the software features defined in previous subsections in a step by step manner. [Non-Conformance]

The screenshot shows the GATE software interface. On the left is a tree view of resources including Applications, Pipeline, ReTA\_Pipeline, Language Resources, and Processing Resources. The main area displays a list of sentences with highlights. A dialog box titled 'TemplateNonConformance' is open, showing a list of conditions and a table of non-conformance details.

Condition	Explanation	Status
1. System Name Missing, usage of Pronoun		✗
2. Proper Modality is missing		✗



# Using Mobile Sensing Mechanism to Assess Smartphone Addiction and Its Negative Impact on Students



PI: Alka Parikh

Co-PI: Kalyan Sasidhar

Number of JRFs: One

Funding Agency: ICSSR

Duration of the Project: 2 Years

Status of the Project: Completed

Number of MTech/PhD: Nil

Sanctioned Funding: 16,00,000 /-

Start Date: 23-03-2018

End Date: 23-10-2020

The Grant Number: G-11/2017-18/ICSSR/RP

## Research Problem Statement:

Reduction in physical and sleep activities are manifesting due to extensive use of social media, games, entertainment and even mindless scrolling of applications on phones .

## Research Publication:

- 1) Vaghela, M., Sasidhar, K., Parikh, A. et al. Assessing Mobile Usage, Physical Activity and Sleep Through Smartphone Sensing: A Digital Phenotype Study. SN COMPUT. SCI. 3, 331 (2022)
- 2) Vaghela M., Sasidhar K., Parikh A, "An Experimental Study of Mobile Phone Impact on College Students", ICT Systems and Sustainability: Advances in Intelligent Systems and Computing 2020, vol 1077. Springer.
- 3) Kalyan Sasidhar, "Quantitative assessment of smartphone usage in college students - A digital phenotyping approach," Internet of Things Based Smart Healthcare: Intelligent and Secure Solutions Applying Machine Learning, SpringerNature. Techniques
- 4) K. Sasidhar, A. Upasini, D. Shah and V. Palaparthi, "Analysis of smartphone sensor bias from an activity recognition experiment in the Wild", IEEE Sensors and Applications Symposium, Malaysia 2020, pp.1-4.
- 5) Maitri Vaghela, Kalyan Sasidhar, "Analyzing the human behavior using pervasive sensing system", 21st ACM International Conference on Distributed Computing and Networking, Kolkata 2020, pp 1-5.
- 6) D. Shah, A. Upasini and K. Sasidhar, "Findings from an experimental study of student behavioral patterns using smartphone sensors," 2020 International Conference on COMMunication Systems & NETWORKS (COMSNETS), Bengaluru, India, 2020, pp. 768-772,
- 7) Maitri Vaghela, Kalyan Sasidhar, Alka Parikh, "An experimental study of mobile phone use impact on college students," ICT4SD 2020, Goa, India.

## Deliverables:

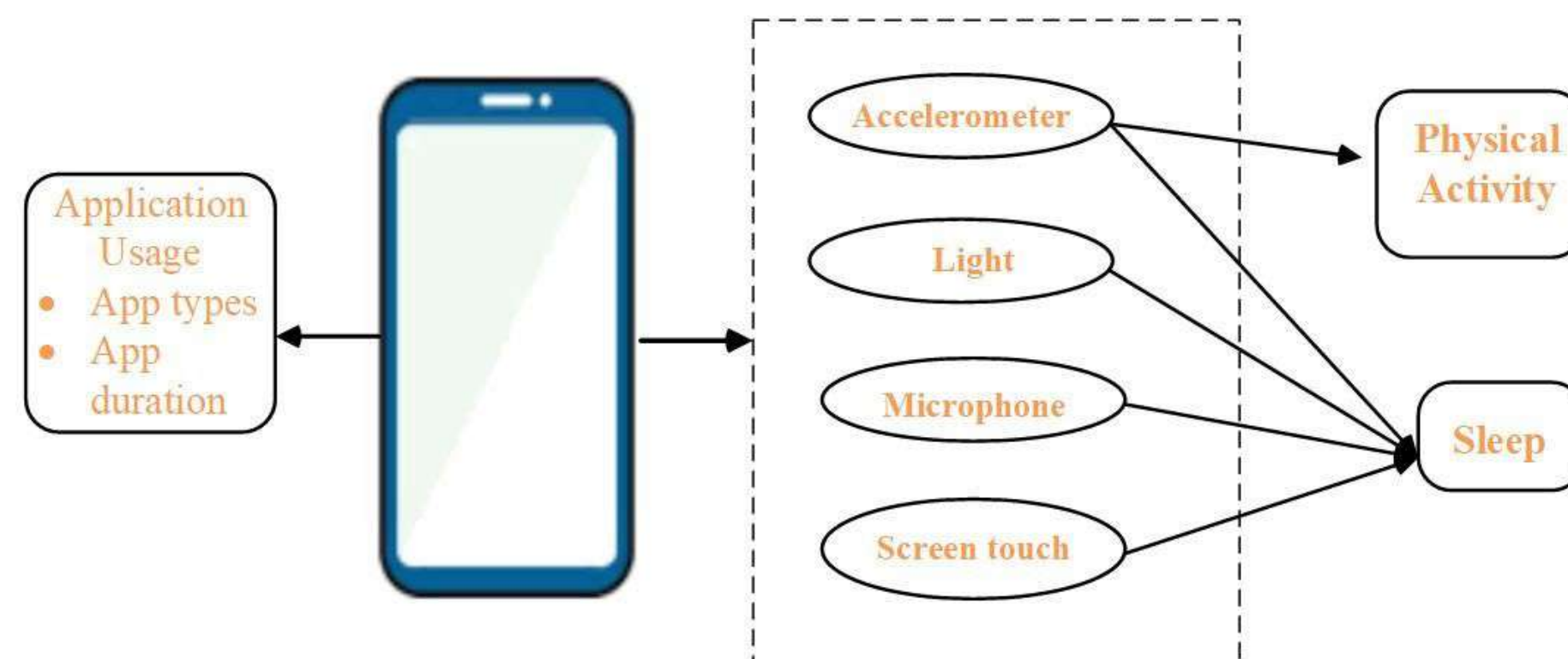
Study findings, mobile app

## Objectives & Proposed Approach:

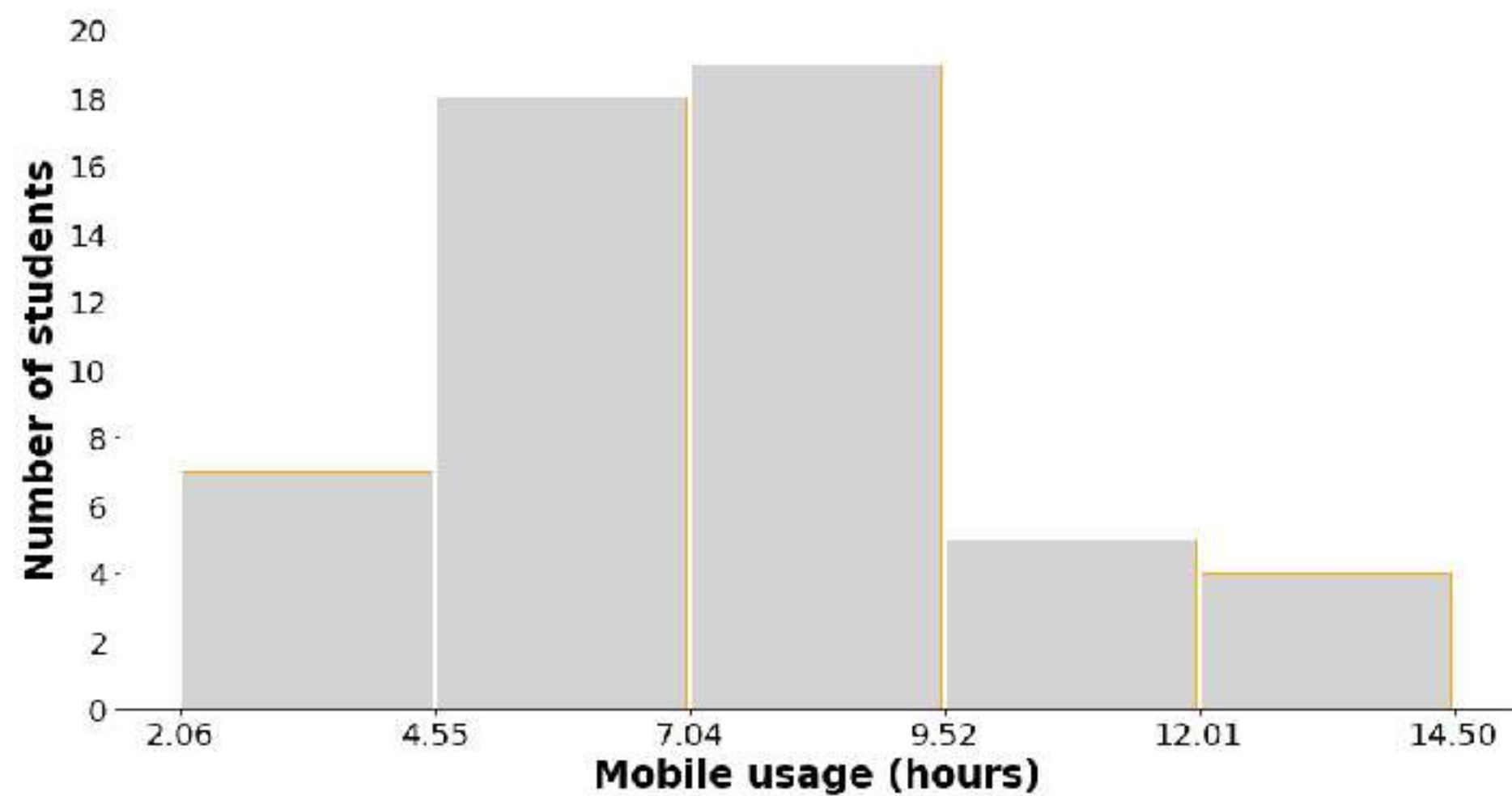
This study aims to quantify smartphone usage behaviour and its impact on health - both physical and mental. The novelty in this project lies in utilizing the smartphone as a platform for measuring and monitoring daily usage behaviour. Our study was experiment based wherein we recruited 48 students for a period of 45 days to assess their mobile usage behavioural trends and their impact on health. For understanding the effect on health, we detect and quantify in hours per day the activity type (idle or moving or sleeping), the social interaction levels and the mobility patterns on campus.

## Introduction:

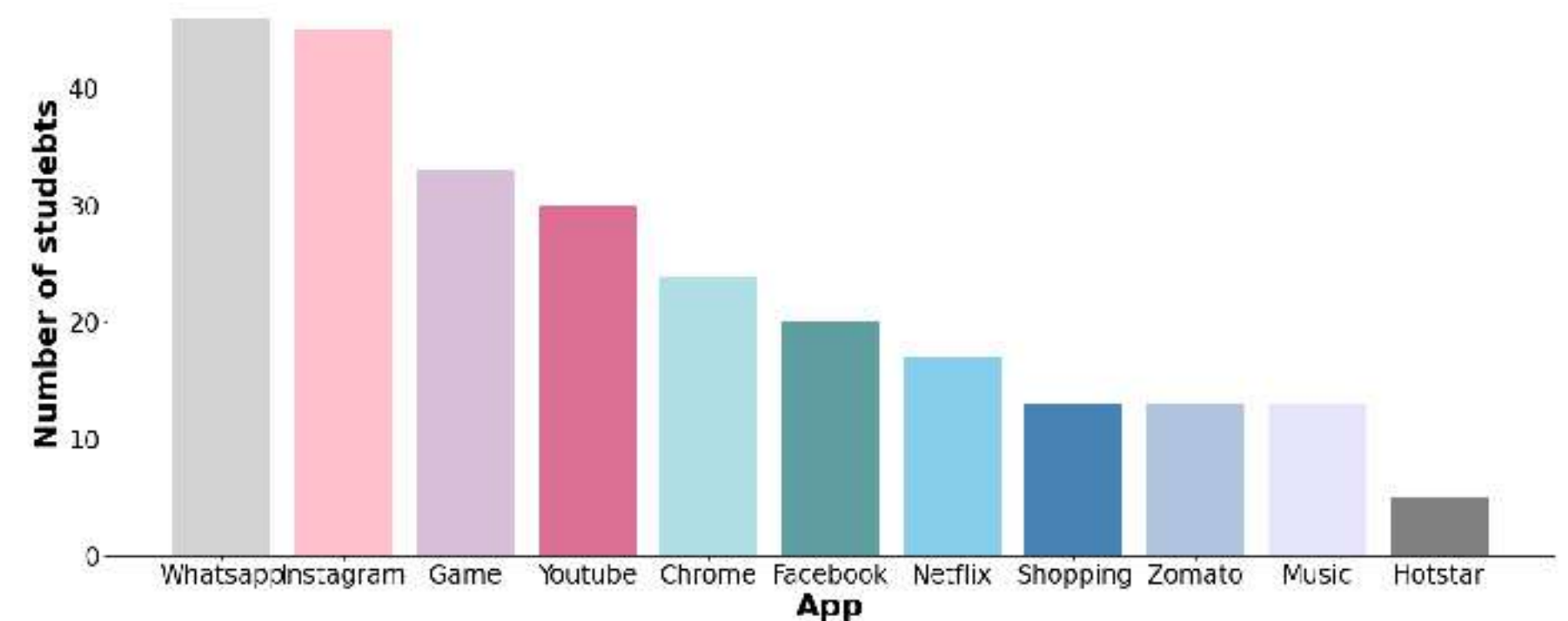
Smartphones come built-in with sensors such as accelerometers, gyroscopes, barometers, light, proximity, and microphone. This rich sensor set has made sensing much easier, leading to the mobile sensing paradigm. Mobile sensing typically involves collecting raw sensor data, processing, and applying machine learning algorithms to infer human physical activity, mobility, location, and so on. The study aims to quantify mobile usage behavior, and infer physical activity and sleep patterns across the students.



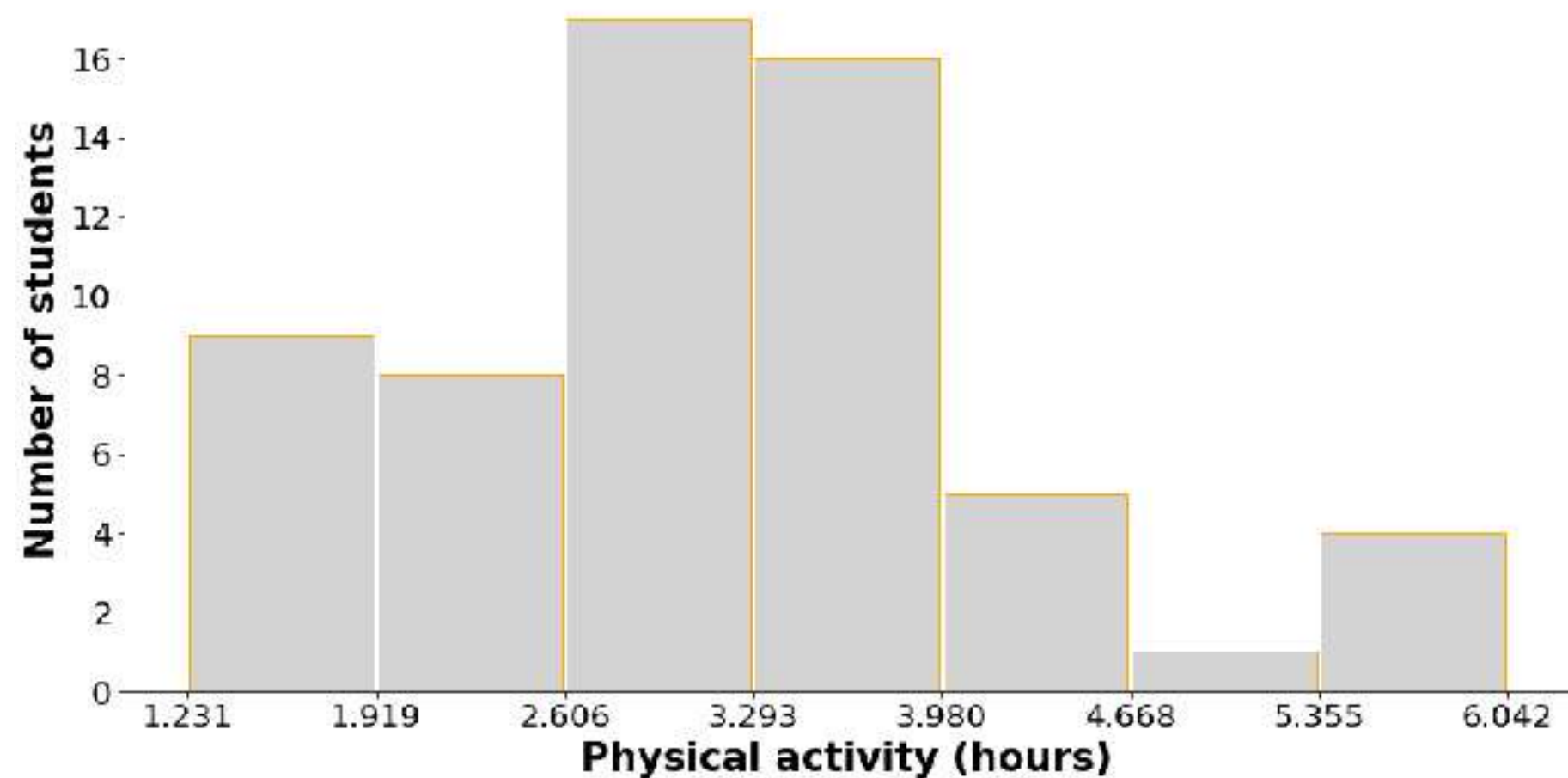
System architecture showing the tasks that our mobile application does which include sensing data from various sensors and monitoring app usage.



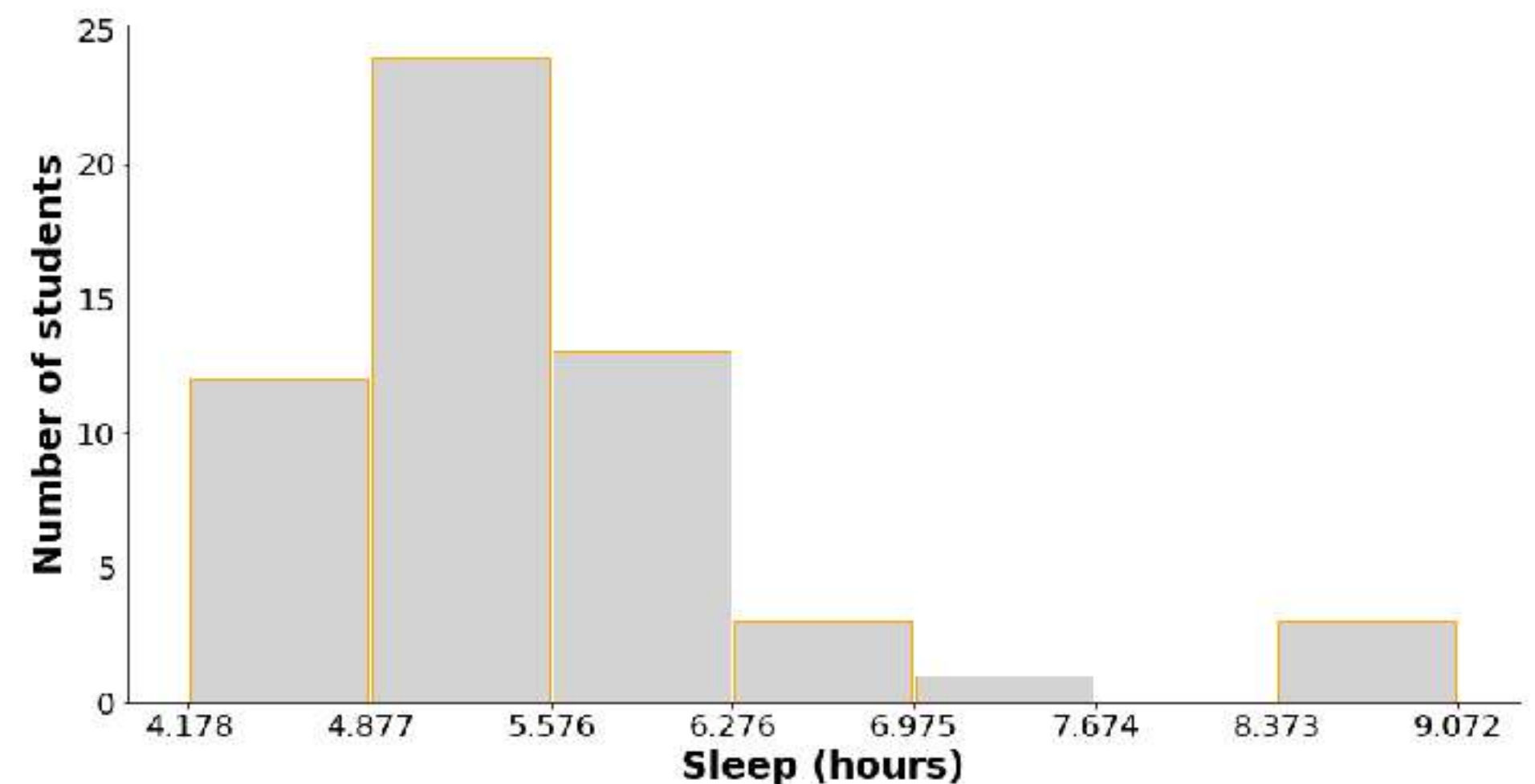
The distribution shows that 35% of the students used their phones between 7-9 hours. Around 33% of them used between 5-7 hours. The reason for the high usage could be social media and gaming.



This shows the categorized application based on maximum usage to a minimum on an average of overall students.



68% of students are physically active for 2.6 to 4 hours daily which is considered good levels of physical activity. 32% fall into < 2.6 and 20% are behaving at higher levels of physical activity > 4.



42.8% of students were having slept for 4.8-5.5 hours, ideally, it is considered lesser sleep hours. 21.4% of students were sleeping < 4.8 hours. Similarly, 23.2% of students were having slept from 5.5-6.2 hours. And only 8% of students were sleeping more than 7 hours.

# Archival Vector DNA Data Storage

PI: Manish K. Gupta

Duration of the Project: 2 Years

Start Date: 01-04-2022

Start Date: 25-09-2019

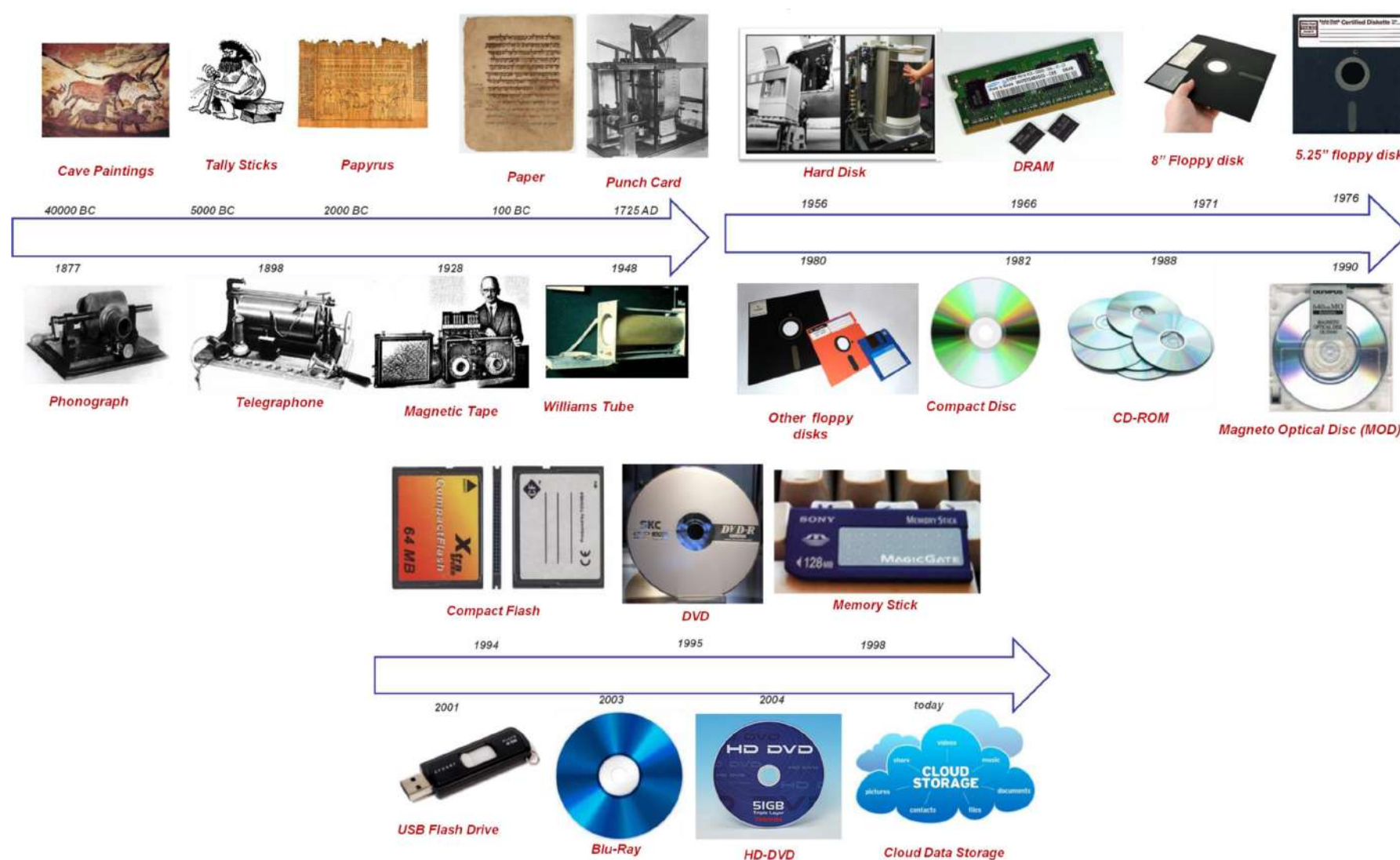
Status of the Project: Ongoing

Number of MTech/PhD: One

The Grant Number: DST/INT/DAAD/P-14/2019

Funding Agency: DST, DAAD

## History of Storage Technology



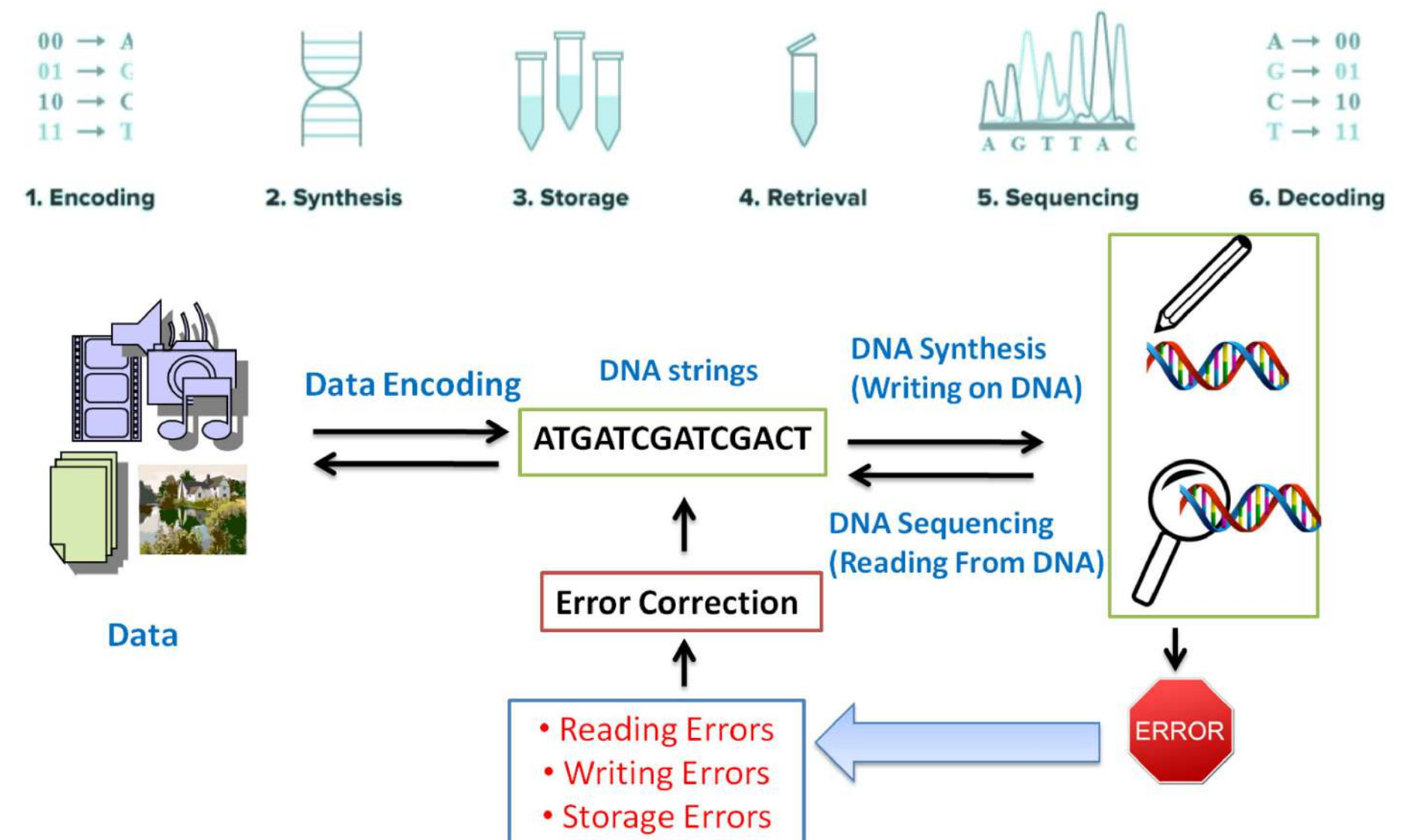
## Next Gen Storage Device -DNA, DNA as Storage Medium



	Hard disk	Flash memory	Bacterial DNA	WEIGHT OF DNA NEEDED TO STORE WORLD'S DATA
Read-write speed (μs per bit)	~3,000-5,000	~100	<100	~1 kg ©nature
Data retention (years)	>10	>10	>100	
Power usage (watts per gigabyte)	~0.04	~0.01-0.04	<10 <sup>-10</sup>	
Data density (bits per cm <sup>3</sup> )	~10 <sup>13</sup>	~10 <sup>16</sup>	~10 <sup>19</sup>	

<http://www.nature.com/news/how-dna-could-store-all-the-world-s-data-1.20496>

## How DNA Data Storage System Works?



## Support





## Collobarators



Taslimarif Saiyed  
Director  
**C-CAMP**  
Centre for Cellular and Molecular Platforms  
NCBS, Bangalore



David M. Smith  
Head  
**Fraunhofer**  
IZI  
Fraunhofer Institute for Cell Therapy and Immunology (IZI)



Vaanet Aggrawal  
Assistant Professor  
**PURDUE**  
UNIVERSITY



Martin Sajfutdinow  
PhD scholar  
**Fraunhofer**  
IZI  
Fraunhofer Institute for Cell Therapy and Immunology (IZI)

## Software Products at Gupta Lab



3DNA



DNACloud



3DNA Printer



Bacteria Cloud



DNA Pen



Xtile & Xtilemod



DNA ImagePro



CRN2DSD



Biospectrogram



Codon Optimization



KonCAD



Antsoft



DNAG



DrugCalc

## Press Coverage

### Times of India: 25 March 2018 DATA STORAGE ON DNA FROM FICTION TO REALITY

Researchers At DA-IICT Achieve Breakthrough In Technology, Hopeful Of Its Commercial Viability In Near Future

When the Indian and Israeli prime ministers inaugurated ICT campus near Ravla in January this year, they witnessed a demonstration of how their joint message of ICT will be saved for at least a thousand years — on a strand of DNA!

The tiny speck of DNA in a vial not only contained their images and the text of the speech but also an audio and a video file. The encoding of data on synthetic DNA was done by Gandhinagar based Dhruvraj Ambani Institute of Information and Communication Technology (DA-IICT). The Institute is one of the few working in the field of DNA computing in India.



**HOW DNA STORAGE WORKS**  
Researchers choose digital data in binary form (0,1) and convert it into ternary or base 3 format (0,1,2) for compression.  
DNA has four nucleobases: adenine (A), thymine (T), guanine (G) and cytosine (C). The researchers make a matrix of ternary code on one side and nucleobases on another, providing a code for each of the numeric value.  
The data can be retrieved by getting the DNA analyzed at any biology lab.  
The process will decode the ATGC sequence of the data. Special software can convert it into ternary and then into binary forms.  
DNA is fragmented and indexed to quickly retrieve the desired data. Sometimes repeated reverse data is also encoded to provide protection against data loss.  
Once the binary data — the language of computers — is retrieved, it can be read, viewed or played by any computer system.

**THE NEXT FRONTIER?**  
DA-IICT researchers have already set their eyes on the next step — storage of digital data on E. Coli bacteria. Arun Agrawal, a BSc student, is working on the project along with other students. Agrawal is currently in Germany, working on a DNA sequencing project. The living organisms with 4,200 protein coding genes provide an opportunity for codes to take the data to next generation of progeny with high production rate. One can literally save their data in their gut! The team applied for a patent for the process in 2016. The researchers want to gradually move upwards towards more complex organisms including plants.

**STORAGE STORY**  
10<sup>6</sup> Megabytes: Used in floppy discs and DVDs of yore  
10<sup>9</sup> Gigabytes: The standard storage format for smartphones and digital storage devices  
10<sup>12</sup> Terabytes: A feature of new PCs and

**THE FUTURE**  
DNA is made of four nucleobases — adenine (A), thymine (T), guanine (G), and cytosine (C). The researchers convert them into 0 and 1 through a specially written programme.  
DNA is fragmented and indexed for the desired data. The specialised software reads the sequences, then stored in a solution for longevity. The same machine is required for carrying out the entire process in reverse for extraction.

### Times of India: 7 December 2021

storage capacity of conventional magnetic data storage devices used for the past five decades. But in academic circles, the concept has remained limited to labs across the globe for the past decade due to two factors—uniformity and cost-effectiveness.

**BACTERIA CONTAINING DATA!**  
Prof Gupta's team had started working on E coli to store data which can be preserved for generations. Sources said that the technology has also attracted the attention of military experts from across the globe. However, without uniform algorithms, the experiments have remained limited to specific labs or groups of scientists. The consortium thus aims to provide uniform guidelines to all practitioners. Prof Gupta admits that it might take a decade more for the dream of making the technology viable for wider use. "But the encouraging part is that the field has attracted several researchers and students from around the world," he said.

**THE FUTURE**  
DNA is made of four nucleobases — adenine (A), thymine (T), guanine (G), and cytosine (C). The researchers convert them into 0 and 1 through a specially written programme.  
DNA is fragmented and indexed for the desired data. The specialised software reads the sequences, then stored in a solution for longevity. The same machine is required for carrying out the entire process in reverse for extraction.

**STORAGE STORY**  
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**THE FUTURE**  
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## Our Experiment Demo: January 2018, Prime Minister India & Israel





# Development of an Integrated Surveillance System for Suspicious behaviour analysis



PI: Manish Khare

Co-PI: Nil

Number of JRFs: One

Funding Agency: SERB, DST

Duration of the Project: 3 Years

Status of the Project: Ongoing

Number of MTech/PhD: Nil

Sanctioned Funding: 56,98,000/-

Start Date: 01-12-2021

End Date: 31-11-2024

The Grant Number: CRG/2020/001982

## Research Problem Statement:

The recent terrorist activities (2019 Pulwama attacks, 2018 and 2017 Sukma attacks, 2015 Gurudaspur attacks, 2013 Patna bombings, 26/11 attacks in Taj Hotel Mumbai etc.) in India have demonstrated that there is a strong need for improvement in existing video surveillance capabilities of public areas in order to prevent terrorist activities.

Now the aim is to develop an integrated intelligent video surveillance system, which can automatically detect and classify the moving and suspicious objects and track them across field of view of various cameras, understand and describe human activities and behaviors to replace the traditional passive video surveillance system.

Most of traditional surveillance techniques that so far exist are not fully automatic and as the number of cameras exceeds, it is difficult for human operator to monitor them. Also manpower required to supervise them is expensive. Consequently the video data obtained from the camera used in these techniques is often used merely as a record to examine an incident once it is known to have taken place.

Development of smart video surveillance system is one of the challenging problems in image processing and computer vision applications.

With the emergence of interactive multimedia systems, the areas where video surveillance can be used for applications are state and local governments, military and police, and several commercial applications like, enterprise-wide network security systems, secured banking and financial transactions, law enforcement, time/attendance and access control for corporate, educational and manufacturing industries and health services.

The present research proposal originates from the shortcomings of the existing surveillance systems. The existing methods often require special markers attached with the objects being tracked, which prevent the widespread applications. Other problems with the existing surveillance system are:

- 1) They depend on data from limited field of view, i.e. fixed or PTZ camera which have limited view
- 2) It is very difficult to track the same object across various camera network and require a lot of human intervention to track the same object in case the multiple cameras are used
- 3) Human operators are required to monitor activities
- 4) Lack of human behavior prediction and anomaly detection methods

The major demand for improvement in the existing surveillance system is to detect, classify and analyse automatically the different types of human and suspicious object motion, interaction of humans with different object(s) and to recognize human gestures by facial expression or by some other means, perform real time intrusion detection and generate warnings in case any suspicious activity is detected in complex environment.

Understanding of human behavior and analyzing facial expressions is a complex process. Several parameters are required to be analyzed for correct prediction of human behavior.

Multiple camera calibration, fusion of data obtained from multiple visible ranges optical and infrared cameras, object identification and tracking of multiple objects require a lot of computer science theories and programming skill, whereas development of automatic camera control system and integration of several modules for making a complete system require basic knowledge of electronics and control engineering.

Thus the proposed project is a true example of interdisciplinary research. Implementation of the proposed project will have many potential applications, such as security for important buildings, traffic surveillance in cities, detection of military targets etc.

Visual surveillance system placed in important public areas (e.g. airports, railway stations, parking lots, bridges, etc.) can analyze abnormal behaviors of a group of persons which is indicative to some abnormal activity.

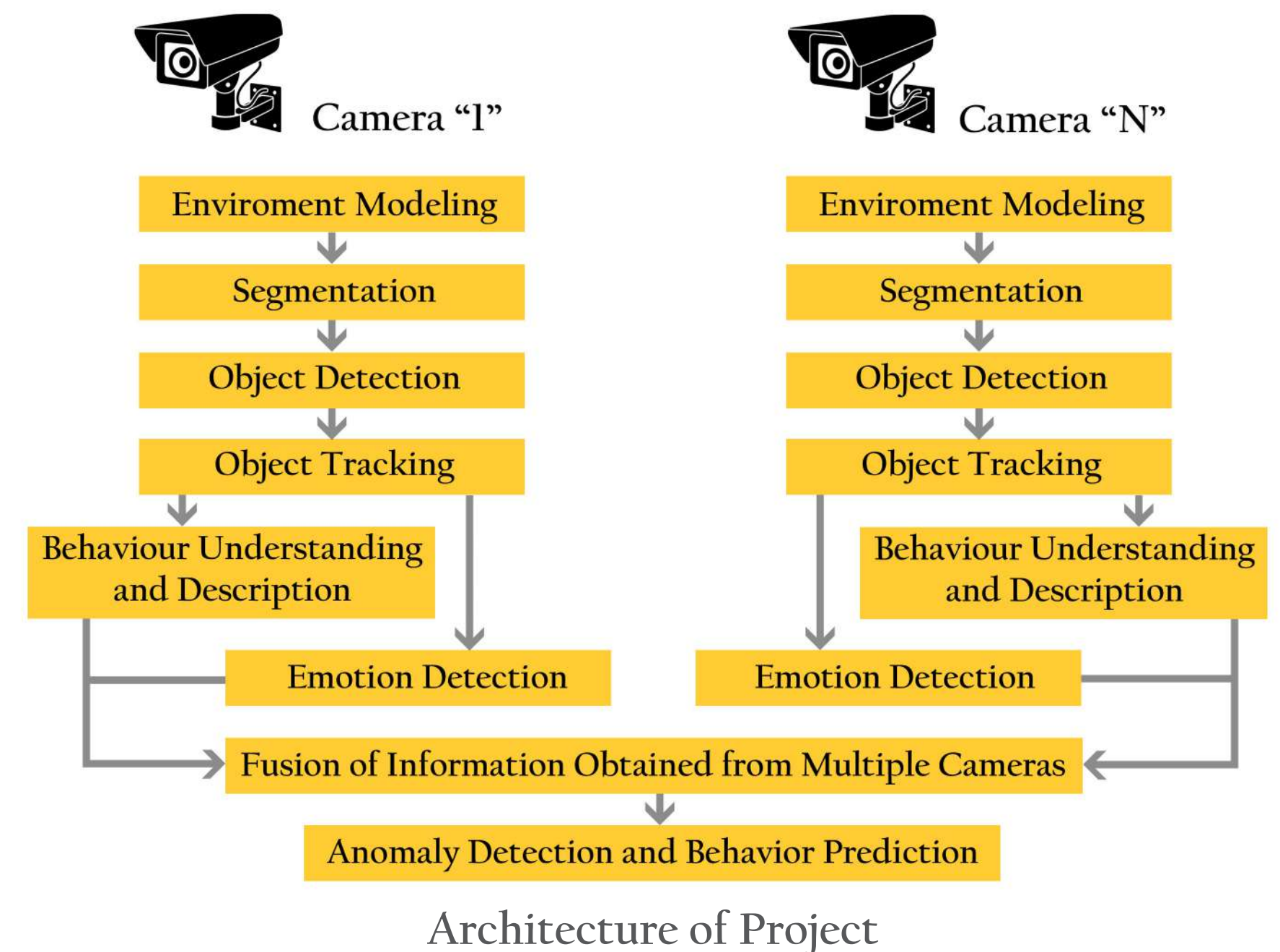
## Objectives & Proposed Approach:

The goal of this project is to propose and develop the methods and system which can automatically track multiple objects, between the frames grabbed by different Omni-directional cameras, and reduce the burden of operator by developing a system that can analyze video content automatically and predict the human behavior and intention. The main objectives of this research are as follows –

- 1) Development of a system for acquisition and fusion of images obtained from multiple visible range optical and infrared cameras.
- 2) Development of algorithms for extracting moving objects from scene, object description and multiple object tracking.
- 3) Development of intelligent algorithms and system for understanding and description of scene in video.
- 4) Development of a system based on induced emotions in individual that differentiates between spontaneous and deliberately expressed human expressions.
- 5) Real time identification and prediction of human behavior.
- 6) Development of a fully automatic system where no manual intervention is needed and generates warnings in case of suspicious activity is detected.
- 7) Realizing a FPGA prototype of the system designed is proposed here.

## Deliverables:

Research findings as an outcome of this project may be published in form of good papers in SCI journals. The outcome of the project will have the long-term commercial importance. The research findings of the project and the prototype model developed may be converted into product after finishing the project. The idea and product obtained after completion of the project will be patented.



## Research Publication:

- 1) Manish Khare, Moongu Jeon, “Multi-resolution approach to human activity recognition in video sequence based on combination of complex wavelet transform, Local Binary Pattern and Zernike moment”, Multimedia Tools and Applications (ISSN: 1573-7721), Accepted.
- 2) Nikhil Kumar Singh, Manish Khare, Harikrishna B. Jethva, “A Comprehensive Survey on Person Re-Identification Approaches: Various Aspects”, Multimedia Tools and Applications (ISSN: 1573-7721), Vol. 81, No. 11, pp. 15747-15791, 2022.
- 3) Abhishek Shah, Noopur Srivastava, Manish Khare, “Effect of Reconstruction Losses in Discriminative and Generative Learning based Networks for the Person Re-identification”, in International Conference on Machine Learning and Data Engineering (ICMLDE 2022), pp.--, 07-08 September 2022, Dehradun, India.
- 4) Manan Mapara, Noopur Srivastava, Manish Khare, Bakul Gohel, “Region-based Multiple Object Tracking with LSTM supported Trajectories”, in 18th International Conference on Computer Science and Education in Computer Science (CSECS 2022), pp. --, 24-27 June 2022, Sofia, Bulgaria.



# Speech Technologies in Indian Languages under the project titled, NLTM: BHASHINI



इलेक्ट्रॉनिकी एवं  
सूचना प्रौद्योगिकी मंत्रालय  
MINISTRY OF  
**ELECTRONICS AND  
INFORMATION TECHNOLOGY**

सत्यमेव जयते

PI: Hemant A. Patil

Duration of the Project: 3 Years

Start Date: 01-04-2022

Co-PI: Nil

Status of the Project: Ongoing

End Date: 31-03-2025

Number of RAs: Two, Part Time: Four

Number of MTech/PhD: One

The Grant Number: 11(1)2022-HCC(TDIL)

Funding Agency: MeitY

Sanctioned Funding: 85,26,000/-

## Research Problem Statement:

Building Assistive Speech Technologies for the Challenged

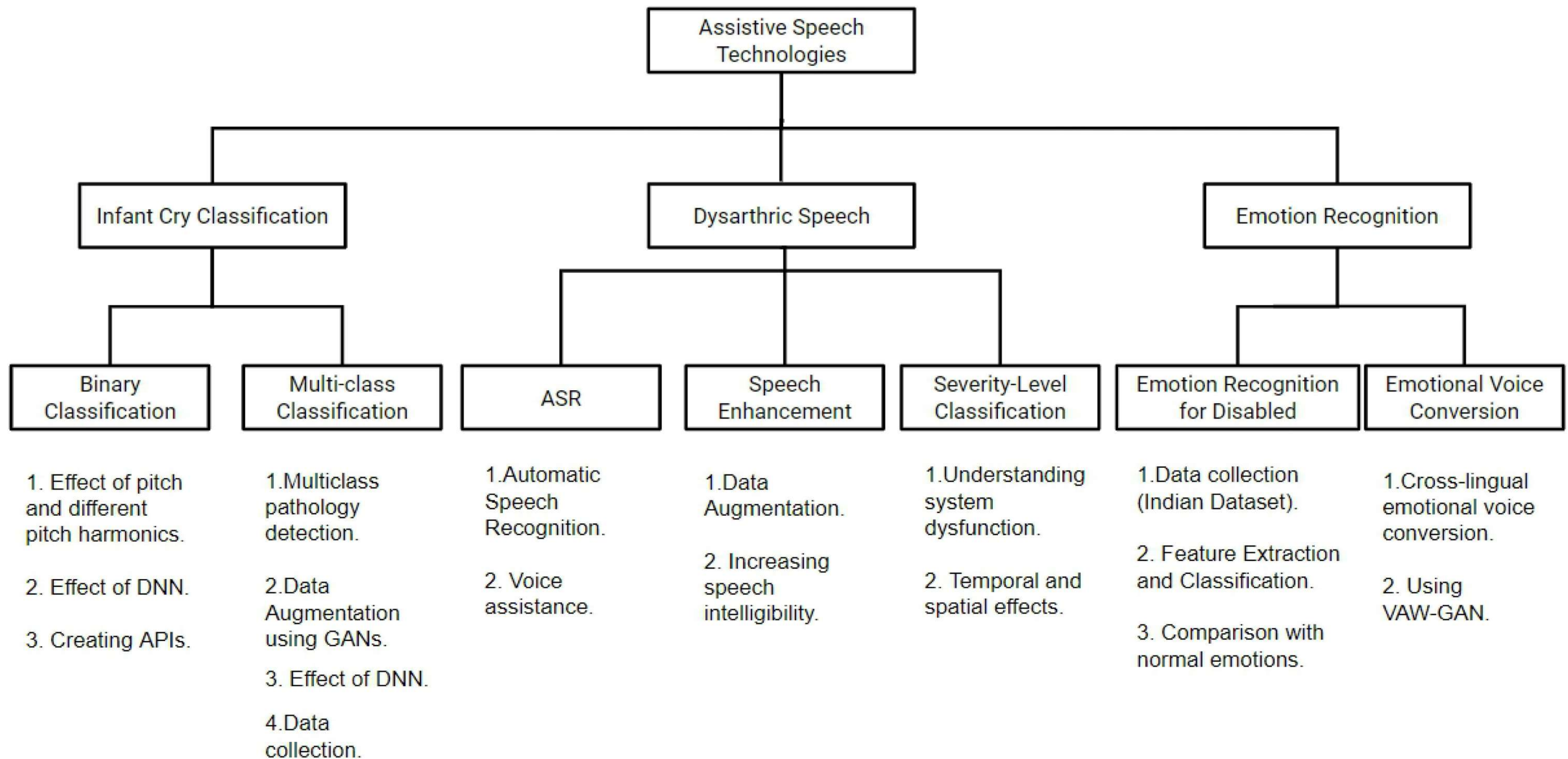
Assistive Technologies (AT) allows individuals with disabilities to do things that would otherwise be difficult for them. Assistive technologies provide universal access to televisions or telephones to make them accessible to those who are visually challenged or have hearing impairments e.g. designing screen readers for its integration with TTS voice for visually challenged and cerebral palsy patients. Further, Augmentative and Alternative Communication (AAC) deals with technologies for disabled.

## Objectives & Proposed Approach:

This NLTM consortium project funded by the Ministry of Electronics and Information and Technology (MeitY) New Delhi, India is a humble step to bridge this gap, more so, in the Indian context. In particular, the project PI Prof. Patil has gained experience in various assistive speech technologies over a period of last 15 years. In particular, he brought three co-edited books in this area. Prof. Patil and his team of DA-IICT plan to use this experience to develop assistive speech technologies for the disabled.



NLTM Project PI and Staff Presenting Demo at Digital India Week 2022



Activity Tree of NLTM Sponsored Project@DA-IICT

#### Deliverables:

- 1) Development of Deep Learning and Machine Learning Algorithms for Data Augmentation and Pattern Recognition
- 2) Research on Generative Adversarial Networks (GANs)
- 3) Development of Application Programming Interface (API) for Assistive Speech Technologies
- 4) Speech Data and Metadata Collection from the Hospitals
- 5) Research Publications in Top Conferences and Journals

#### Research Publication:

- 1) Anand Therattil, Aastha Kachhi, and Hemant A. Patil, "Cross-Teager Cepstral Coefficients For Dysarthric Severity-Level Classification," 2022.
- 2) Aastha Kachhi, Priyanka Gupta and Hemant A. Patil, "Features Motivated from Uncertainty Principle for Classification of Normal vs. Pathological Infant Cry," 2022.
- 3) Ankur T. Patil, Aastha Kachhi and Hemant A. Patil, "Subband Teager Energy Representations for Infant Cry Analysis and Classification," 2022.
- 4) Priyanka Gupta, Piyushkumar K. Chodingala, Hemant A. Patil: Morse Wavelet Features for Pop Noise Detection. SPCOM 2022.

# Design and Simulation of Beamforming Algorithms and Baseband Technologies for SATCOM On the Move (SOTM) Networks

PI: Yash Vasavada

Duration of the Project: 3.5 Years

Start Date: 01-02-2019

Co-PI: Rajib Lochan Das

Status of the Project: Completed

End Date: 31-07-2022

Number of JRFs: Two

Number of MTech/PhD: Nil

The Grant Number: ISRO/RES/3/804/18-19

Funding Agency: Department of Space

Sanctioned Funding: 26,05,000/-

## Research Problem Statement:

The objective of this project is to develop an efficient design for SATCOM On The Move (SOTM) – the systems with a relative motion between satellite and the mobile terminal. We are in the process of developing an efficient and agile communication receiver that

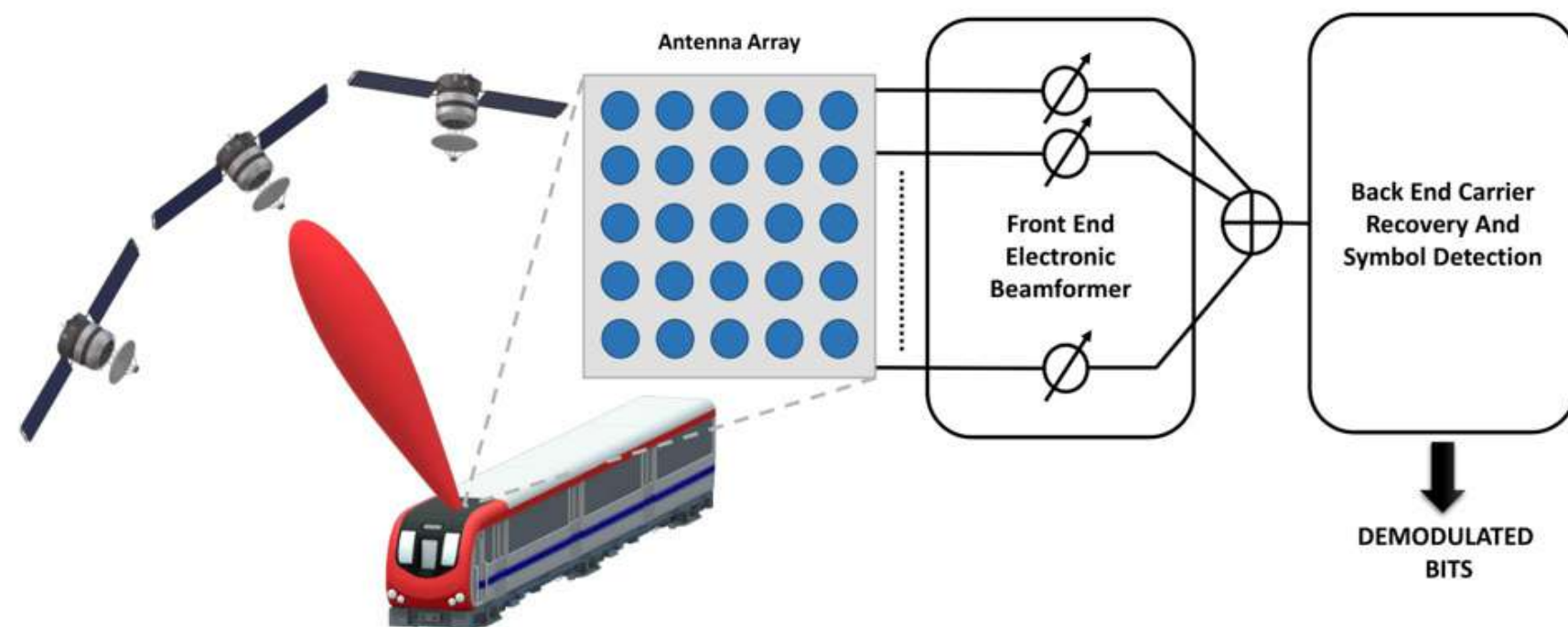
accurately tracks the received signal under a fast-changing link environment (due to a high Doppler rate and interfering signals).

## Objectives & Proposed Approach:

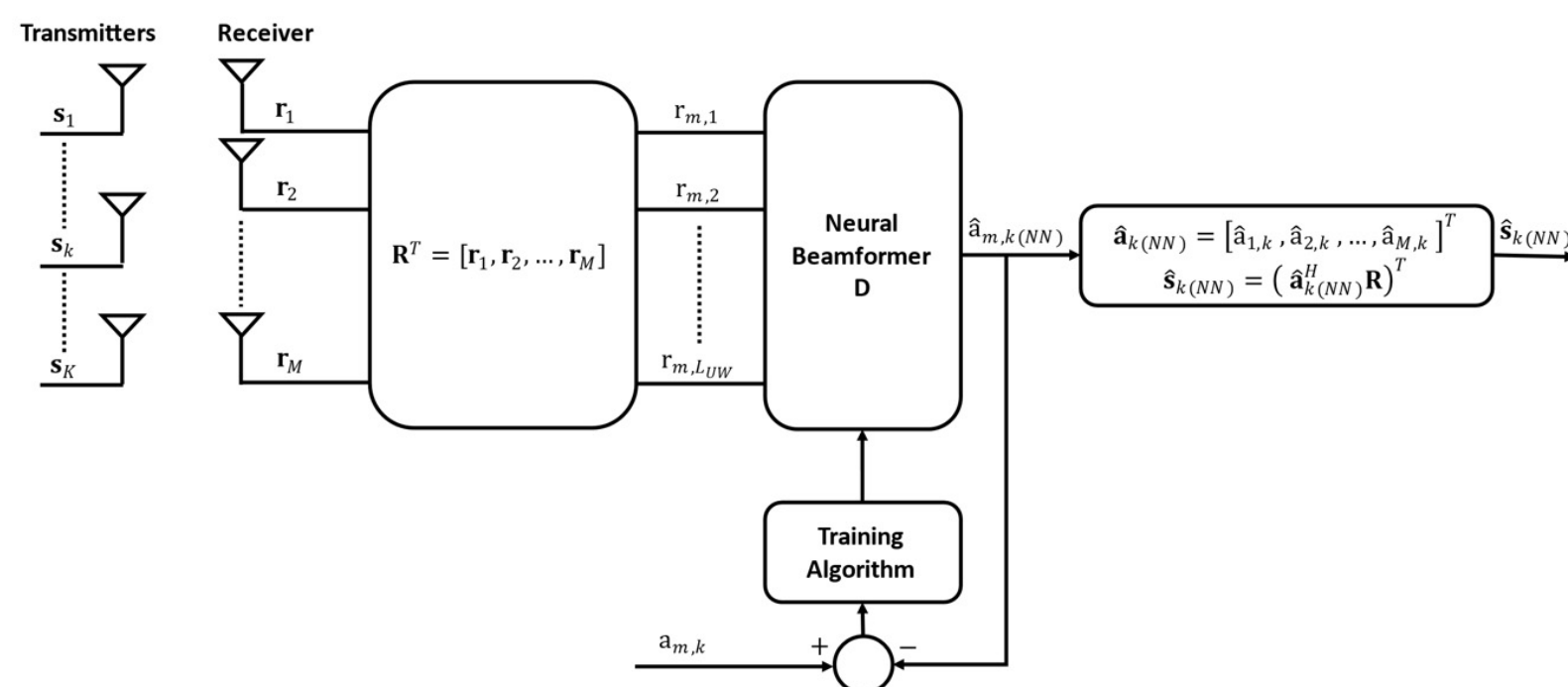
We have developed and designed an adaptive algorithm that makes use of Uniform Planar Array of antenna to electronically steer the beam in the direction of Signal of Interest (SoI) and to control the beam width. Our algorithms allow the use of on-board sensors (e.g., gyroscope, compass, GPS, etc.) and satellite ephemeris data for an efficient implementation on an FPGA.

## Deliverables:

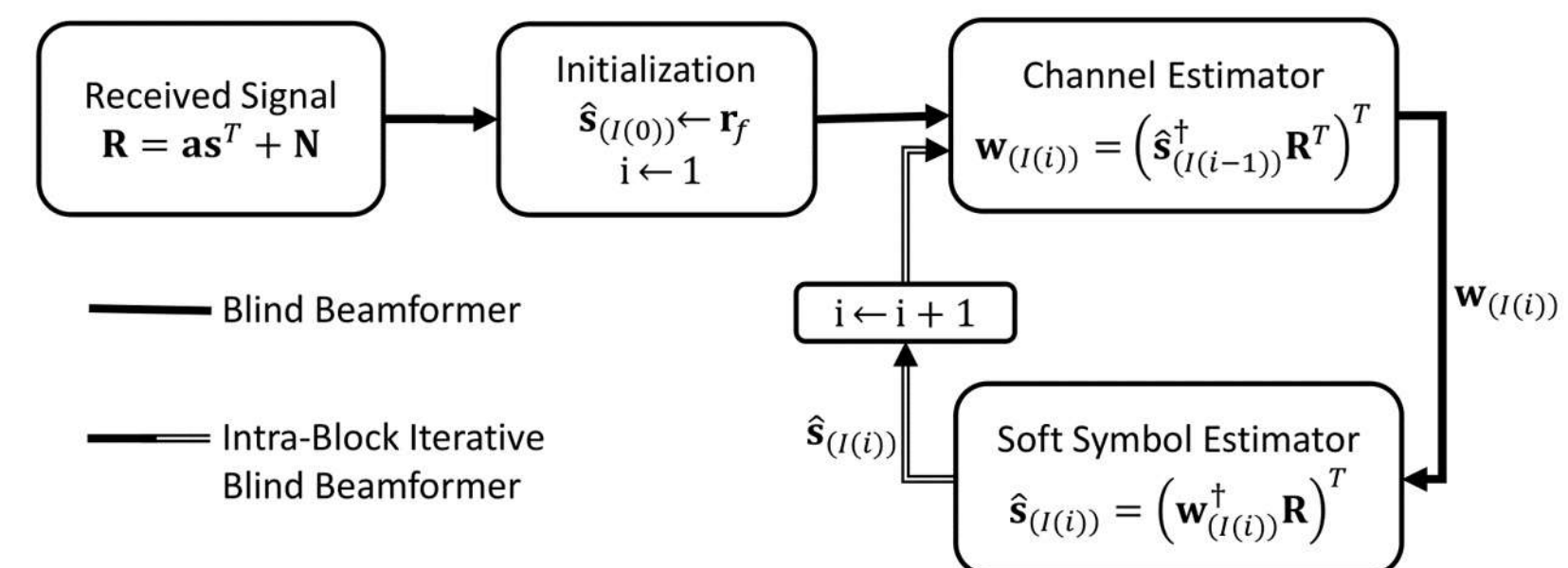
System Design Document and Implementation Software



Phased array beamforming for Satellite On The Move (SOTM) systems



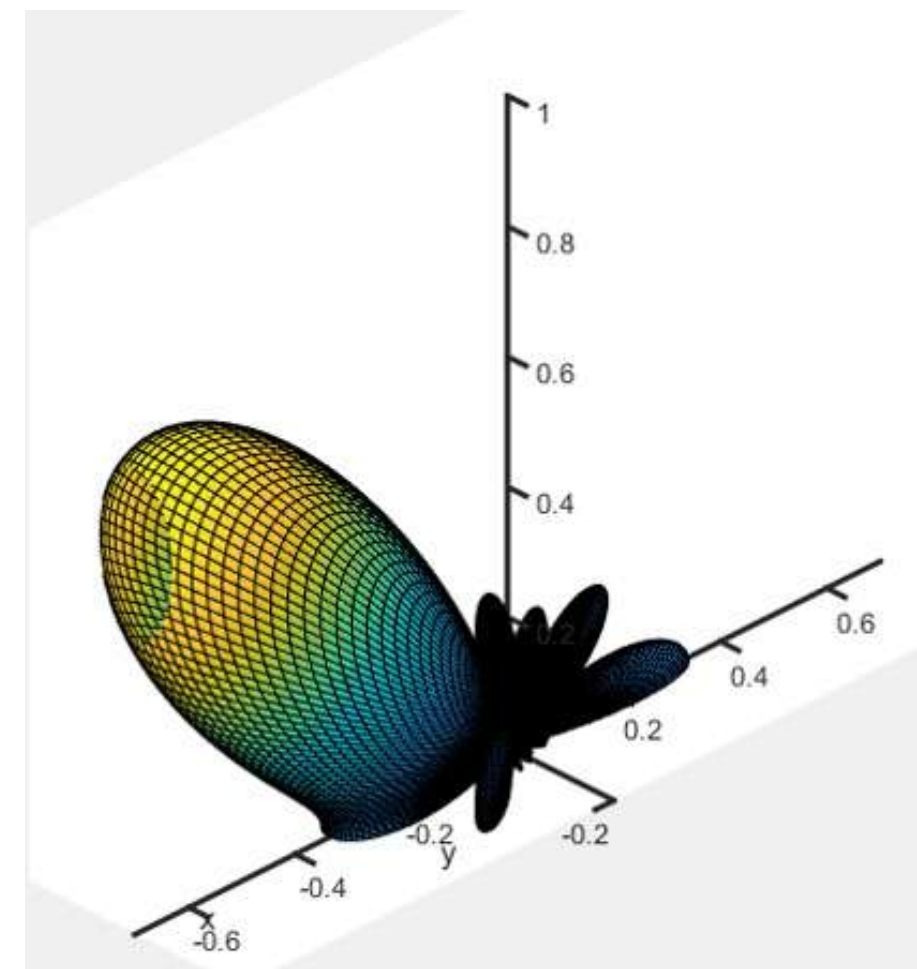
A neural network based beamforming algorithm



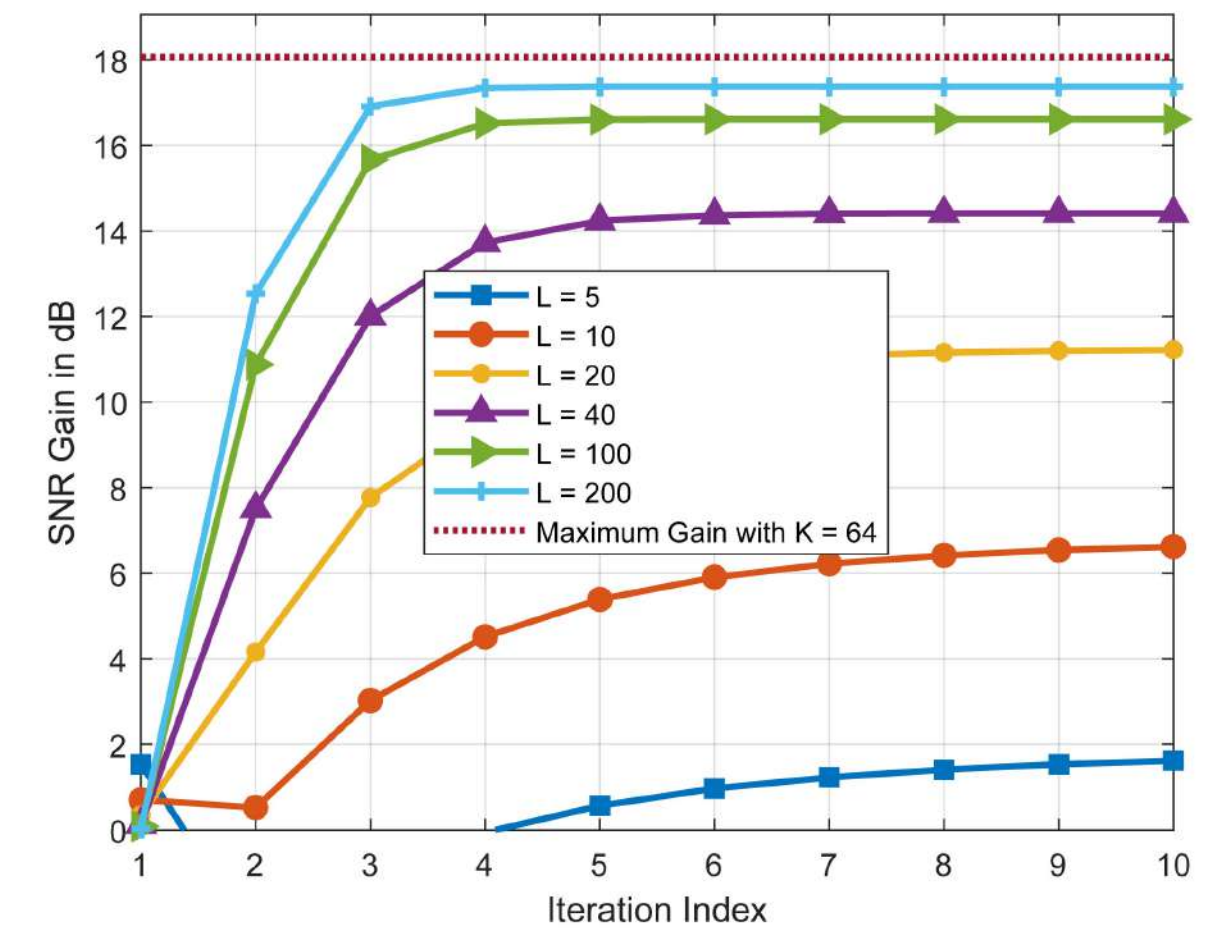
A novel blind iterative beamforming algorithm

## Research Publication:

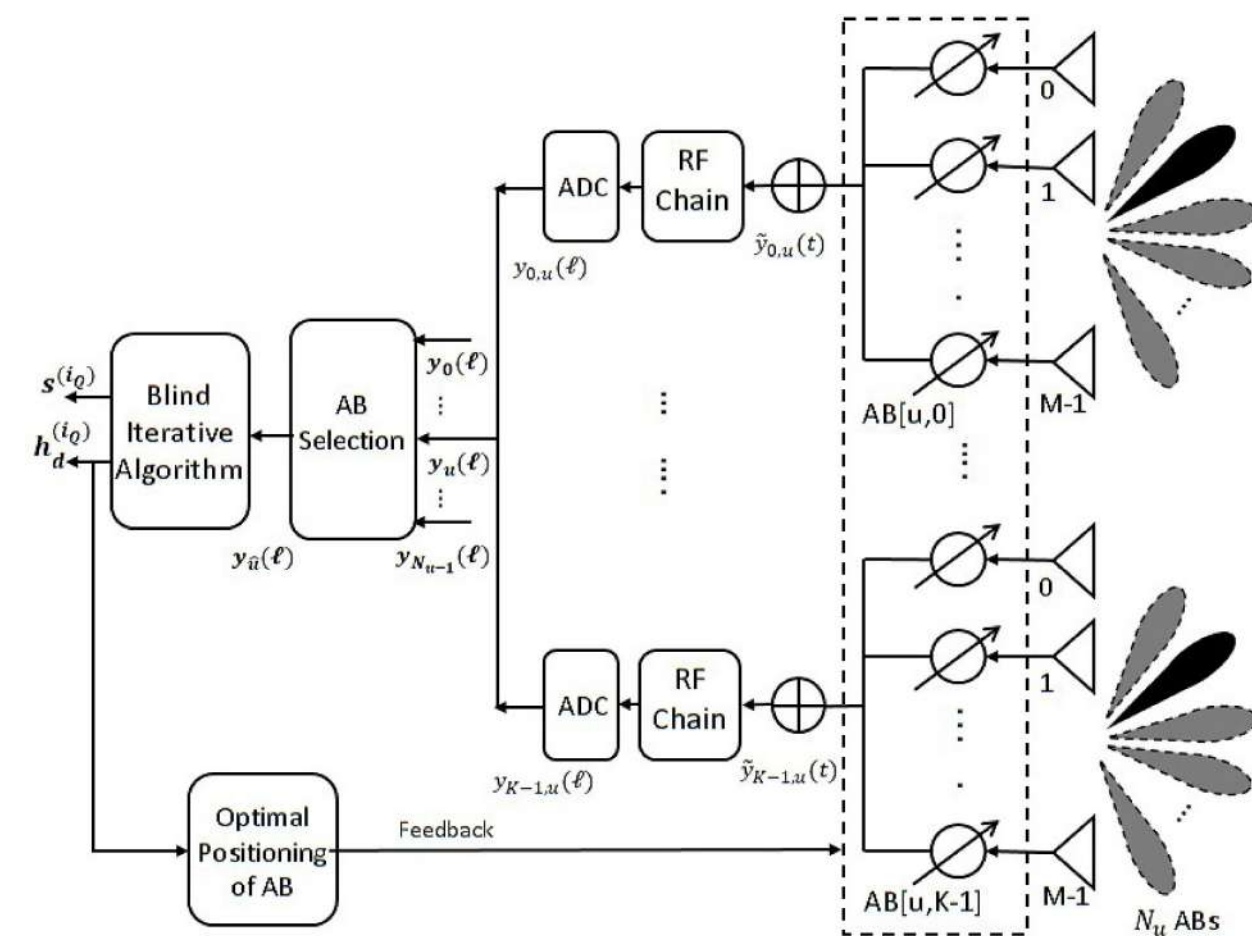
- 1) Y. Vasavada, A. Dhimi, J. H. Reed, N. Shah, "Low-Complexity Blind Hybrid Beamforming for mmWave MIMO Reception," 2022 International Conference on Signal Processing and Communications (SPCOM), 2022
- 2) Y. Vasavada, N. Parekh, A. Dhimi, C. Prakash, "A Blind Iterative Hybrid Analog/Digital Beamformer for the Single User mmWave Reception using a Large Scale Antenna Array," 2021 National Conference on Communications (NCC), 1-6, 2021
- 3) A. Dhimi, N. N. Parekh and Y. Vasavada, "Digital Beamforming for Antenna Arrays," 2019 IEEE Indian Conference on Antennas and Propagation (InCAP), 2019



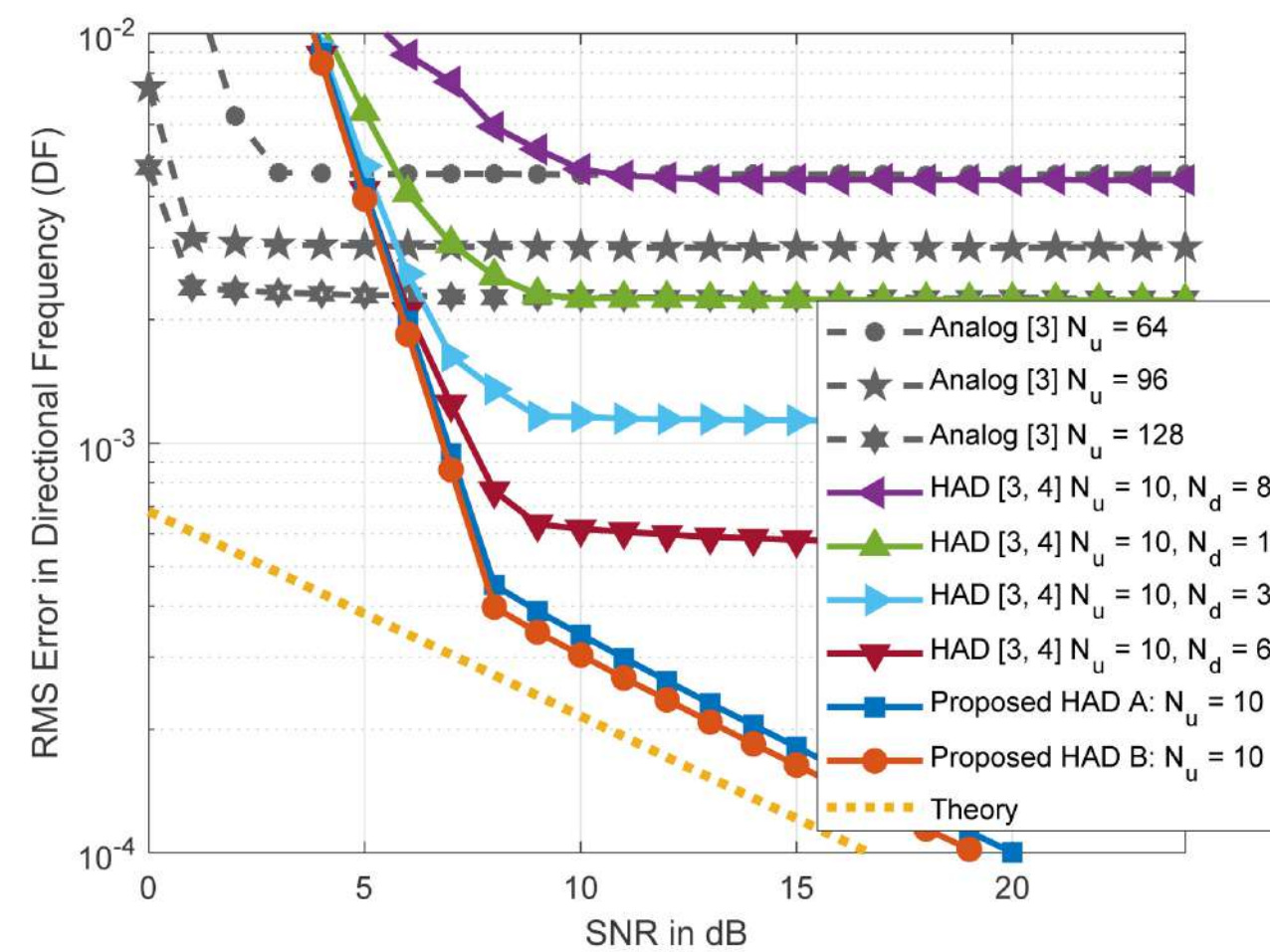
Simulated beamforming pattern in Azimuth and Elevation angle directions



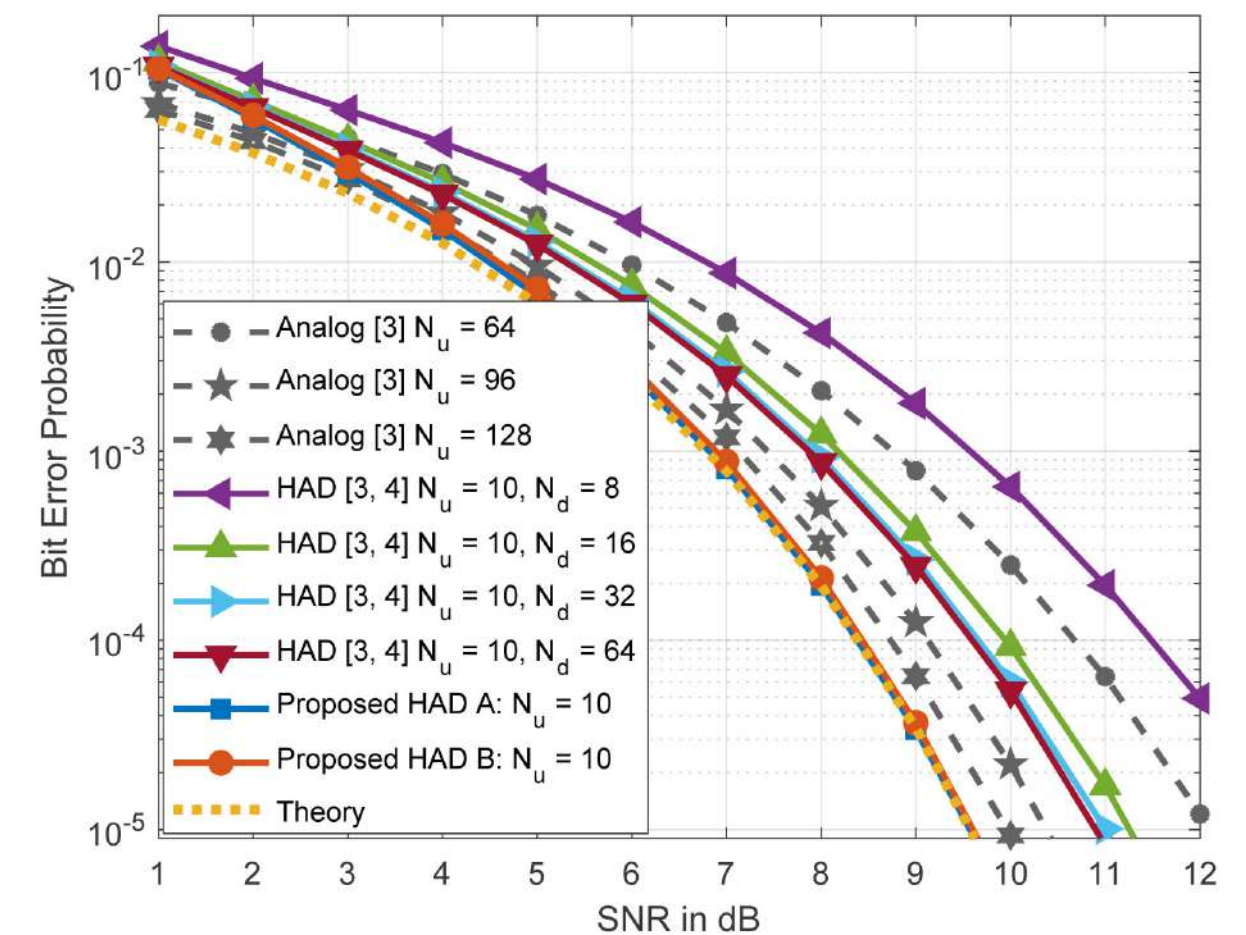
Convergence characteristics at different SNR of the proposed blind iterative algorithm



A hybrid analog-digital (HAD) beamformer for mmWave MIMO systems



BER and RMSE DFoA estimation of the proposed blind iterative HAD beamformer outperforms alternative HAD beamforming techniques in the literature



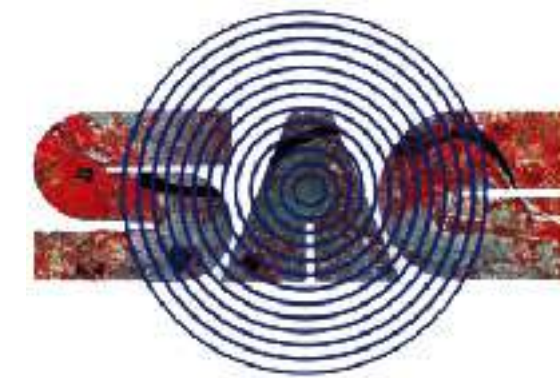


# Design and Simulation of Physical Layer and Medium Access Control (MAC) Layer Functionalities of Future Mobile Satellite Systems



अंतरिक्ष विभाग  
DEPARTMENT OF  
**SPACE**

सत्यमेव जयते



PI: Rajib Lochan Das

Co-PI: Yash M. Vasavada

Duration of the Project: 3 Years

Status of the Project: Completed

Start Date: 16-07-2019

End Date: 31-07-2022

Number of JRFs: Four

Funding Agency: DoS, SAC, ISRO

Number of MTech/PhD: Nil

Sanctioned Funding: 27,46,000 /-

The Grant Number: ISRO/RES/3/809/19-20

## Research Problem Statement:

The statement of the problem of this research is to (i) develop several modulation and demodulation techniques and (ii) channel coding schemes and provide their implementation results in this report. Modulation and demodulation are fundamental modules for communication systems. The modulation techniques — Offset QPSK (OQPSK),  $\pi/2$  BPSK,  $\pi/4$  QPSK and GMSK — are frequently applied in the power-constrained wireless communication links (e.g., the terminal transmission links of several 2G, 3G and 4G terrestrial and satellite air-interface standards). However, their detailed numerical comparison of the performance and functional characteristics are currently lacking in the literature.

The prior studies have focused on a comparison of at the most two of these four schemes (typically OQPSK versus GMSK). One of the objectives of this report is to bridge this gap. We provide a detailed comparison of (i) the spectral regrowth and (ii) probability of bit error versus  $E_b/N_0$  performance of these four modulation schemes in the presence of AM/AM and AM/PM non-linearities with varying backoff (BO). This Report provide a detailed study Channel Encoding schemes based on 4G and 5G communication and optimal selection of schemes based on BER for various code rate, frame size and constraint length. In this report we will have a detailed understanding of convolutional codes using NSC encoder with both hard and soft decision decoding and turbo codes using RSC encoders and SOVA decoding, with and without puncturing.

## Objectives & Proposed Approach:

We have proposed the following approach as a part of this project:

- 1) The selection of an optimum length for unique word which is embedded in between information so as to help the receiver in compensating for channel impairments before performing actual demodulation on the received symbols.
- 2) The selection of an optimum length for information symbols within each block so as to maintain a high efficiency after optimizing the length of unique words in a burst.
- 3) Study and analysis of Channel Encoding schemes based on 4G and 5G communication and optimal selection of schemes based on BER for various code rate, frame size and constraint length, encoding and decoding techniques for the LDPC and the Polar codes, e.g., the successive cancellation decoder and its variants and neural network based LDPC and Polar decoders.

## Research Publication:

- 1) Bhavesh Singh, Kishan Chandra, Yash Vasavada, “Neural successive list and flip decoders of the polar codes,” manuscript in preparation
- 2) Tilak Nanavati, Yash Vasavada, “A comparison of several modulation schemes for power-constrained communication links,” submitted to IEEE ANTS for review

## Deliverables:

System design document, Preliminary Design Review Presentation, Final Design Review Presentation, Implementation Software





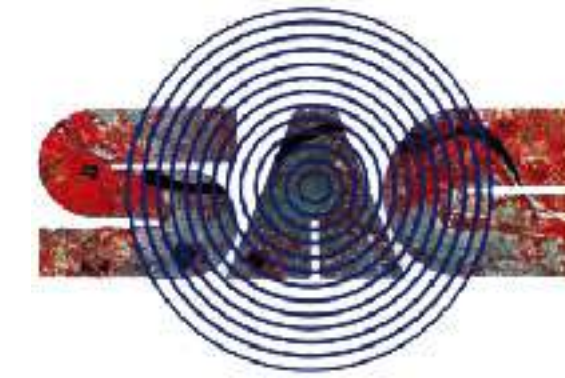


# System Design for Ground-Based Beamformer



अंतरिक्ष विभाग  
DEPARTMENT OF  
**SPACE**

सत्यमेव जयते



PI: Rajib Lochan Das

Co-PI: Yash M. Vasavada

Duration of the Project: 3 Years

Status of the Project: Completed

Start Date: 16-07-2019

End Date: 31-07-2022

Number of JRFs: Four

Funding Agency: DoS, SAC, ISRO

Number of MTech/PhD: Nil

Sanctioned Funding: 27,46,000 /-

The Grant Number: ISRO/RES/3/809/19-20

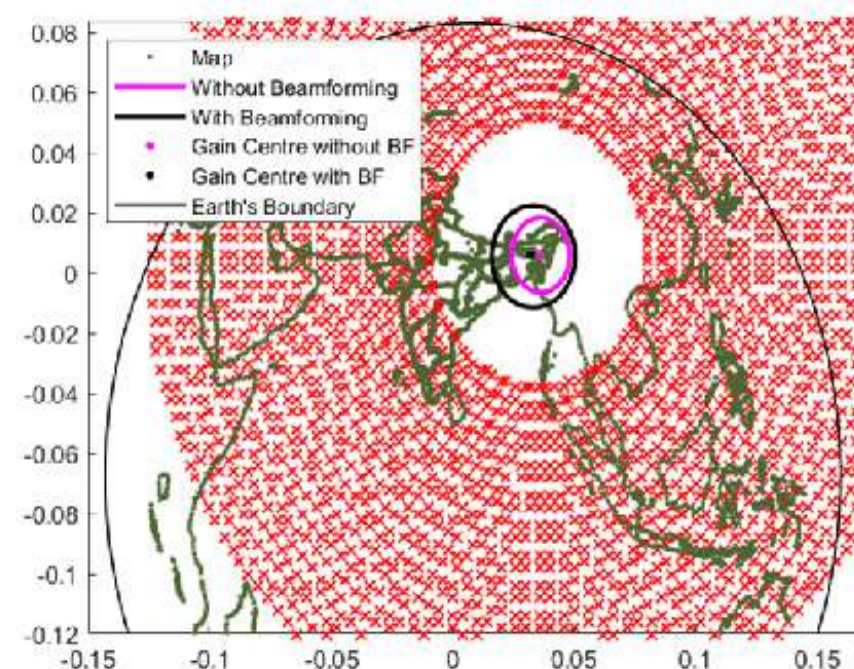
## Research Problem Statement:

ISRO has observed a noticeable interference on several GEO satellite return links. This interference is likely due to terrestrial LTE/4G systems operating outside of India (e.g., in Bangladesh, Burma, Russia, etc.) Suppression of this interference is crucial for a successful operation of the ISRO satellite links. The statement of this research problem is to investigate the spatial domain suppression of co-channel interference using a ground-based beam former (GBBF).

The objectives are to develop (i) the advanced ground-based beamforming (GBBF) algorithms for co-channel interference mitigation, (ii) calibration and pointing system design, including the calibration and pointing algorithm and calibration earth station placement.

## Research Publication:

Sesha Sai Anudeep, Joel Fernandez, Yash Vasavada, "System design and development for the ground-based beamformer of a GEO satellite system," manuscript in preparation



Proposed Null Placement for the MVDR Beamformer to Minimize the Sidelobes of the West Bengal Beam

## Objectives & Proposed Approach:

In the first year of the project, we have conducted a detailed study on the achievable spatial interference rejection on the S band by the GBBF. This study applied the beamforming algorithms (such as MVDR and Wiener-Hopf method) to the elemental beam patterns provided by ISRO, and determined the efficacy of suppressing the interference arising from the regions close to the Indian border while achieving the target Directivity within the Indian regions of interest. In the second year, we have developed advanced algorithms for two key functionalities of the GBBF, i.e., the feederlink calibration and the satellite RPY (roll, pitch, yaw) pointing estimation. We have conducted detailed simulation to evaluate the performance of the proposed calibration and pointing algorithms. The performance of these algorithms is influenced, among others, by the number of the calibration earth stations (CESs) and their placement within the Indian subcontinent. Our study in the second year of the project also included development of machine learning algorithms for near optimal placement of the CESs.

## Deliverables:

System Engineering Design, System Design Document, Presentations for the Preliminary and the Interim Design Reviews, Implementation Code

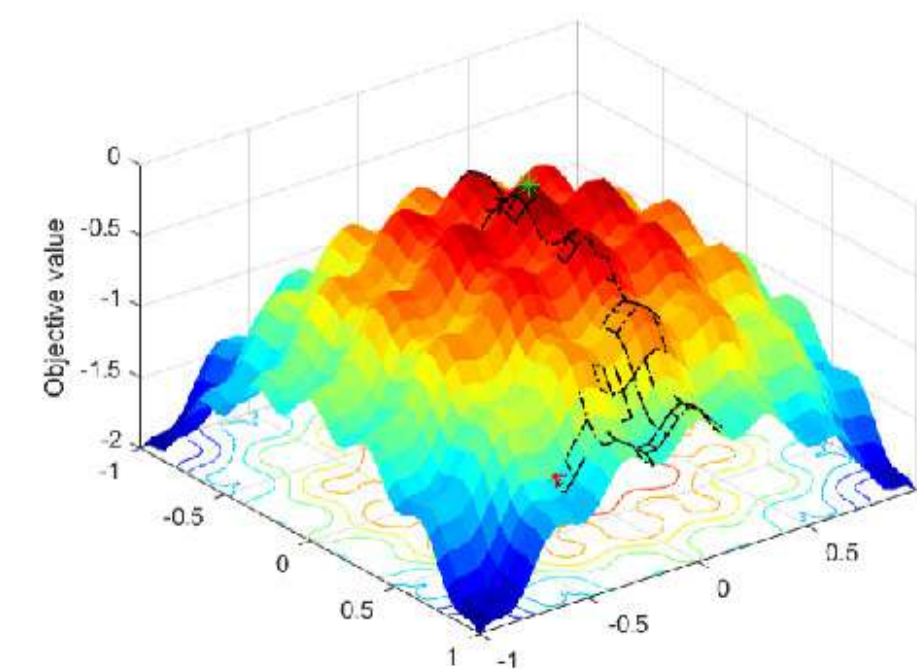
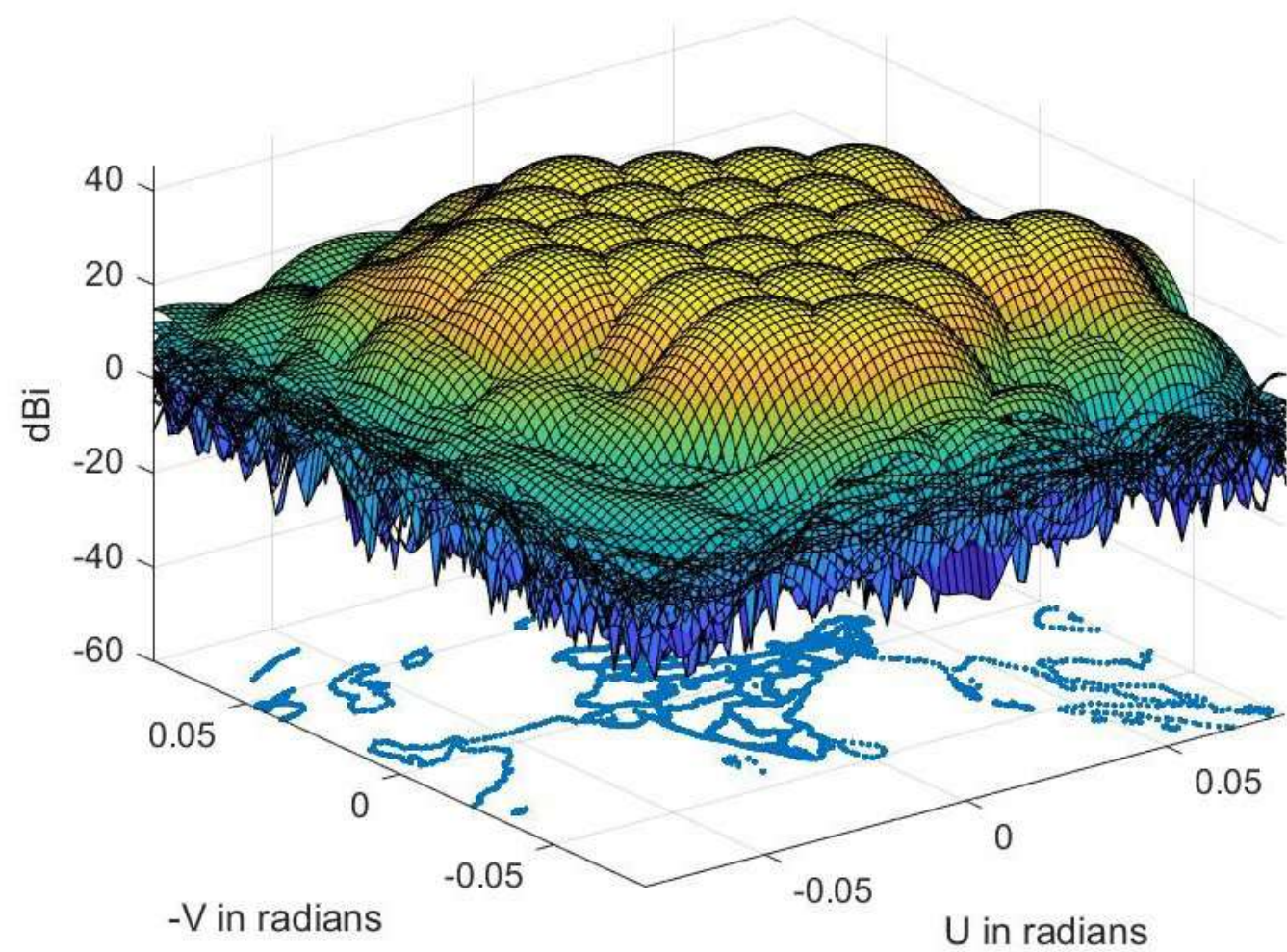
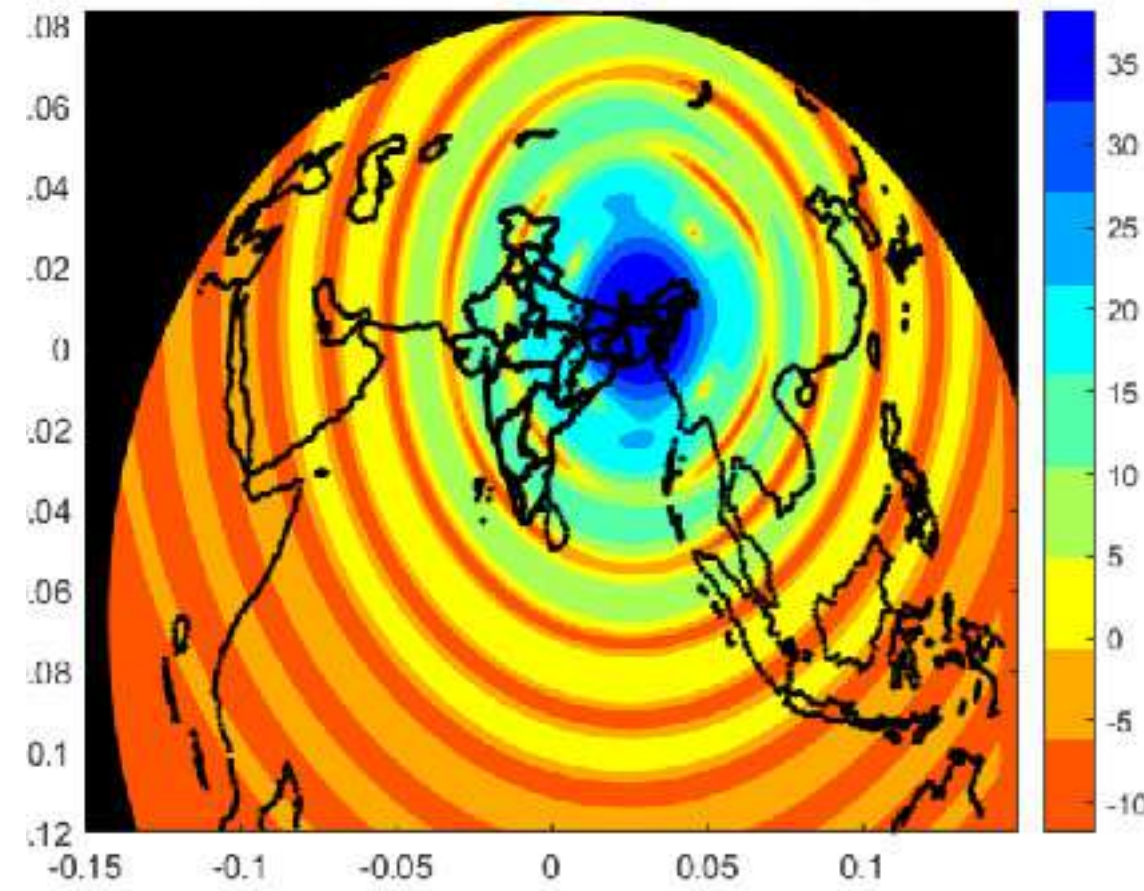


Illustration of Simulated Annealing Algorithm Applied to Optimize the Placement of GBBF Calibration Earth Stations (CESs)

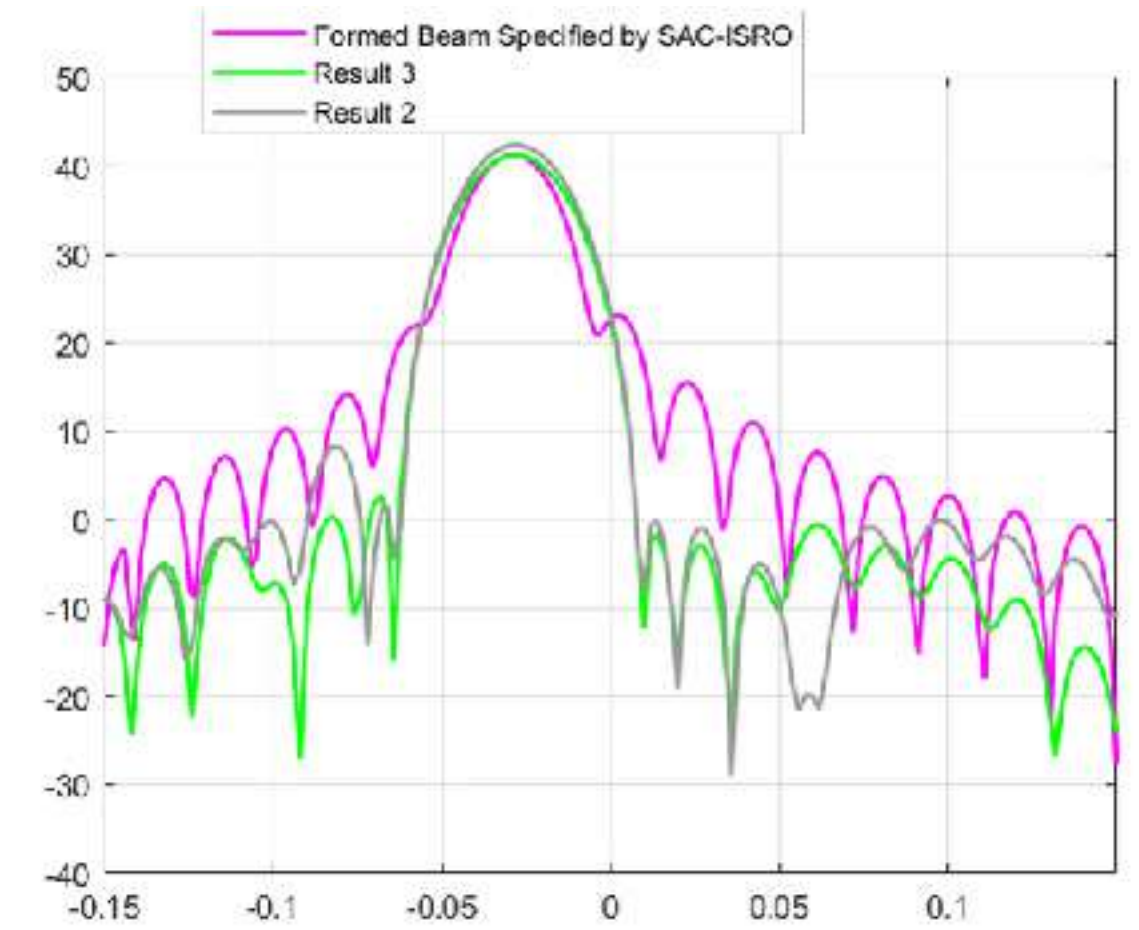
Satellite at 83 deg E, Boresight at 23° N, 80° E



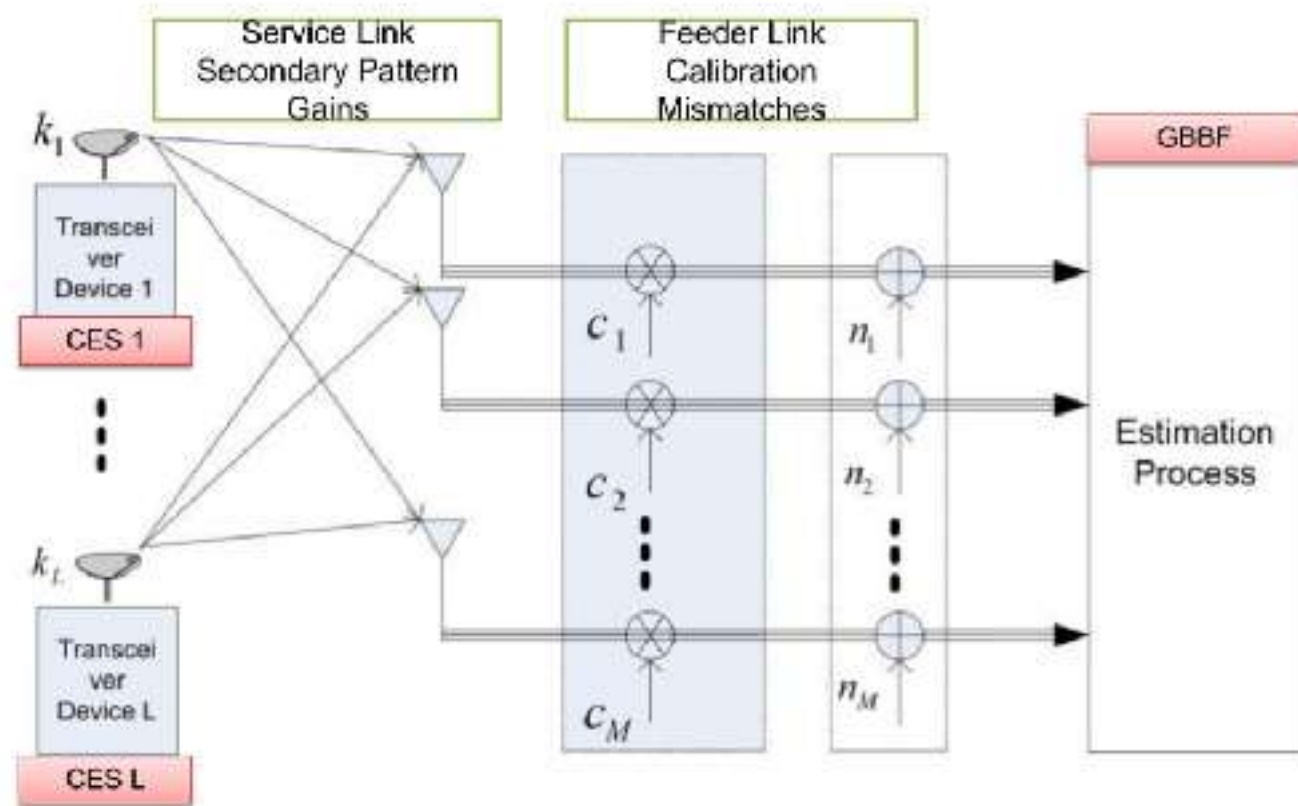
Transmit Antenna Radiation Pattern for a Multibeam Satellite in the Antenna U-V Plane



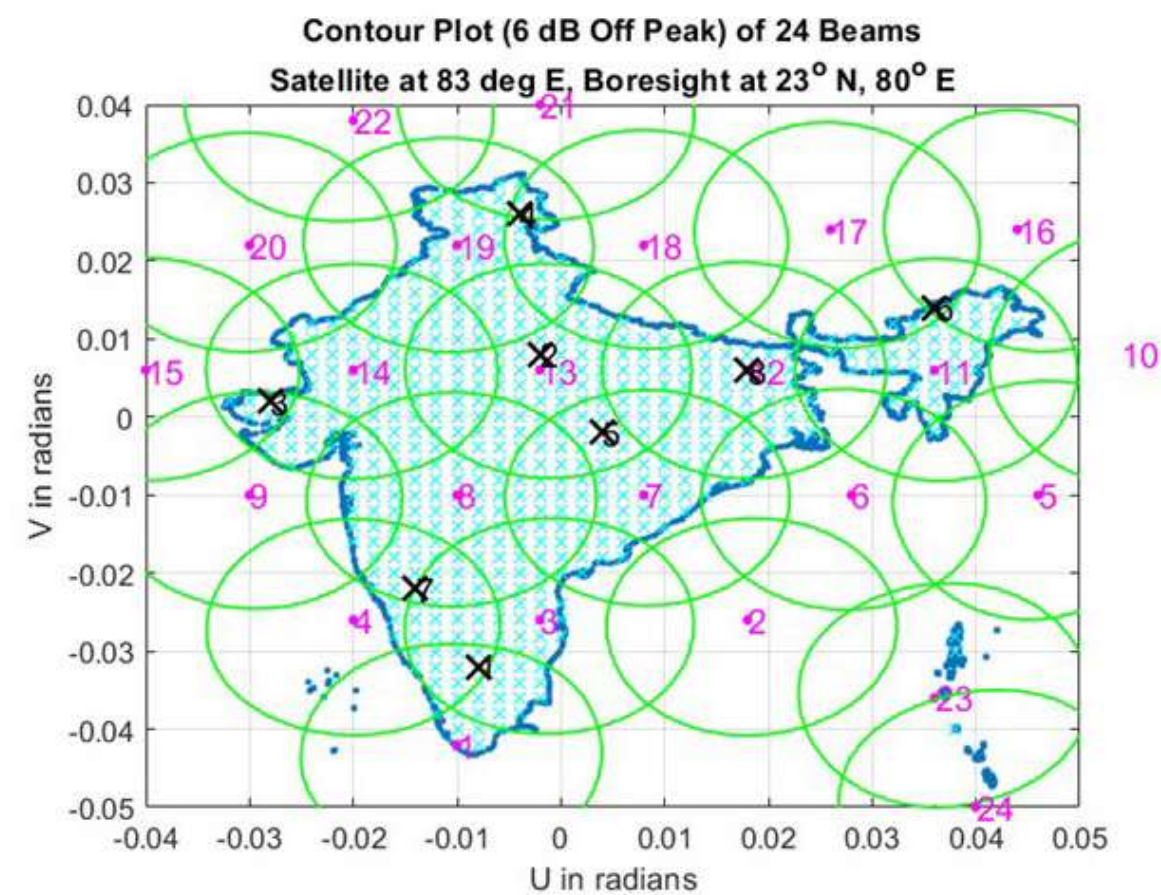
Heat Map (Magnitude Response) of a Formed Beam over West Bengal



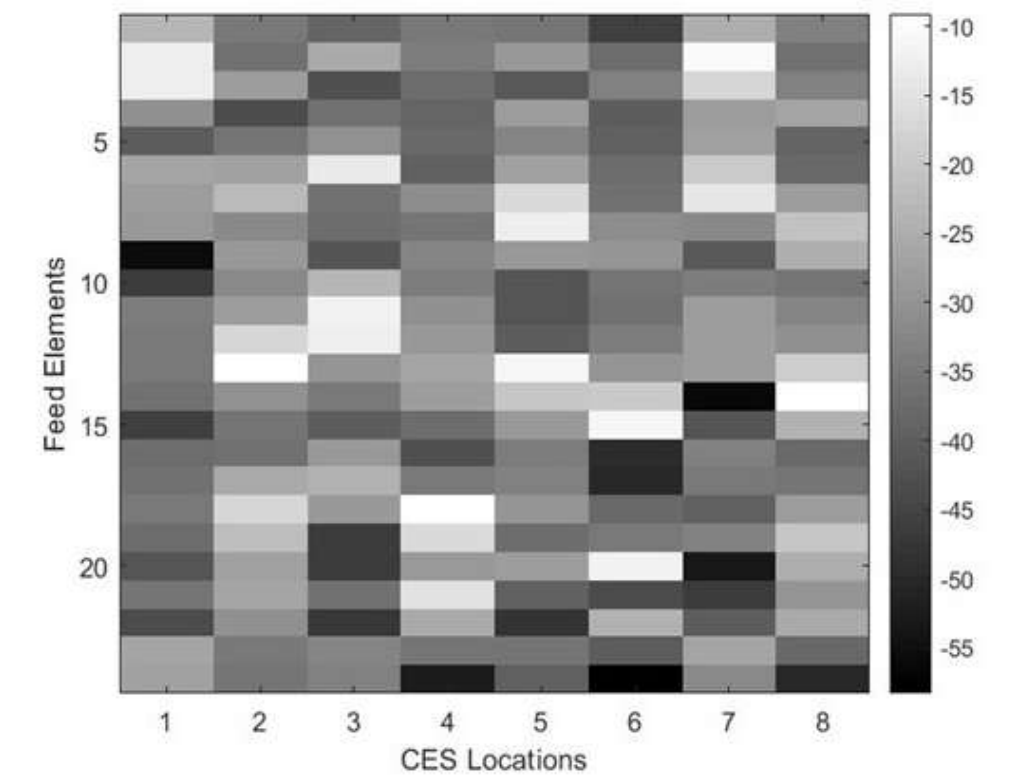
Sidelobe Suppression by Advanced Beamforming (U-cut of Beam's Radiation Pattern shown)



Schematic Diagram for the Calibration of GBBF Feederlink



Chosen CES locations  
Optimal Placement of the CESs



Grayscale Pixel Chart  
Feed Element - CES Connectivity for the Chosen CES Locations

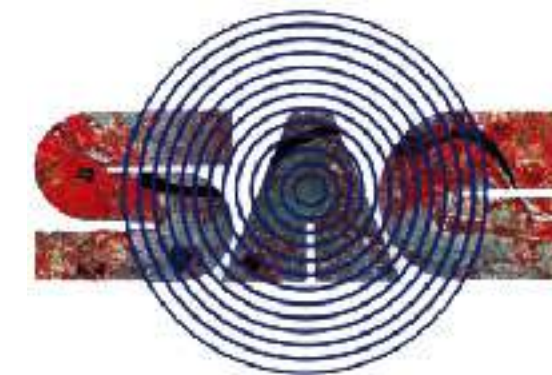


# Adaptive Beam Forming for Mitigation of Interference and Jamming at the Ground Terminal of Global Navigational Satellite Systems (GNSS)



अंतरिक्ष विभाग  
DEPARTMENT OF  
**SPACE**

सत्यमेव जयते



PI: Sanjeev Gupta

Co-PI: Yash Vasavada

Duration of the Project: 2 Years

Status of the Project: Ongoing

Start Date: 01-08-2020

End Date: 31-12-2022

Number of JRFs: Two

Funding Agency: DoS, SAC, ISRO

Number of MTech/PhD: Nil

Sanctioned Funding: 15,98,000 /-

The Grant Number: ISRO/RES/3/854/19-20 DT. 24.12.2019

## Research Problem Statement:

The GNSS receiver is susceptible to the interference/jamming. This can be either due to adversarial jamming of the GNSS downlink signal or due to non-adversarial co-channel interference. The objective of this research project is to investigate the ground terminal based methods of interference/jamming suppression. Specific objectives are to

- A) Investigate (both study and simulate) baseband digital signal processing algorithms available in the literature for beamforming using Uniform Planar Array, Linear Array, Circular Array,
- B) Develop a novel GNSS interference mitigation scheme that optimizes the obtained interference nulling performance (i.e., it achieves the target goal of -50 dB interference suppression in addition to -30 dB anti-jamming capability inherent in the GNSS signal itself), and
- C) Provide an implementation friendly prototype of the algorithm to ISRO (i.e., it achieves SAC-ISRO's current baseline for implementation, which assumes a seven-element antenna array)

## Research Publication:

System Design and Engineering, System Design Document, Presentations for the Preliminary and Interim Design Reviews, Implementation Code

## Accomplishments:

- 1) Held **two technical interchange meetings (TIMs)** with the SAC ISRO focal team. Understood the project requirements and specifications from the ISRO's team
- 2) Developed a model in Matlab of the Uniform Linear Array (ULA) and a preliminary model of the Uniform Planar Array (UPA)  
We will be also building a model of Uniform Circular Array (UCA)
- 3) **Developed five different Direction of Arrival (DoA) estimation techniques** using the ULA model in Matlab  
Spatial DFT, MVDR (Capone's Algorithm), MUSIC, Expectation Maximization and ESPRINT

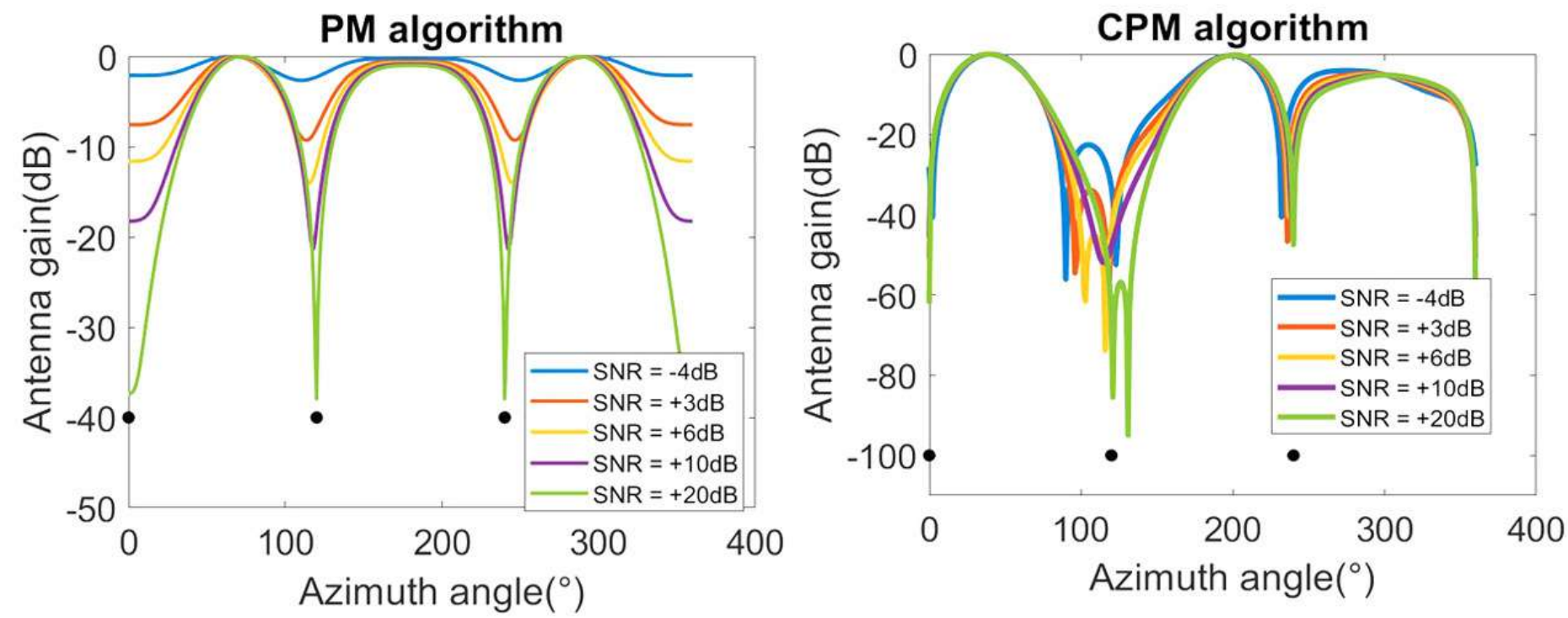
## Objectives & Proposed Approach:

- A) Completed a detailed survey of the literature on GNSS interference mitigation
- B) Direction of Arrival (DoA) Estimation Algorithms: Implemented in Matlab the following algorithms for DoA estimation: power spectral estimation, MVDR, MUSIC, ESPRIT, and EM. Conducted a detailed simulation-based comparative performance evaluation of these algorithms and evaluated Root Mean Squared Error (RMSE) in DoA estimation provided by these algorithms with different number of array elements and different number of jamming signals with varying separation in the spatial domain
- C) Interference Nulling Algorithms: Implemented in Matlab the following algorithms for the interference nulling: matched filter, Least Squares Decorrelator, Minimum Mean Squared Error (MMSE) Wiener-Hopf scheme, and LCMV scheme. Obtained the results that show the ability of these algorithms under the constraint of a fixed number (e.g., five or seven) of array elements in forming deep spatial nulls in the close vicinity of the direction of the peak Directivity (which is aligned to the DoA of the GNSS signal)

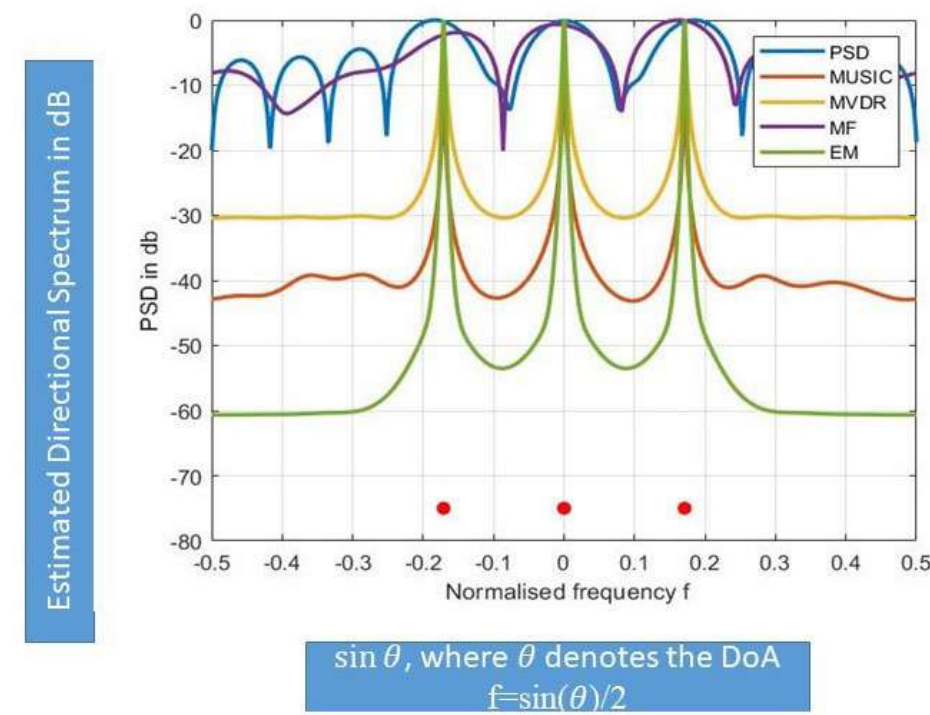
## Deliverables:

System Engineering Design, System Design Document, Presentations for the Preliminary and the Interim Design Reviews, Implementation Code

- 4) **Developed four different jamming signal rejection (JR) techniques** using the estimated DoAs  
Least Squares, MMSE, Successive Interference Cancellation, Multistage Interference Cancellation
- 5) **Developed a Monte-Carlo simulation tested** that incorporates the DoA estimation and the JR algorithms  
Allows us to run computer experiments with different number of antenna elements, different array geometries and different signal environments (J/S ratios, various DoAs, etc.)



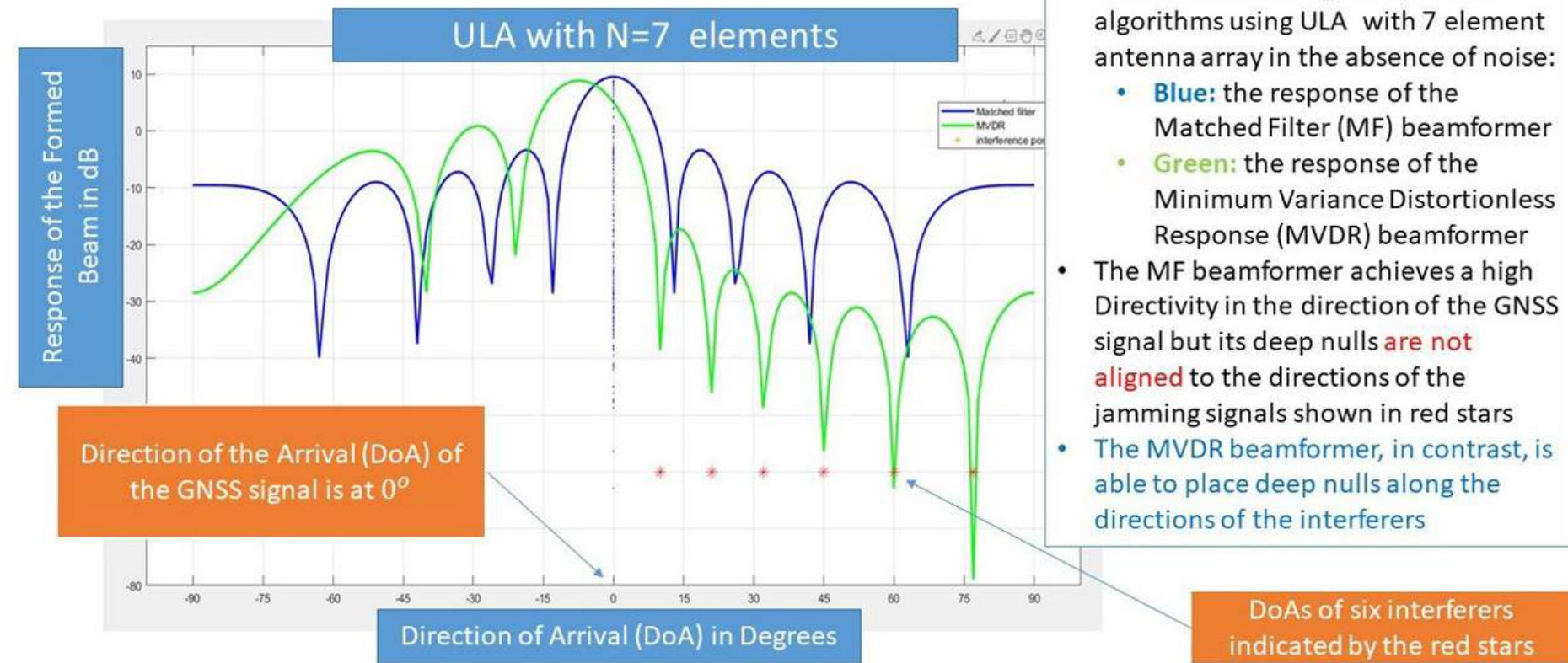
Efficacy of the Spatial Null Placement at the Interference Locations (shown in Black Dots) by the PM and the CPM Algorithms



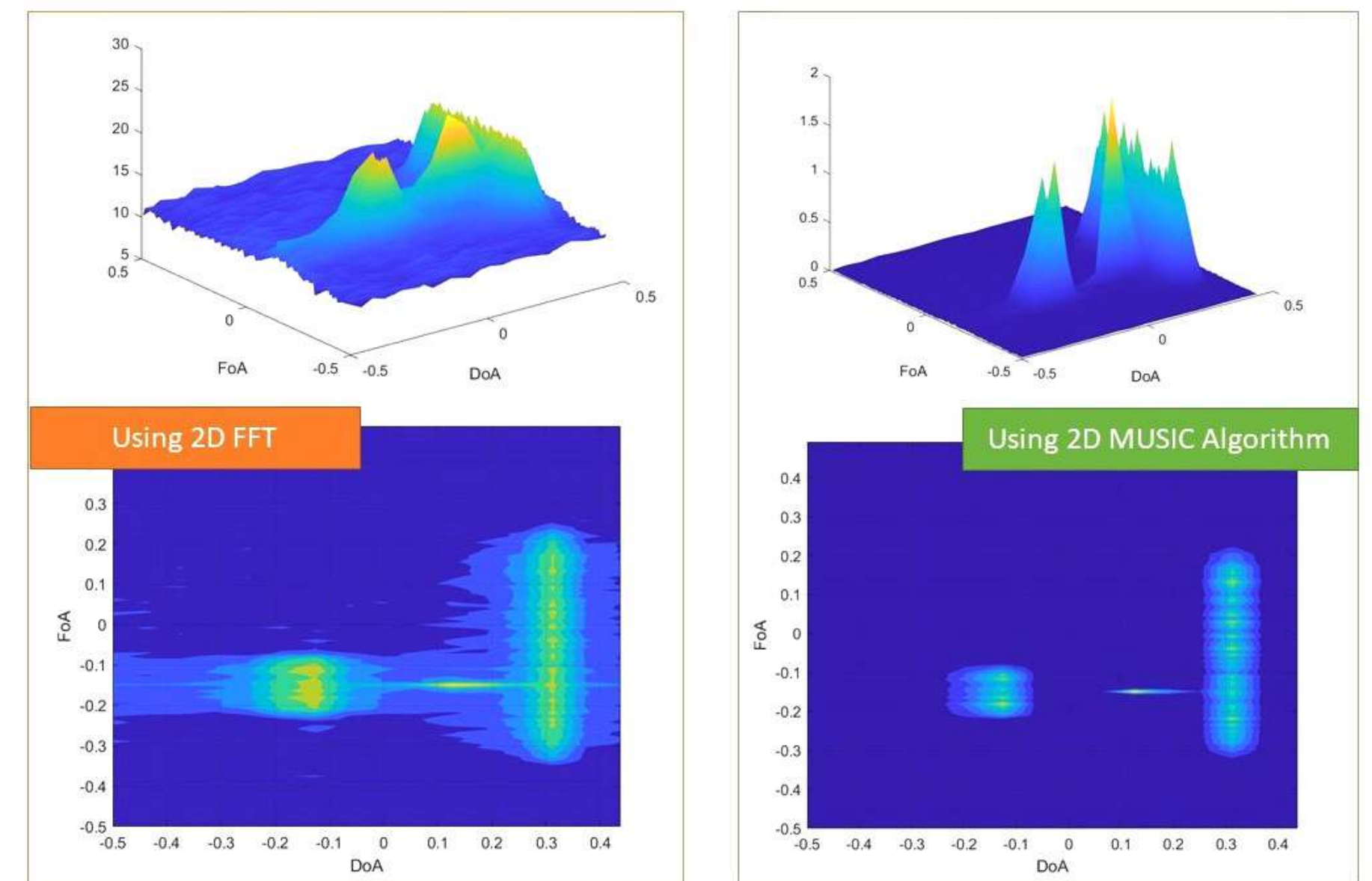
ULA with N=12

- This simulation result compares the performance of these DoA estimation algorithms:
  - ✓ The matched filter or the power spectrum density (PSD) estimation algorithm
  - ✓ The MUSIC algorithm
  - ✓ The MVDR algorithm
  - ✓ Expectation Maximization
- The signal directions are shown by the red circles at the bottom of the chart in normalized frequency
- The result shows that the MVDR, MUSIC and the EM algorithms are able to "pin-point" the DoAs more accurately compared to the PSD based method or Matched filtering method

Comparative Evaluation of Several Direction of Arrival (DoA) Estimation Algorithms for the ULA Antennas



Efficacy of the Spatial Null Placement at the Interference Locations (shown in Black Dots) by the MVDR versus Spatial Matched Filter Beamforming



GNSS Signal Identification by Two-Dimensional DoA/FoA Spectral Analysis

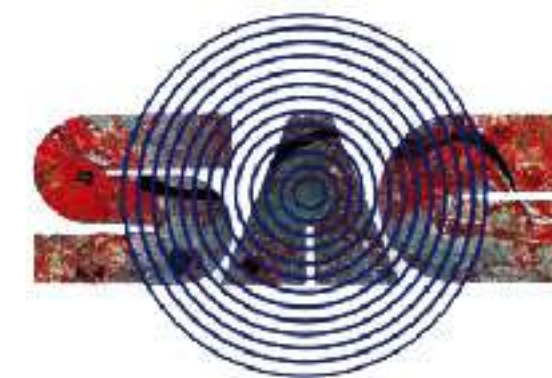


# Satellite Network Simulator with ULPC and ACM features



अंतरिक्ष विभाग  
DEPARTMENT OF  
**SPACE**

सत्यमेव जयते



PI: Bhaskar Chaudhary

Co-PI: Yash Vasavada

Duration of the Project: 2 Years

Status of the Project: Ongoing

Start Date: 24-02-2020

End Date: 31-12-2022

Number of JRFs: Two

Funding Agency: DoS, SAC, ISRO

Number of MTech/PhD: Nil

Sanctioned Funding: 14,18,000 /-

The Grant Number: ISRO/RES/3/850/19-20 dated 3.12.2019

## Research Problem Statement:

The research problem statement is to develop a satellite Network Simulator or SNS with the following capabilities:

- An offline software tool that can be used to generate data about and collect data-driven insights into the satellite network level planning and design activities.
- The SNS will model a number of Subscriber Terminals (STs) that are operational over the satellite network and it will perform a link level analysis by modeling the rain-induced fade and other sources of link impairments. The simulator will model the adaptive coding and modulation (ACM) and uplink power control (ULPC) processes that are implemented over an operational satellite system.
- The objective of developing this SNS is to provide the satellite network planning engineer an aggregate system level data about the potential performance of the operational as well as planned SATCOM systems during the design and planning phases of system engineering. Using this SNS, the system engineer will be able to
- determine the attainable throughputs (Data rates) that are attained in clear-sky as well as in rainy conditions. The simulator will produce this data on a per-user basis as well as for the entire network.
- identify the operational limits of the planned satellite system and the bottlenecks in the satellite network planning.
- collect insights into the potential avenues of removing or reducing the bottlenecks so that the overall system capacity is improved.

## Research Publication:

Jui Telawane, Yash Vasavada, "Modeling the routing protocols for the flying adhoc networks," manuscript under preparation

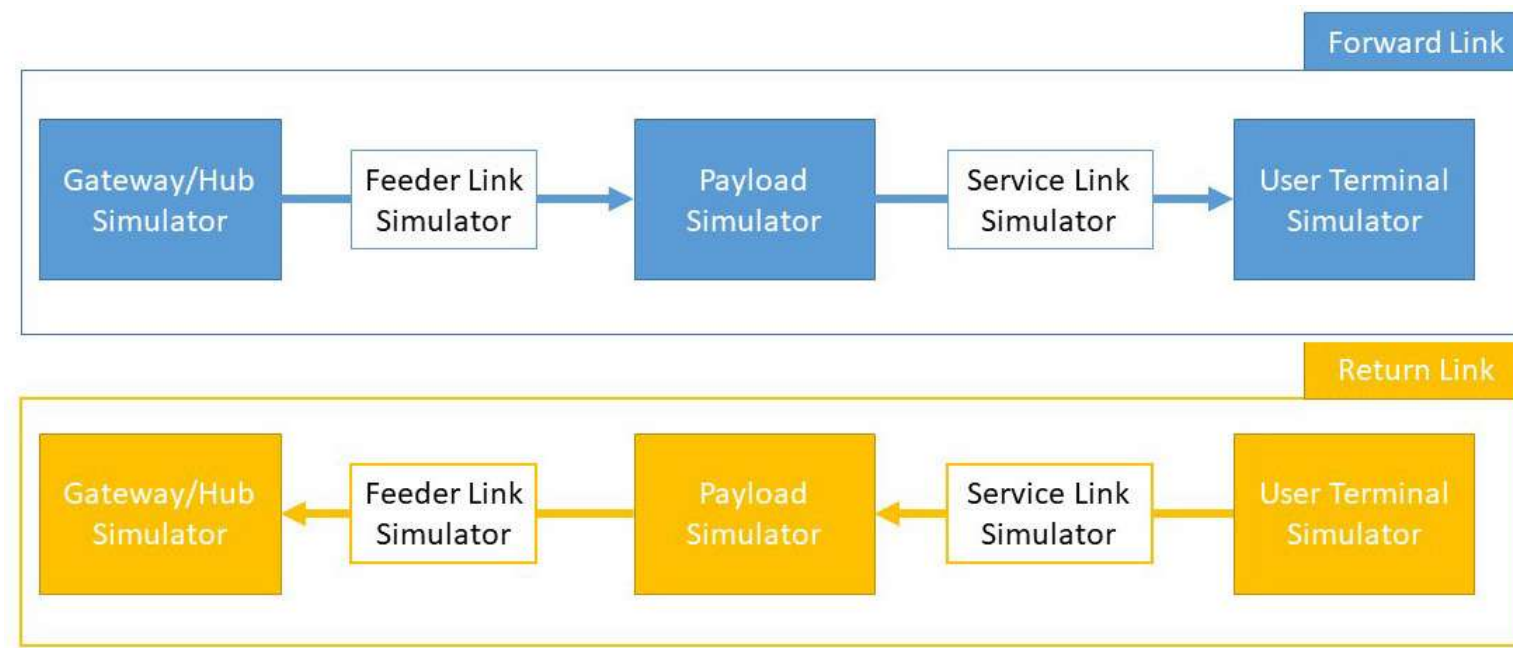
## Deliverables:

A GUI-based software simulator for the GEO satellite systems, a system design document, preliminary and interim design review presentations, & implementation code

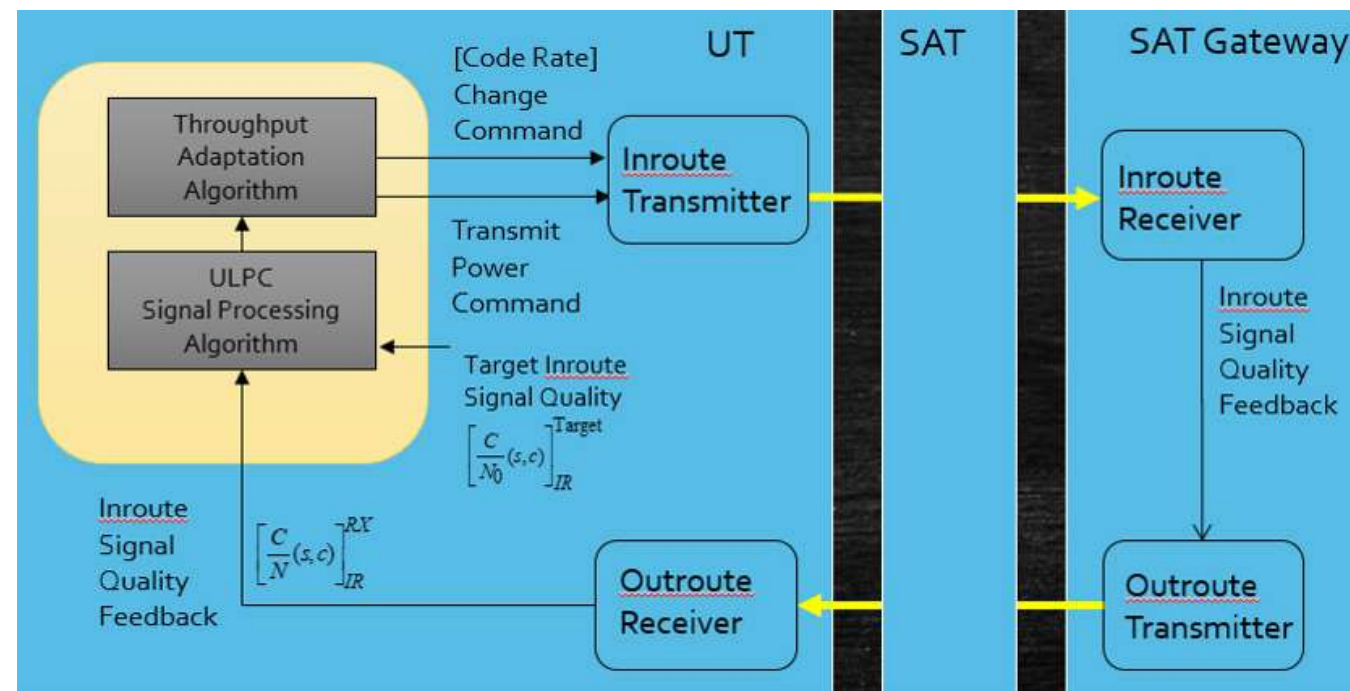
## Objectives & Proposed Approach:

The block diagram of the proposed satellite network simulator (SNS) has linkages to the satellite system/network engineering evaluations and verifications. The SNS can be used to model per site channel conditions and to evaluate the achieved system throughput to ensure the proposed approach is feasible with real world conditions. The SNS simulates different components of a satellite system including satellite gateway, the satellite payload and subscriber terminals. The SNS models the forward link from the Gateway to the satellite to the subscriber terminals separately from the return link (from the terminal to the Gateway via the satellite). The proposed SNS supports

- A configurable number of subscriber terminals (Sts).
- A configurable set of locations for these STs. These can either be manually entered or the simulator can statistically generate these locations.
- The simulator will model the temporal rain fade events depending on the location of the individual Sts.
- The simulator can optionally incorporate the frequency reuse patterns over satellite spot beams. This will allow modeling of the intra system co-channel interference.
- The simulator will have a link budget analysis model that will be continually updated at each simulator time epoch for each ST.
- The link budget analysis will be tied to the VCM, ACM and ULPC algorithmic processes operating on a per-user basis.
- The output of the simulator will be several satellite network level quality of service (QoS) metrics such as the overall system level and per user level throughputs that are attained (given the programmed values of the bandwidth and the power levels on the forward and return links and the satellite transponder gain) and the system planning parameters such as the number of simultaneous co-channel users that can be supported in the system.

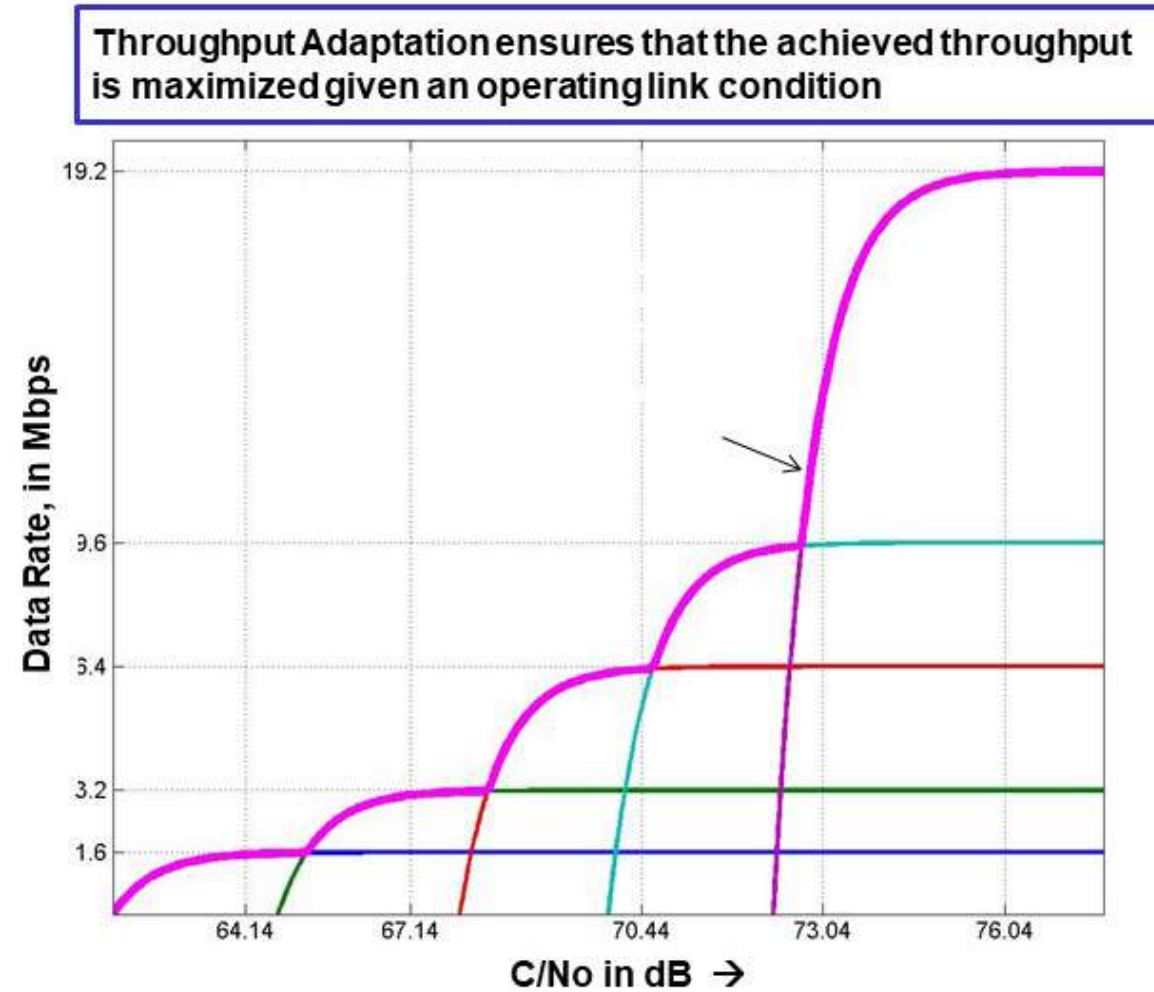


Satellite Forward and Return Link Modeling in the Proposed Satellite Network Simulator (SNS)



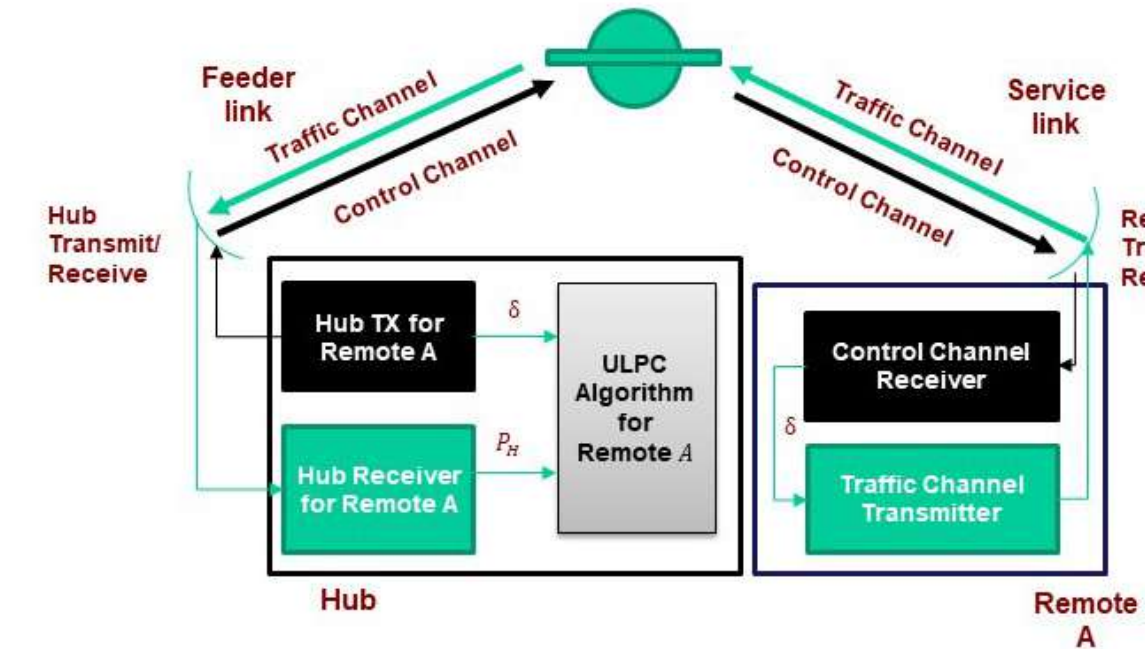
Schematic of the Uplink Power Control (ULPC) and Adaptive Coding and Modulation (ACM)

- Without the throughput adaptation, the data throughput remains a constant above a  $C/N_0$  threshold, and approaching zero below the threshold
- ❖ With throughput adaptation, as the link condition improves and the received  $C/N_0$  increases, the achieved throughput increases as well
- ❖ If the link condition degrades, the throughput gradually reduces instead of falling off a cliff



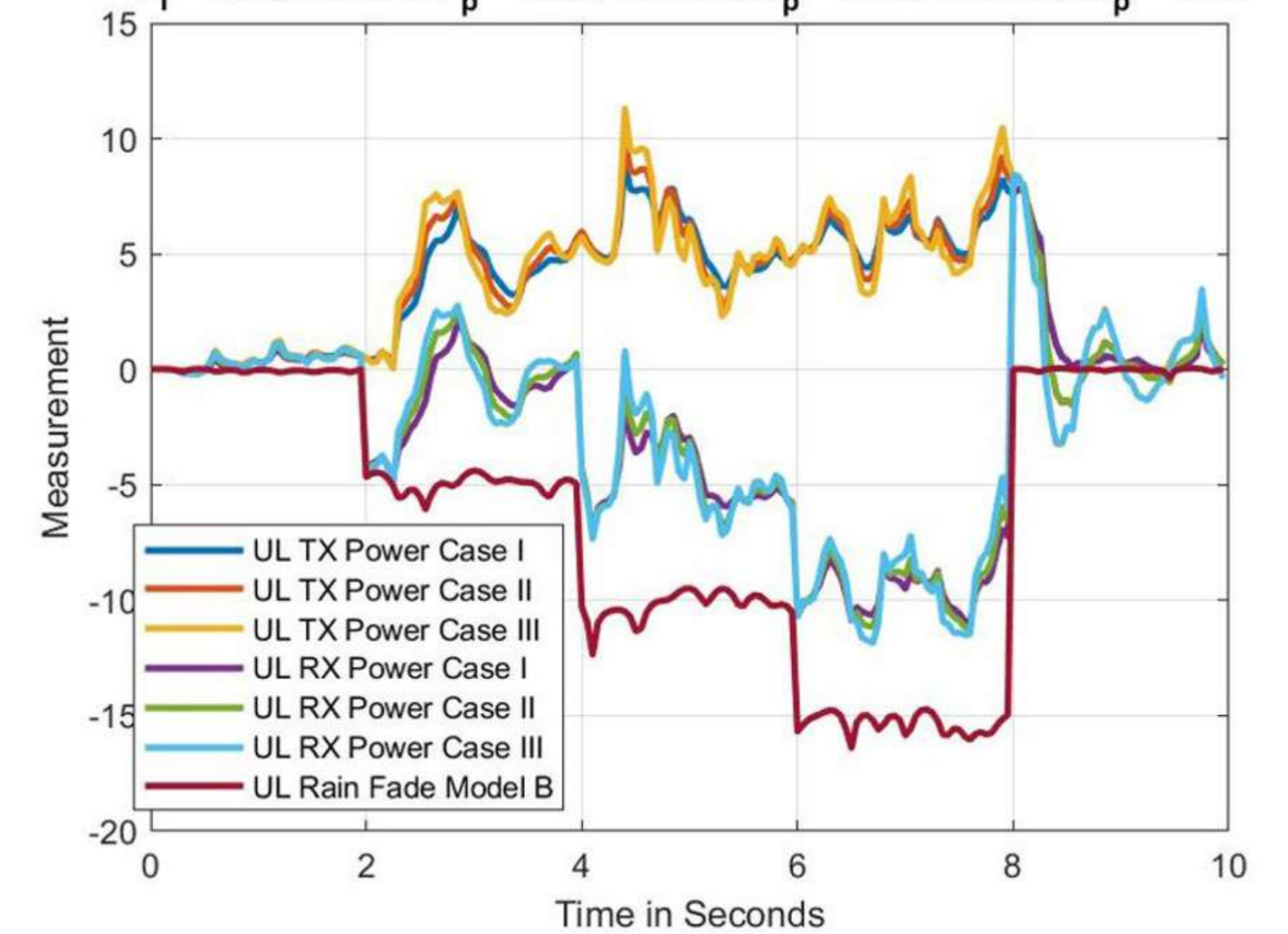
ACM: A Conceptual Illustration

- The feederlink fade variations are assumed to be compensated by the feederlink ULPC
- A particular remote, say, Remote A, transmits the traffic channel on the service uplink
- The Hub measures its received power  $P_H$  (or the signal to noise ratio SNR) on the feeder downlink
- The Hub compares  $P_H$  against a fixed target, the difference is fed to the ULPC algorithm operating at the Hub for Remote A
- The ULPC correction  $\delta$  is sent by the Hub to the Remote A via the control channel



Service Link ULPC: A Conceptual Illustration

ULPC+ACM Response; Delay: 250 ms; Sample Duration: 50 ms  
 $K_i = 0.35$ ; Case I:  $K_p = 0.35$ ; Case II:  $K_p = 0.45$ ; Case III:  $K_p = 0.55$



Simulated Response of the ULPC and ACM Loops in the Presence of Rain and Atmospheric Fades



# Kinetic Modeling of Large size Negative Ion Sources for Fusion Application using Emerging Parallel Processing Computer Architectures



PI: Bhaskar Chaudhury

Co-PI: Mukesh Tiwari

Number of JRFs: One

Funding Agency: DAE, BRNS

Duration of the Project: 4 Years

Status of the Project: Completed

Number of MTech/PhD: One

Sanctioned Funding: 27,00,000/-

Start Date: 01-04-2016

End Date: 31-03-2020

The Grant Number: 201509MSS03RP01994-BRNS

## Research Problem Statement:

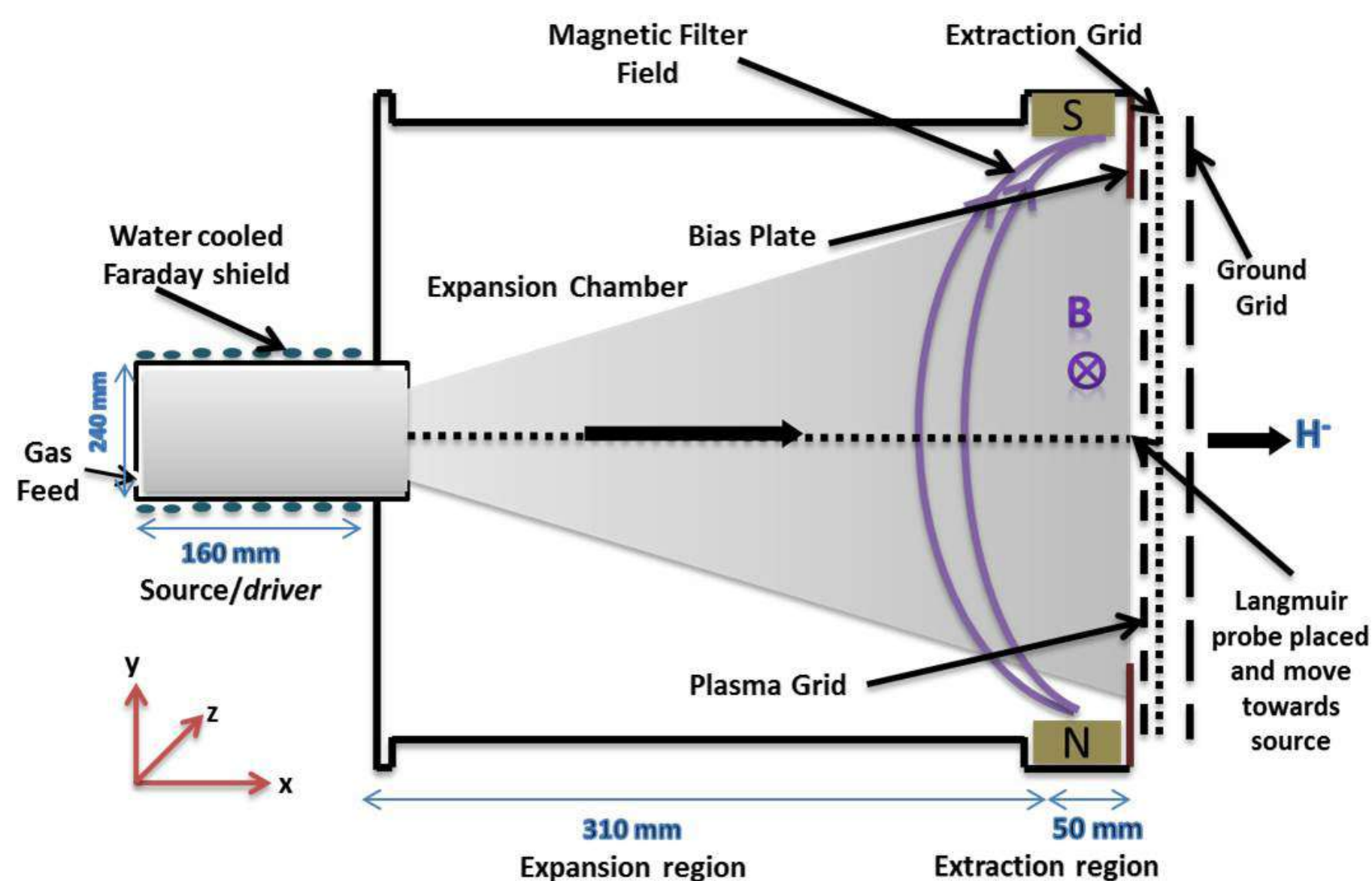
- 1) Understanding important physics issues regarding production, transport and extraction of negative hydrogen ions in negative ion sources for fusion applications. Special emphasis on understanding plasma transport across magnetic fields in general.
- 2) Parallel Particle-in-Cell-Monte Carlo Collision (2D/3D PIC-MCC) Code development on latest heterogeneous shared memory computer architectures in the context of negative ion sources for ITER-NBI systems.
- 3) Comparison and benchmarking of computational results with published experimental data from BATMAN and ROBIN negative ion sources.

## Objectives & Deliverables:

The aim of the proposed computational work is to develop a complete kinetic model of the source, including driver, diffusion chamber, magnetic filter and extraction grid in order to better understand the physics of the source and help in the interpretation of the experimental results from ROBIN. The observable quantities from the simulation can be directly compared to the experimental data and this can increase the confidence in the validity of the model. Finally, model results can inspire new experiments and help interpret observations.

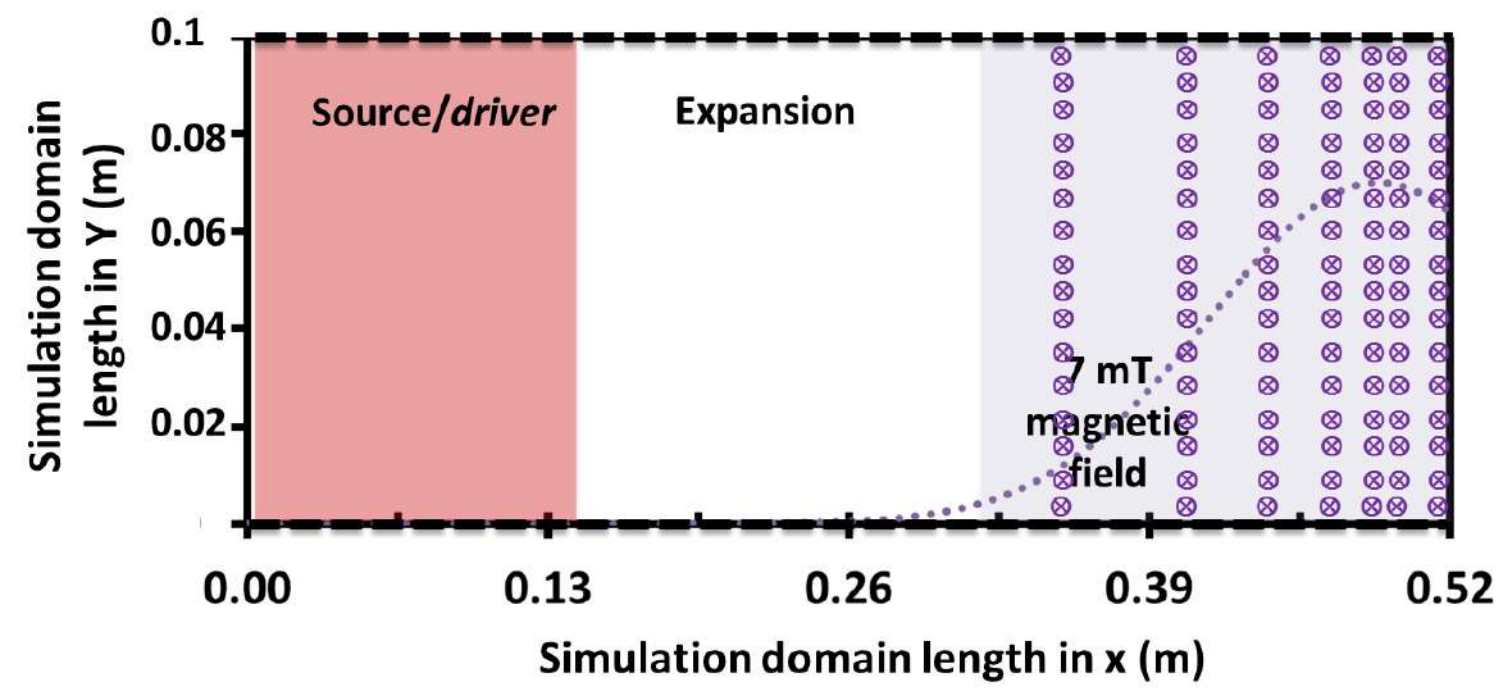
## Research Publication:

- 1) Miral Shah, Bhaskar Chaudhury, Mainak Bandyopadhyay, Arun Chakraborty, "Computational characterization of plasma transport across magnetic filter in ROBIN using PIC-MCC simulation", Fusion Engineering and design, vol. 151, page no- 111402, 2020.
- 2) M Shah, B Chaudhury, M Bandyopadhyay, A Chakraborty, "1D-3v PIC-MCC Based Modeling and Simulation of Magnetized Low-Temperature Plasmas". Advances in Intelligent Systems and Computing, vol 1262. Springer, Singapore, 2021.
- 3) M Shah, B Chaudhury, M Bandyopadhyay, A Chakraborty, "The feasibility of resonance induced instabilities in the magnetic filter region of low temperature plasma based negative ion sources", American Institute of Physics (AIP) Proceeding, 2373, 080003 (2021).
- 4) M Shah, B Chaudhury, M Bandyopadhyay, A Chakraborty, "Observation of double layer formation in low-temperature ExB plasma based negative ion sources", Physics of Plasmas Letters (2022, under review).
- 5) Bhaskar Chaudhury et. al. , "Hybrid Parallelization of Particle in Cell Monte Carlo Collision ( PIC-MCC ) algorithm for simulation of Low temperature Plasmas", Software Challenges to Exascale Computing (SCEC 2018), Communications in Computer and Information Science, Springer, Singapore, vol. 964, page no - 32, 2018.
- 6) H Shah, S Kamaria, R Markandya, M Shah, B Chaudhury, "A novel implication of 2D3V PIC algorithm for Kepler GPU architectures", Proceedings of 24th IEEE International conference of high performance computing, data, and analytics (HIPC-2017), page no-378, 2017.

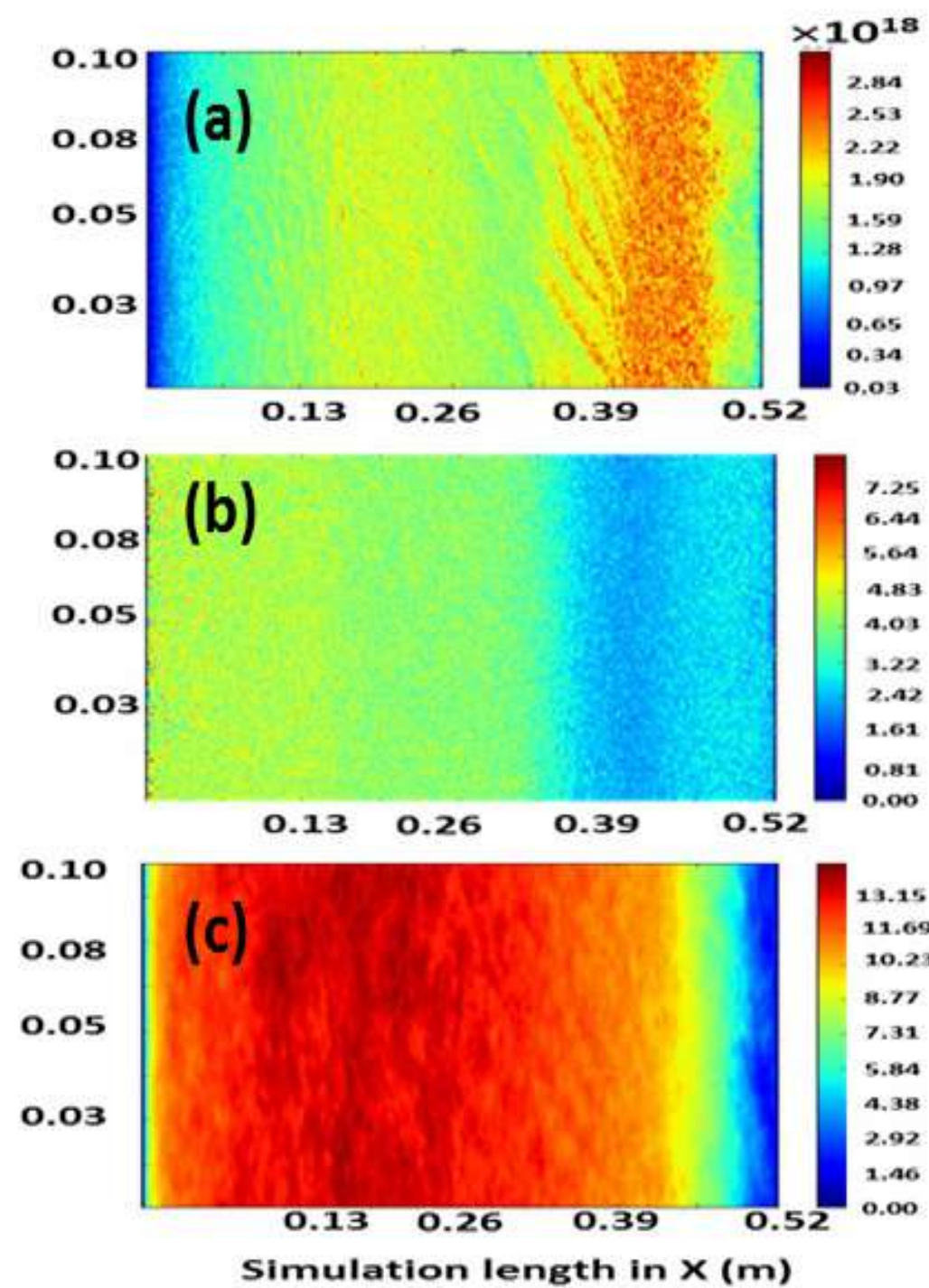


Schematic diagram of ROBIN

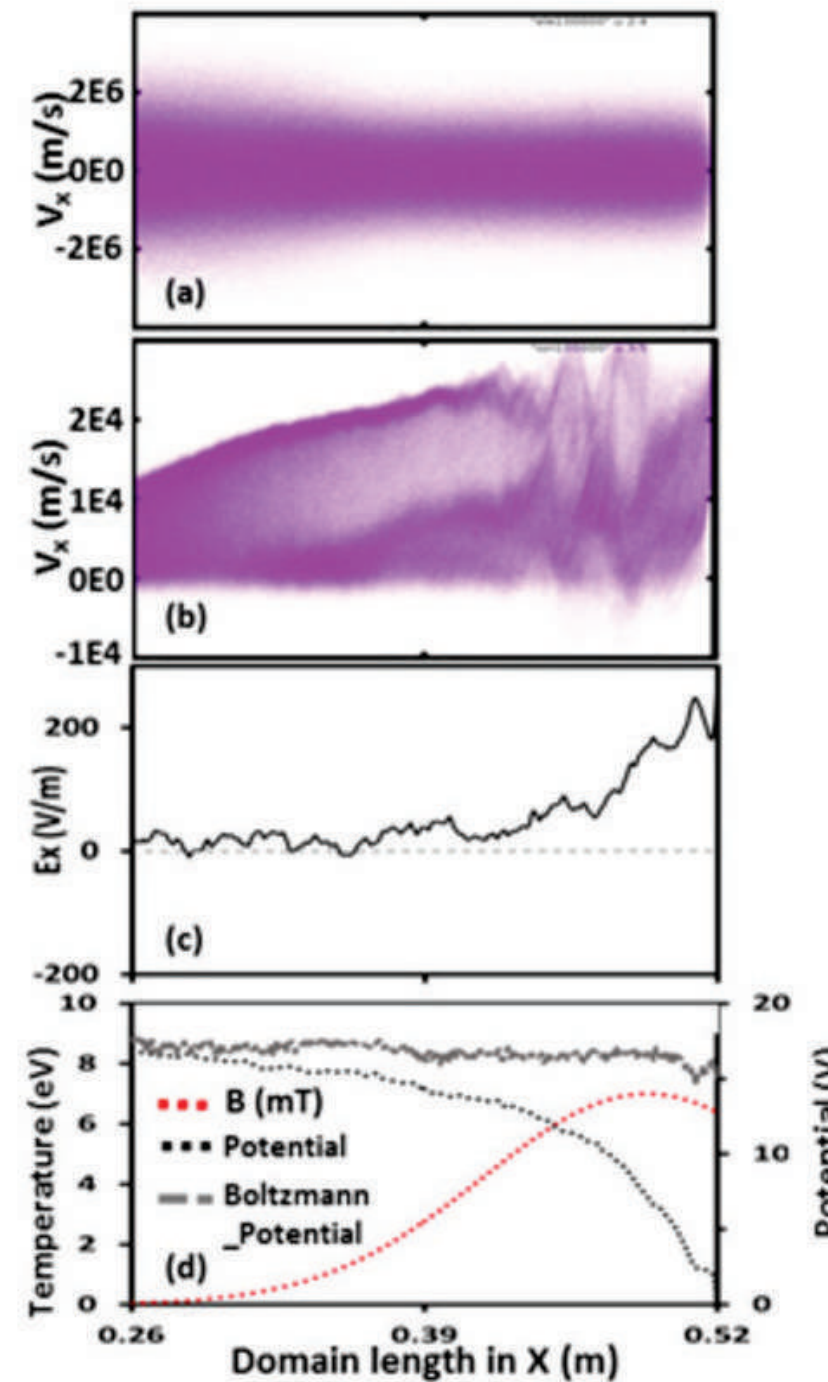




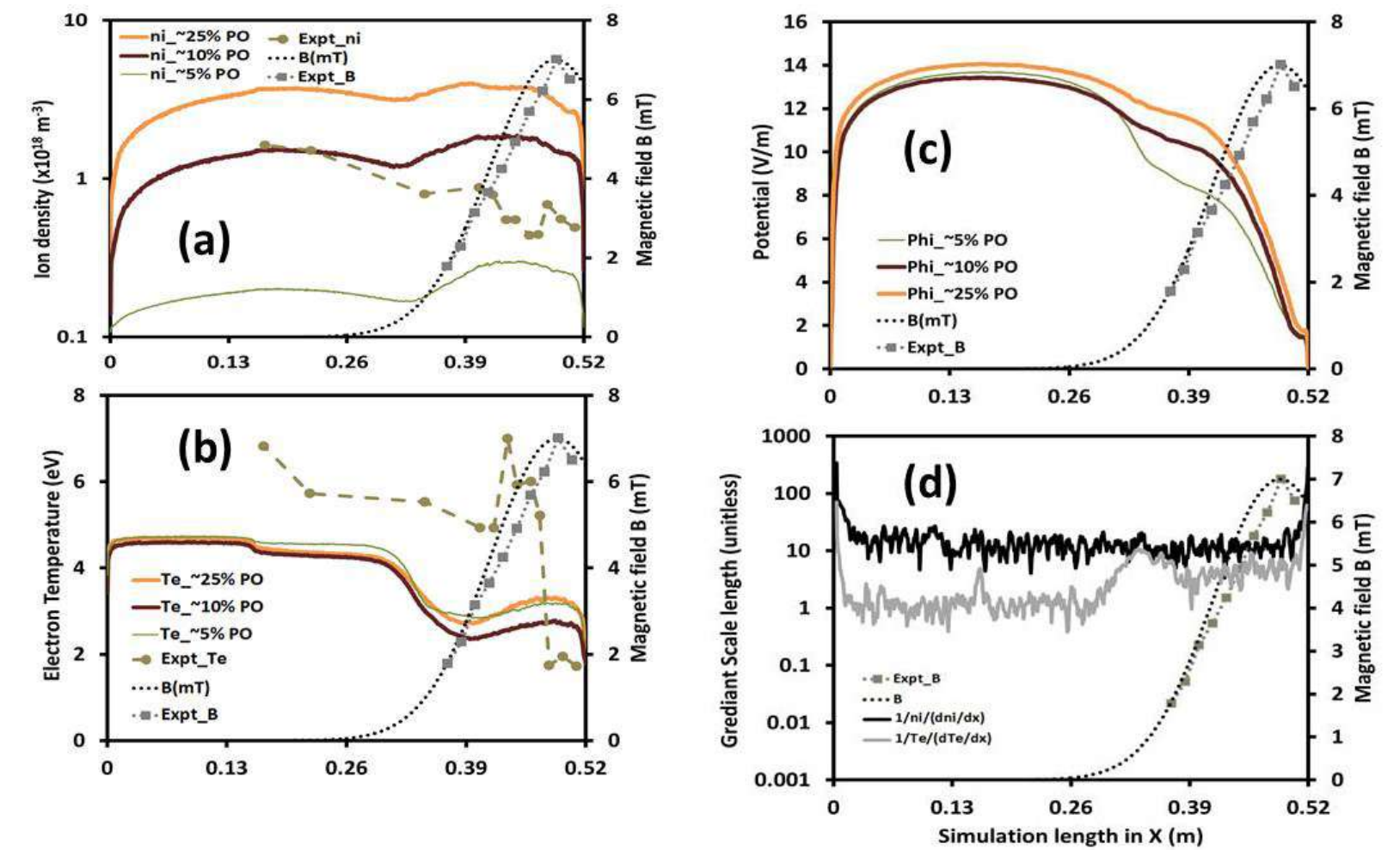
Simulation domain. Magnetic field is perpendicular to the simulation domain



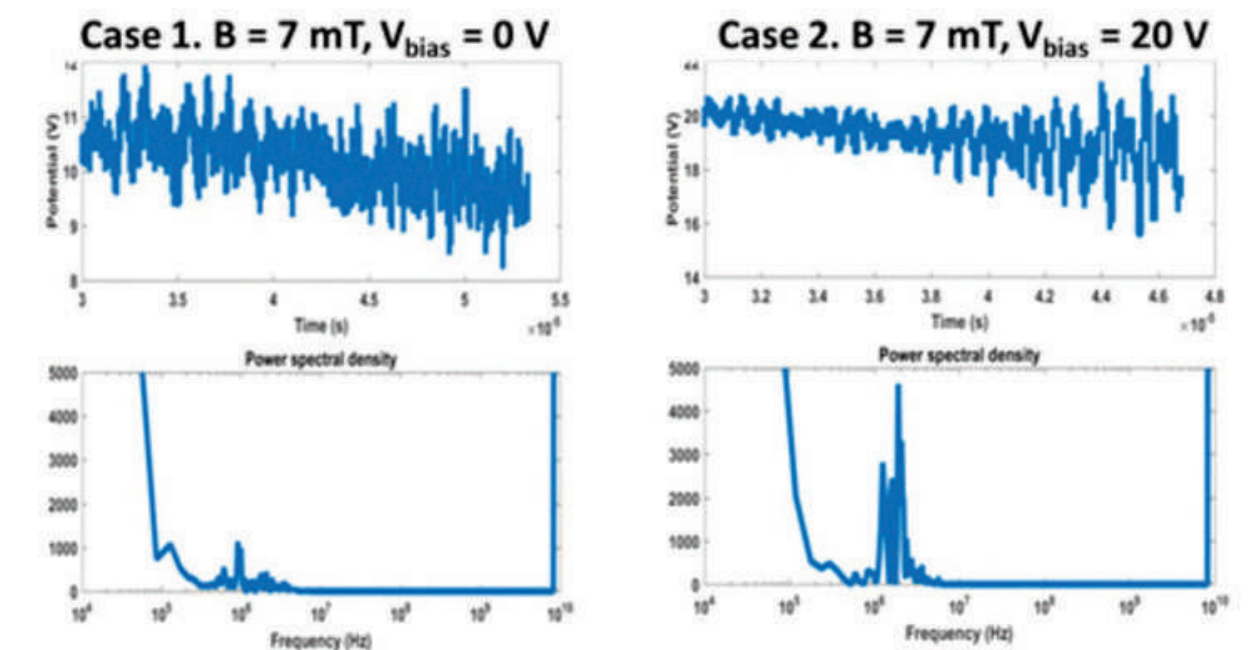
(a) Plasma density in  $m^{-3}$ ,  
 (b) electron temperature (eV), and  
 (c) potential (V/m) at  $50 \mu s$ . PIC-MCC simulations are done under the ROBIN experimental condition.



(a) Electron phase space,  
 (b) ion phase space,  
 (c) Electric field ( $E_x$ ) in (V/m), and  
 (d) ID profile of potential from simulation and derived from Boltzmann relation.



(a) Plasma density ( $m^{-3}$ ) (b) electron temperature (eV) (c) potential (V/m). These results are time ( $45-50 \mu s$ ) and space-averaged (11 points around the central Y-axis of the simulation domain) data for 7 mT magnetic field, olive green color dashed line with circle markers shows ROBIN experimental results. PO is total power given to the system (60 kW). Black and grey dotted lines shows the simulation and experimental magnetic field in mT (secondary Y-axis). (d) gradient scale length (GSL) of plasma density & electron temperature in the magnetic filter region for 10 % power given to the system.



Time series of Potential (at 0.4563 m in X-direction and 0.05 m in the Y-direction) and its FFT analysis is shown for two cases.



# Multiscale Modeling and Simulation of complex Plasma Dynamics during High Power Millimeter Wave Breakdown



PI: Bhaskar Chaudhary

Co-PI: Nil

Number of JRFs: One

Funding Agency: SERB, DST

Duration of the Project: 3 Years

Status of the Project: Completed

Number of MTech/PhD: One

Sanctioned Funding: 21,60,000 /-

Start Date: 27-03-2019

End Date: 31-05-2022

The Grant Number: CRG/2018/003511

## Research Problem Statement:

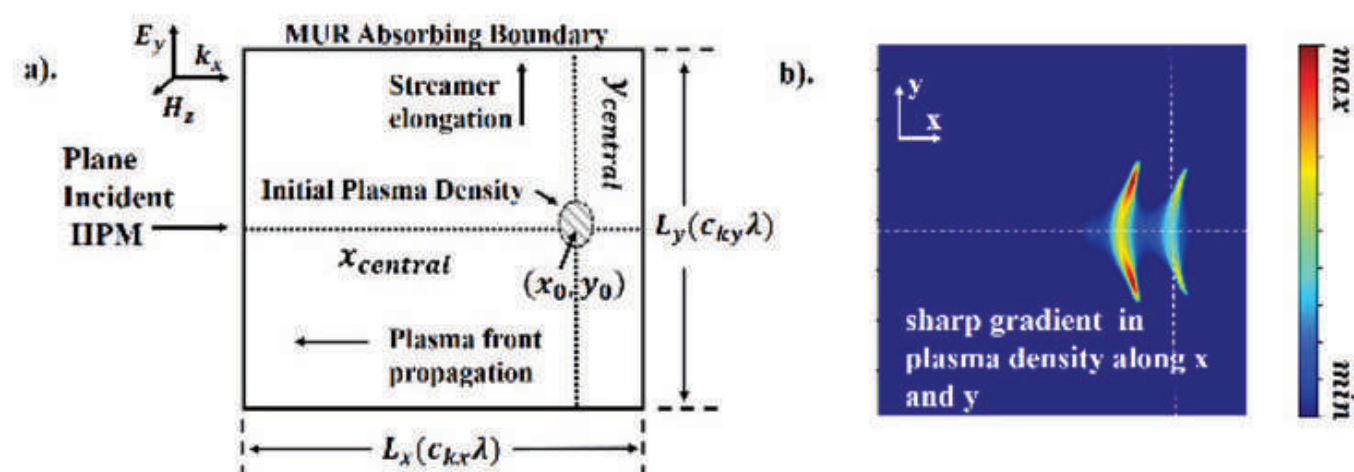
Modeling and simulation of the strong coupling between the high frequency EM waves and the plasma is still a challenging research problem due to the different time and space scales involved in the process. Particularly accurate 2D/3D simulations are computationally very expensive and we require new efficient computational models/ parallel algorithms to investigate this problem for real life applications. Most of the computational studies reported in the literature till now (particularly recent 2D simulations) have focused only on the wave scattering by the plasma and ionization-diffusion mechanism for plasma evolution (time scale of 100s of nanoseconds). However, these simulations have not taken into account the effect of gas heating and plasma evolution at longer timescales (microseconds). We propose to build a computational tool which can be used to study the complete phenomena of high frequency EM wave breakdown starting from wave-plasma interaction (nanoseconds) to the gas heating stage (microseconds). Adaptive Mesh Refinement (AMR) based FDTD formulation of Maxwell's equations coupled with an improved plasma fluid model and a real gas dynamics equation solver will be developed as a part of this proposal. Further, the algorithms will be parallelized to investigate the complete plasma dynamics during millimeter-wave breakdown at high pressures. Better understanding of the physics and the mechanisms leading to the complex structures using the proposed tool will be helpful in evaluating and establishing the potential applications.

## Objectives & Proposed Approach:

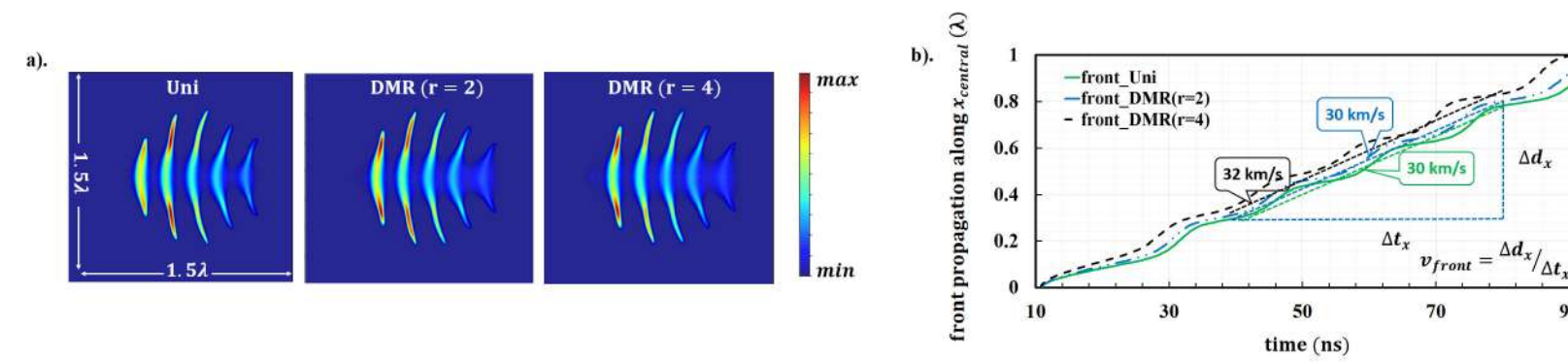
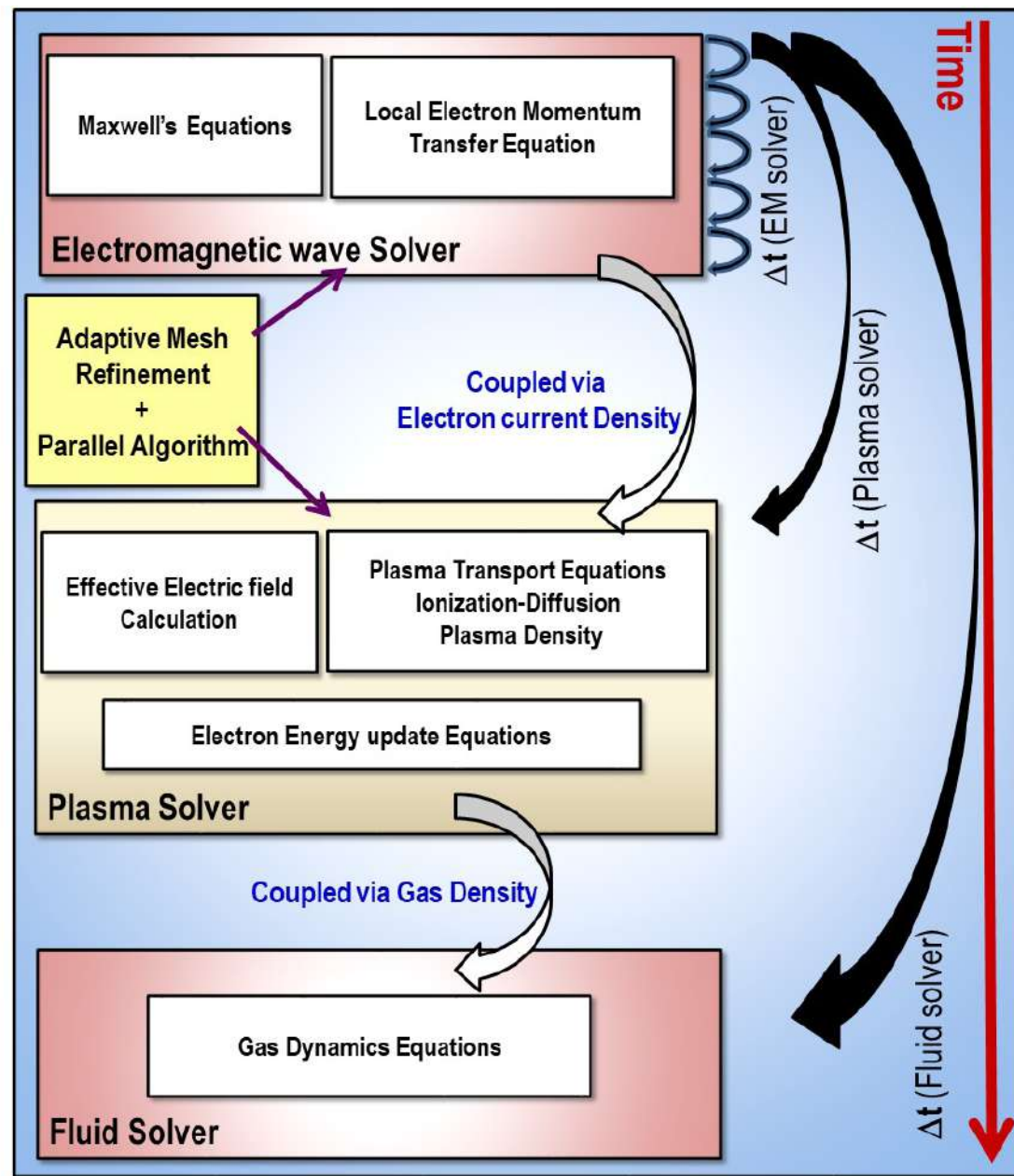
- 1) Development of a novel Modeling and Simulation tool which can be used to study the complete phenomena of high frequency high power EM wave breakdown starting from wave-plasma interaction (nanoseconds) to the gas heating stage.
- 2) Development of Adaptive Mesh Refinement based Electromagnetic wave & Plasma Solver for solution of Maxwell's equations coupled with a plasma fluid model.
- 3) Development of a plasma gas dynamics equation solver.
- 4) Parallelization of computationally expensive components of the solvers on shared and distributed memory architectures.
- 5) The computational tool developed as a part of the project can be used by experimentalists in other National Labs to further investigate the experimental observations. The tool can be also used to train post graduate students in the Institute who wish to pursue research in the area of Computational Electromagnetics, Computational Plasma Physics and specifically plasma-EM wave interaction.

## Research Publication:

- 1) M. Desai, P. Ghosh, A. Kumar and B. Chaudhury, "Deep-Learning Architecture-Based Approach for 2-D-Simulation of Microwave Plasma Interaction," in *IEEE Trans. Microw. Theory Tech.*, vol. 70, no. 12, pp. 5359-5368, Dec. 2022, doi: 10.1109/TMTT.2022.3217138.
- 2) P. Ghosh and B. Chaudhury, "Efficient Dynamic Mesh Refinement Technique for Simulation of HPM Breakdown-Induced Plasma Pattern Formation," in *IEEE Trans. Plasma Science*, Dec 2022, doi: 10.1109/TPS.2022.3226251
- 3) P. Ghosh and B. Chaudhury, "Computational Investigation of Effect of Microwave induced Local Gas Heating in HPM Switching and Protection"; *IEEE MAPCON 2022*, Bangalore, India
- 4) P. Ghosh and B. Chaudhury, "Computational Investigation of Microwave Breakdown in HPM Switching & Protection", *IEEE IMARC 2021*, IIT Kanpur, India
- 5) P. Ghosh and B. Chaudhury, "Mesh Refinement based simulation of complex plasma dynamics during high power millimeter wave breakdown", *IEEE NEMO 2020*, Hangzhou, China

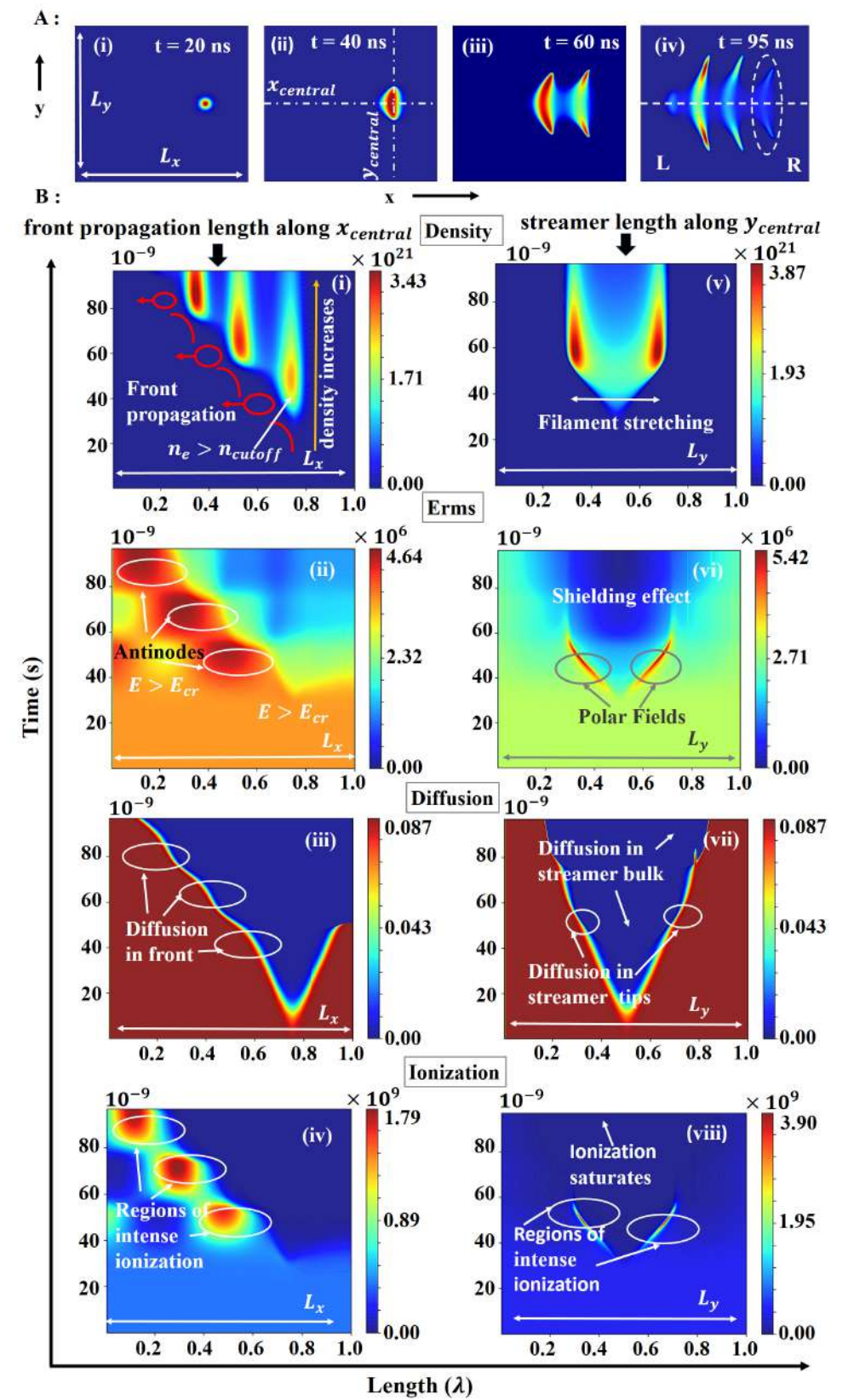


(a) Schematic of the Computational domain. (b) Formation of self-organized plasma filaments during HPM breakdown (snapshot at  $t = 45$  ns,  $E_0 = 5.5$  MV/m,  $\text{freq} = 110$  GHz). The maximum density (max) is  $6 \times 10^{21}$  m<sup>-3</sup> and (min) is 0.

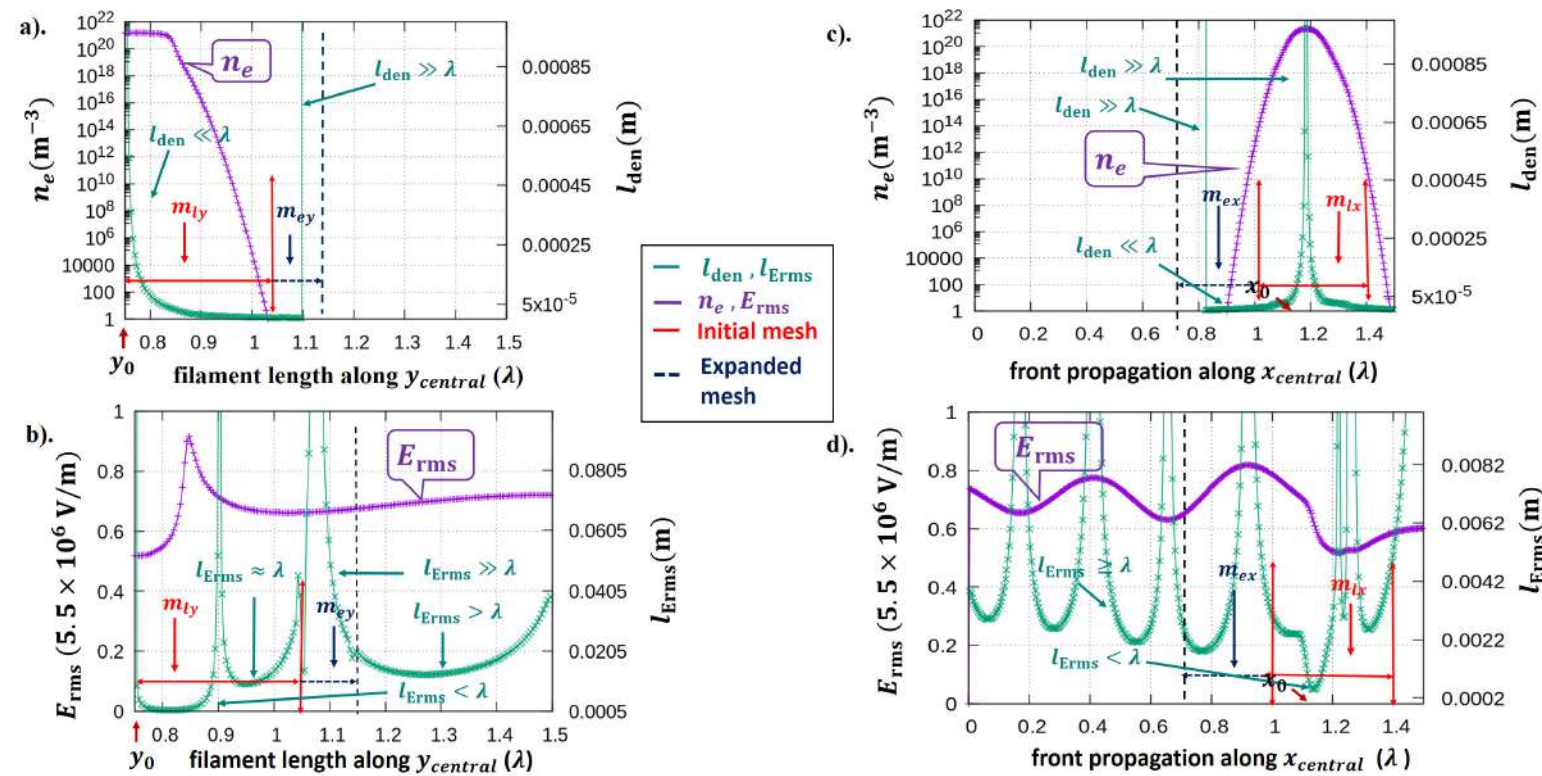


(a) 2D distribution of plasma density profile ( $m^{-3}$ ) in plasma filaments at  $t = 90$  ns using DMR with different refinement factors. (b) Comparison between plasma front propagation along the central  $x$ -axis ( $x_{central}$ ) of simulation domain for uniform mesh (Uni) and dynamic mesh (DMR).

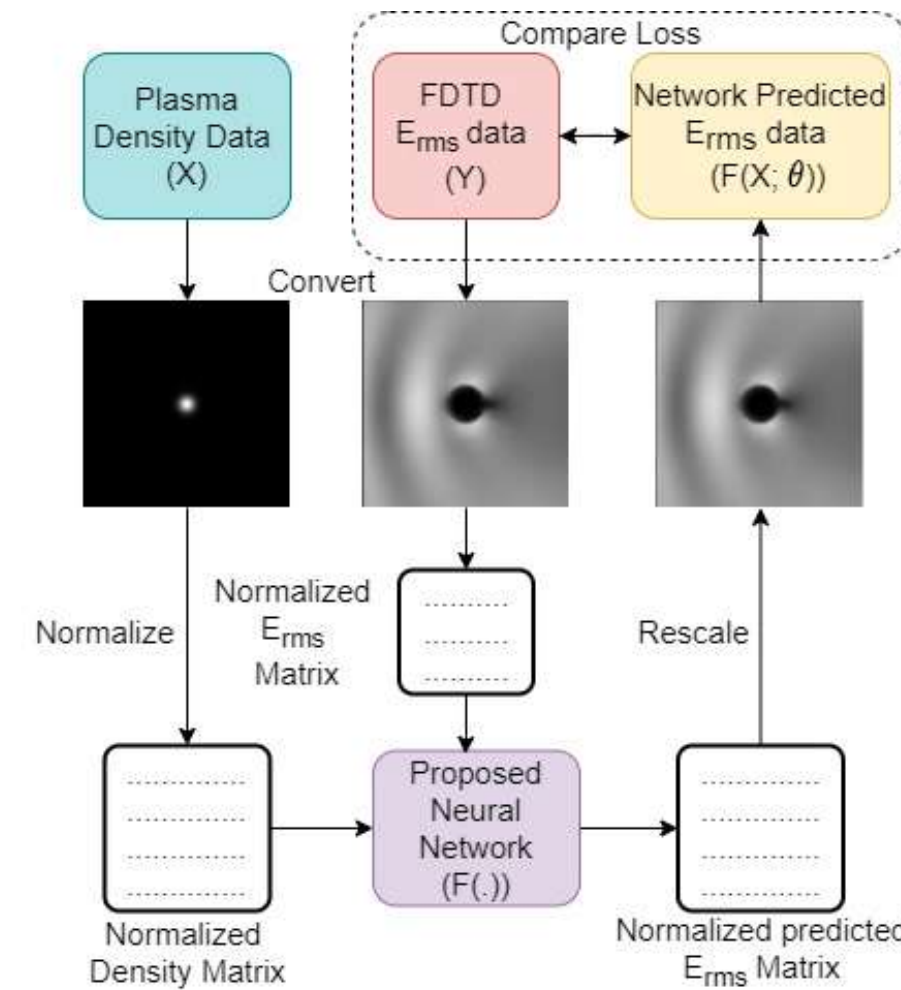
Components and Flow Diagram of the proposed computational tool: Electromagnetic wave Solver, Plasma Solver and the Fluid Solver. The Multi-scale nature (both space and in time), specifically the time scales of each phenomenon is shown here from that ranges from nano to micro seconds.



Part A: (i-iv) plasma density ( $m^{-3}$ ) distribution in the filaments at four time instances. Part B: (i-iv) plasma density ( $m^{-3}$ ) evolution, RMS E-field (V/m), the effective Diffusion coefficient ( $m^2/s$ ) and the rate of ionization ( $s^{-1}$ ) along the  $x_{central}$ . Part B: (v-viii) the evolution of the same quantities along the  $y_{central}$  passing through the centre of the rightmost filament (in dotted circle). Here, L: Left and R: Right,  $L_x = L_y = 1 \mu m$ .



Plasma Topology based Dynamic Mesh Refinement (DMR) - (a,b) : 1D distribution of plasma density and rms E-field along with their corresponding gradient scale length along upper half of central  $y$ -axis ( $y_{central}$ ) and similarly (c,d) along the central  $x$ -axis, through the initial plasma density.  $m_{ly}$  and  $m_{lx}$ , and  $m_{ey}$  and  $m_{ex}$ , are length of the initial refinement region and the mesh expansion along  $x$  and  $y$ , respectively.



Flowchart for deep learning based architecture (CNN-based UNet architecture) to reconstruct the scattered RMS Microwave E-field from the plasma density data.



# Computational investigations of instability driven transport in low temperature magnetized plasma discharges using massively parallel 2D-3v PIC-MCC simulations



Department of Sciences & Technology  
Government of India

PI: Bhaskar Chaudhary

Co-PI: Kalyan Sashidhar

Number of JRFs: Two

Funding Agency: NSM, DST

Duration of the Project: 2 Years

Status of the Project: Ongoing

Number of MTech/PhD: Nil

Sanctioned Funding: 26,95,000 /-

Start Date: 26-06-2021

End Date: 30-06-2023

The Grant Number: DST/NSM/R&D HPC Applications/2021/03:37

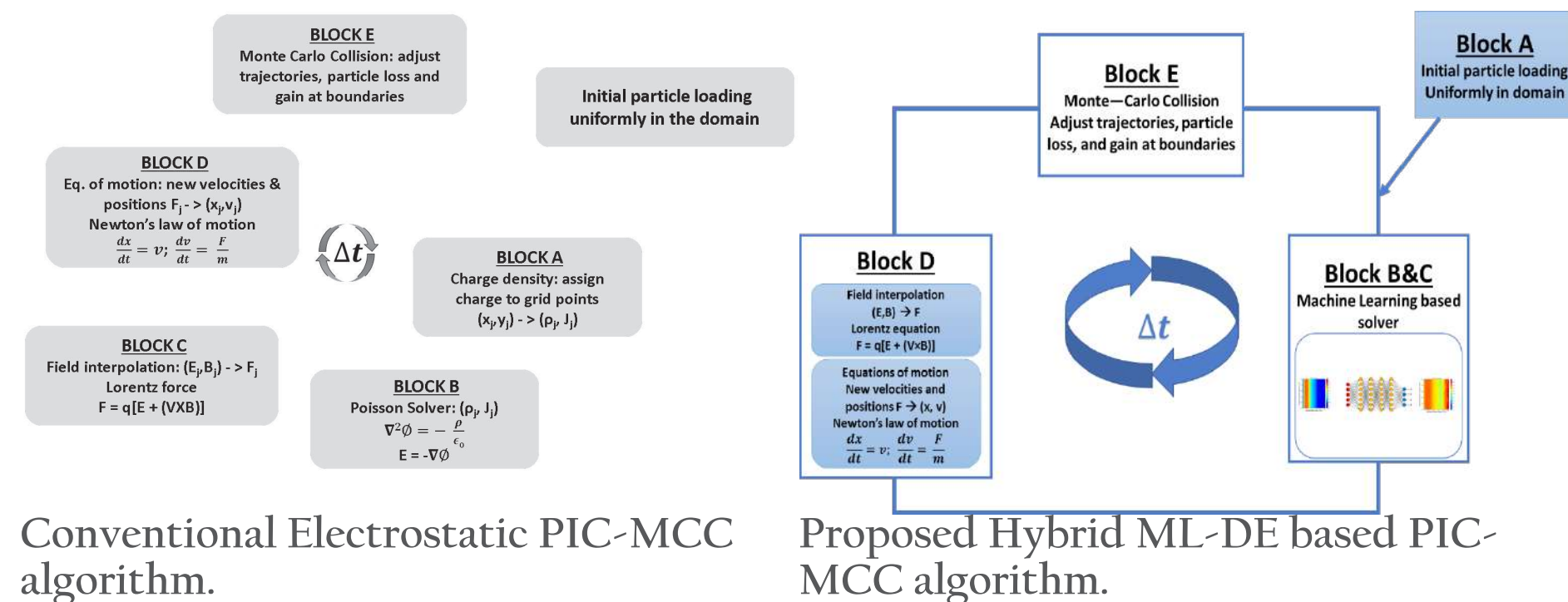
## Research Problem Statement:

The project aims to investigate the origin and role of instabilities in the plasma transport in low temperature plasma discharges (having external transverse magnetic field and self-consistent electric field) under the influence of different drifts using massively parallel computationally intensive 2D-3V PIC-MCC (Particle-In-Cell Monte-Carlo-Collisions) simulations. The presence of an external magnetic field can activate several instabilities in such partially magnetized plasmas. Applications of such plasmas include negative

ion sources, plasma sources for space propulsion and material processing. The project will consider a fusion grade negative ion source configuration having strong variable transverse magnetic filter fields to study the plasma transport. However, the work methodology can also be applicable to any low temperature magnetized or partially magnetized plasma devices and will be attempted in future.

## Objectives & Proposed Approach:

PIC-MCC (Particle in Cell Monte Carlo Collision) method is a computationally expensive technique to investigate low temperature magnetized plasma discharges, and provides temporal and spatial evolution of the charged-particle velocity distribution functions under the effect of self-consistent electromagnetic fields and collisions. This is achieved by following the trajectories of a representative number of charged particles in the phase space on a mesh free Lagrangian grid and taking into account the collective interaction of the particles by solving Poisson's equation using a fixed point Euler grid. The simulation domain is divided in spatial grids with grid size small enough to resolve the variation in plasma parameters. The random sampling based Monte-Carlo Collisions (MCC) method is used to calculate the charged particle collisions with neutral atoms in the PIC-MCC algorithm. Computational cost of the PIC code is determined by the dimensions of the phase-space, grid size, number of computational particles, time-step and total number of iterations required for the simulation.

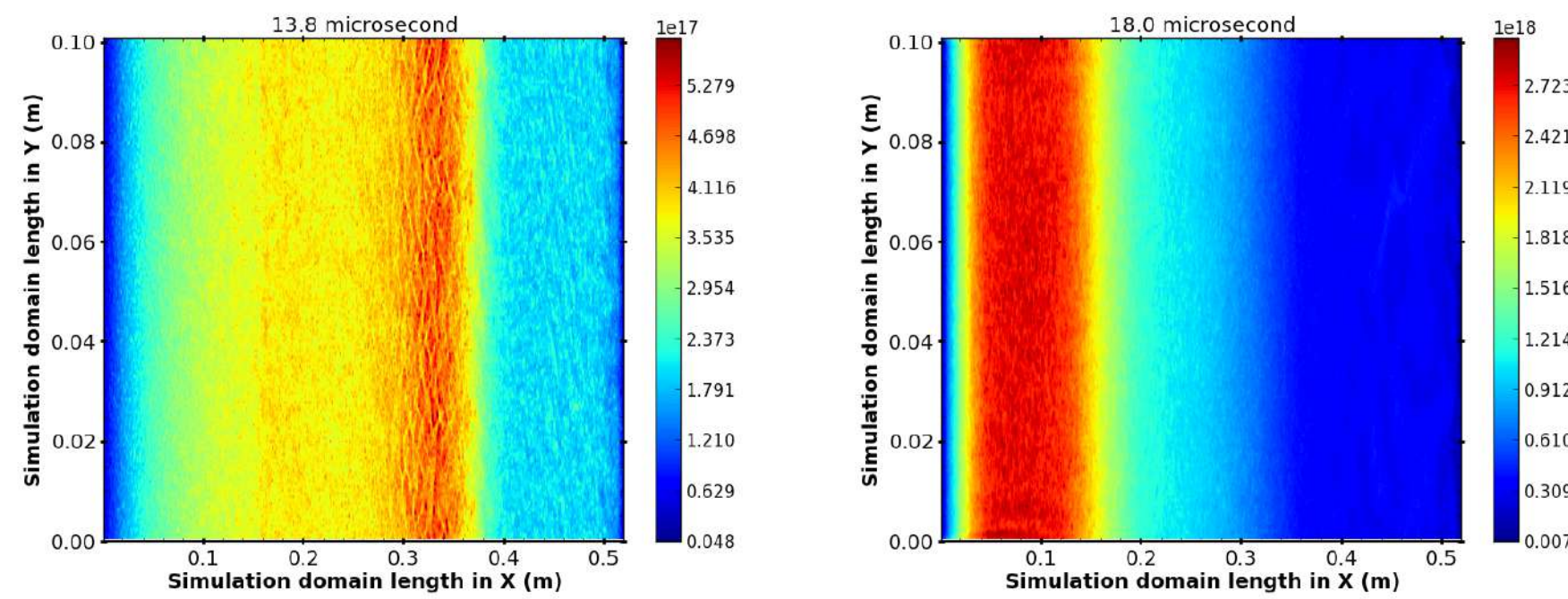


## Objectives & Proposed Approach:

1. Development of 2D-3V hybrid PIC-MCC (Particle In Cell-Monte Carlo Collision) code (shared + distributed).
2. Benchmark and verify our parallel 2D-3V PIC codes with recently published results on Particle-In-Cell benchmark for low-temperature partially magnetized plasmas on supercomputing facilities.
3. Optimization and cache access performance improvement of the code using sorting algorithms.
4. Improve the understanding of plasma transport across magnetic fields in the form of traverse magnetic filters for electrons, and investigate the origin and role of instabilities

in low temperature magnetized or partially magnetized plasma discharges (as used in negative ion source modeling).

5. Investigate the influence of numerical parameters such as grid spacing, time step and number of particles per cell on the simulation results and address the issue of mesh convergence.
6. Extract information about the instabilities and dominant modes; characterize these modes (wave wavelength and frequency) as well as its possible physical interpretation. Explore the phenomena of mode coupling of different instabilities and its role on plasma transport

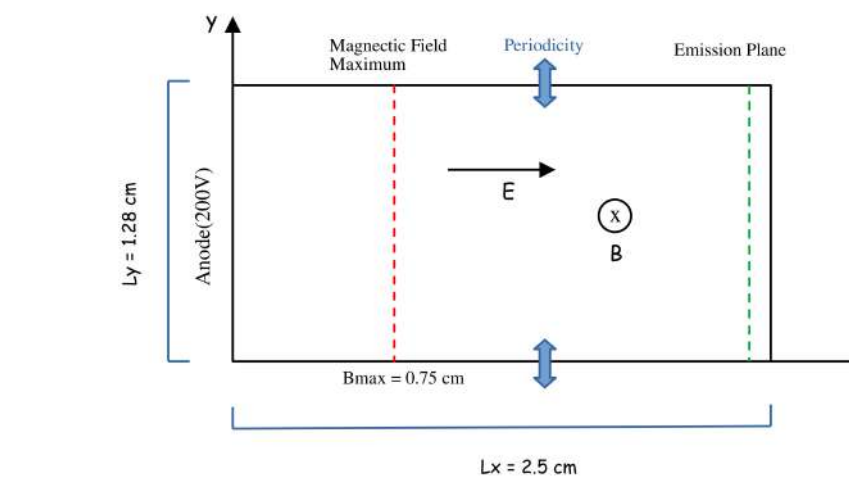


H<sub>2</sub>-Plasma Transport in Negative Ion Source.

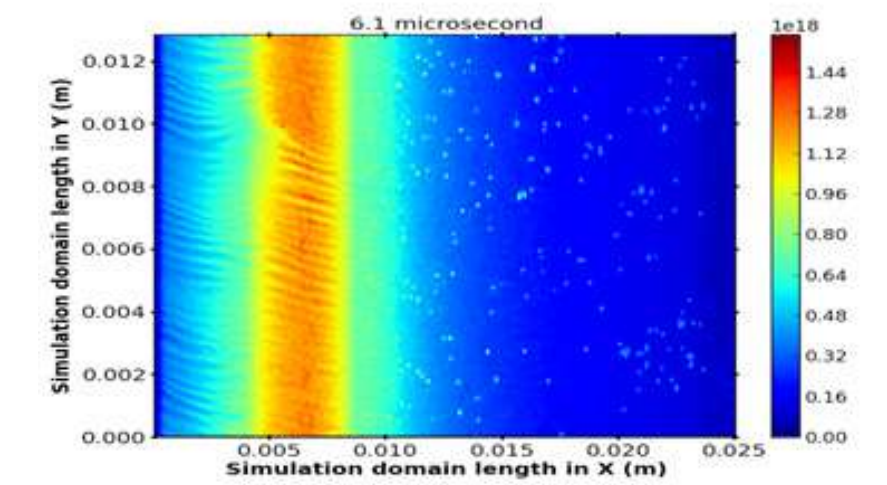
Xe-Plasma Transport Across Magnetic Field

Research Publication:

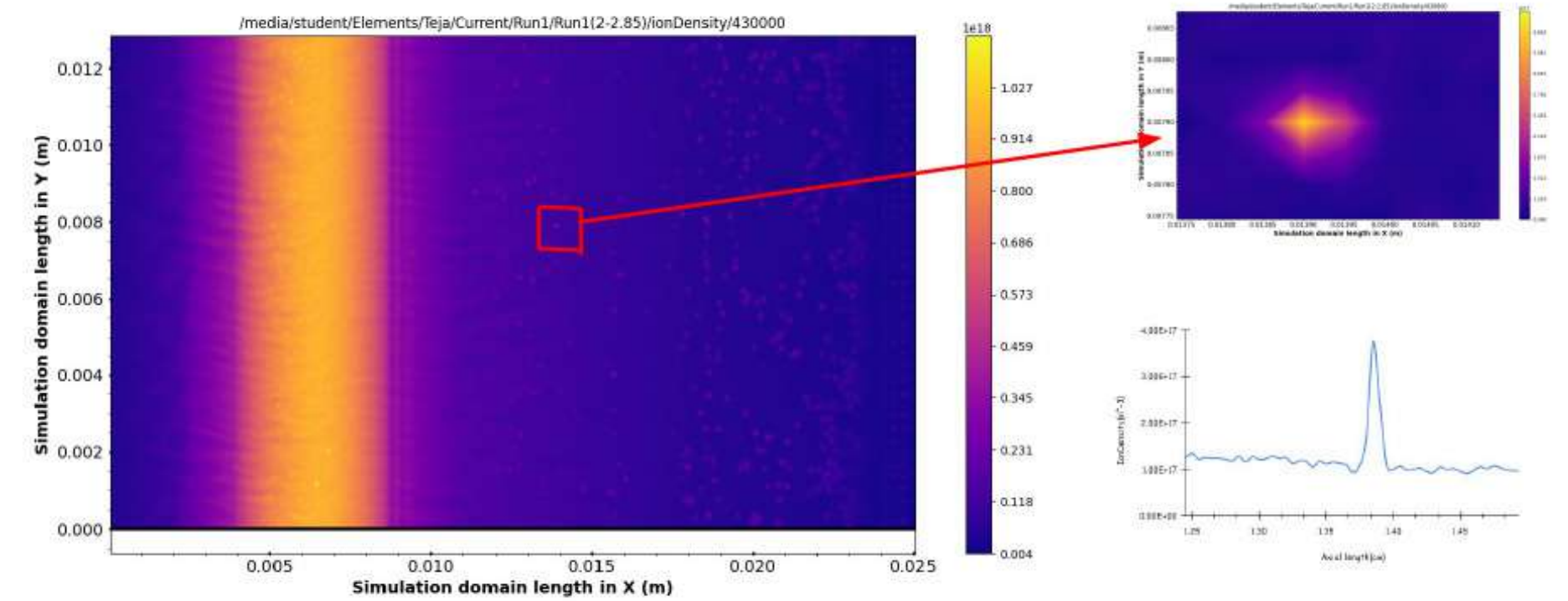
1. B. Chaudhury et. Al.; "Observation of Instability driven propagating localized patterns in E\*B discharges in 2D-axial azimuthal PIC-MCC simulations", Bulletin of the American Physical Society, 75th GEC-2022.
2. B. Chaudhury et. Al.; "Investigating the influence of ion mass on plasma characteristics in low temperature ExB plasmas using 2D-3V PIC-MCC simulations", Bulletin of the American Physical Society, 75th GEC-2022.



2D Geometry of the Computational Domain from International Low temperature Benchmark Plasma Simulation



localized high-density patterns, near the edge of the given ionization profile, is believed to be induced by instabilities.



Data Analysis of localized high-density patterns, near the edge of the given ionization profile, is believed to be induced by instabilities.

Group Members (2022)

From Left:

Ashok Jayaram, Libin Varghese, Pratik Ghosh, Miral Shah, Prof. Bhaskar Chaudhury (PI), Ayushi Sharma, Shubham Gandha



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