# ELECTRICAL ENGINEERING RELOADED

for

Life, Data and Sustainability

The Journey continues in a pandemic year .....

Abubakr Muhammad & the EE Faculty

January, 2021

# University Education in the 21st century

What would it mean to be human in the age of artificial intelligence, synthetic biology and the Anthropocene?

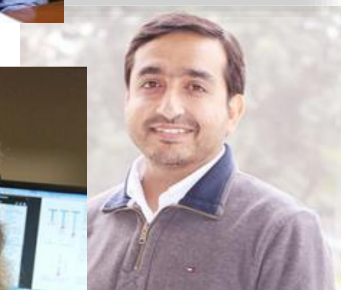
Human experience in 21st Century $\overset{?}{=}$ Life + Data + Sustainability












Communication Systems

Computer Networks

DSP and Image Processing

Electronics & Embedded Systems

Control Systems & Robotics

Energy and Power Systems

Devices and Materials

Optics & Electromagnetics

# REIMAGINING EE

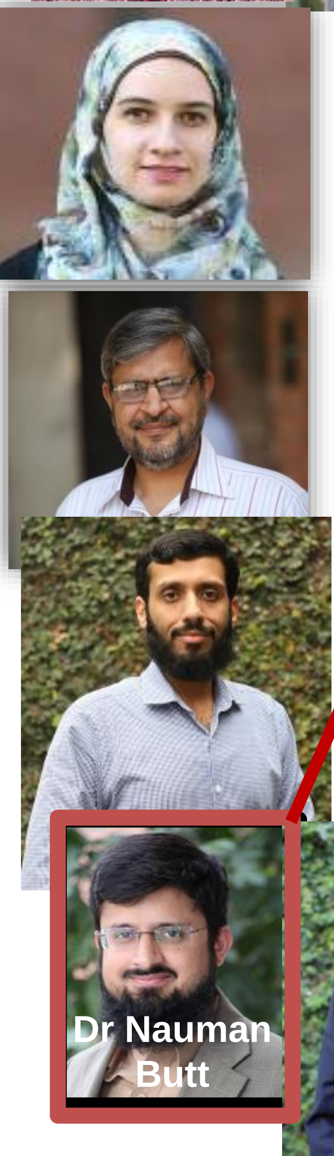










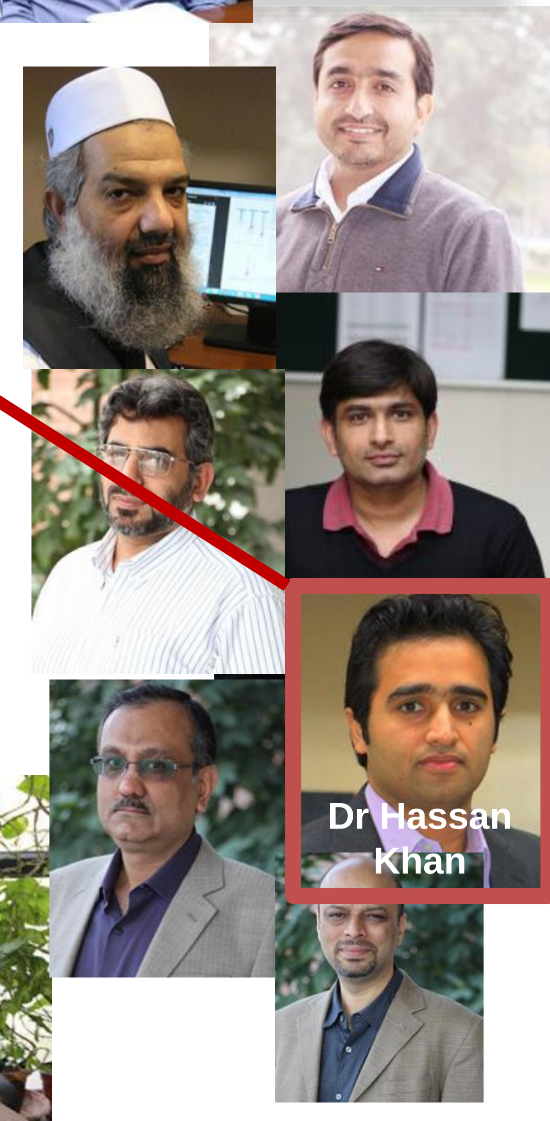





# TENURED

Three tenure applications under review.
> 50% will be tenured by end of 2021.

2 Professors
11 Associate Professors
9 Assistant Professors



(Data) AI Hardware and Theoretical Foundations

(Life) Biomedical Devices and Point-of-Care Healthcare

(Sustainability) Systems View of the Water-Energy-Food Nexus

# Portable lab kits for online-leaning


**EE 324**

**MICROCONTROLLERS & INTERFACING**

**Dr. Jahangir Ikram**

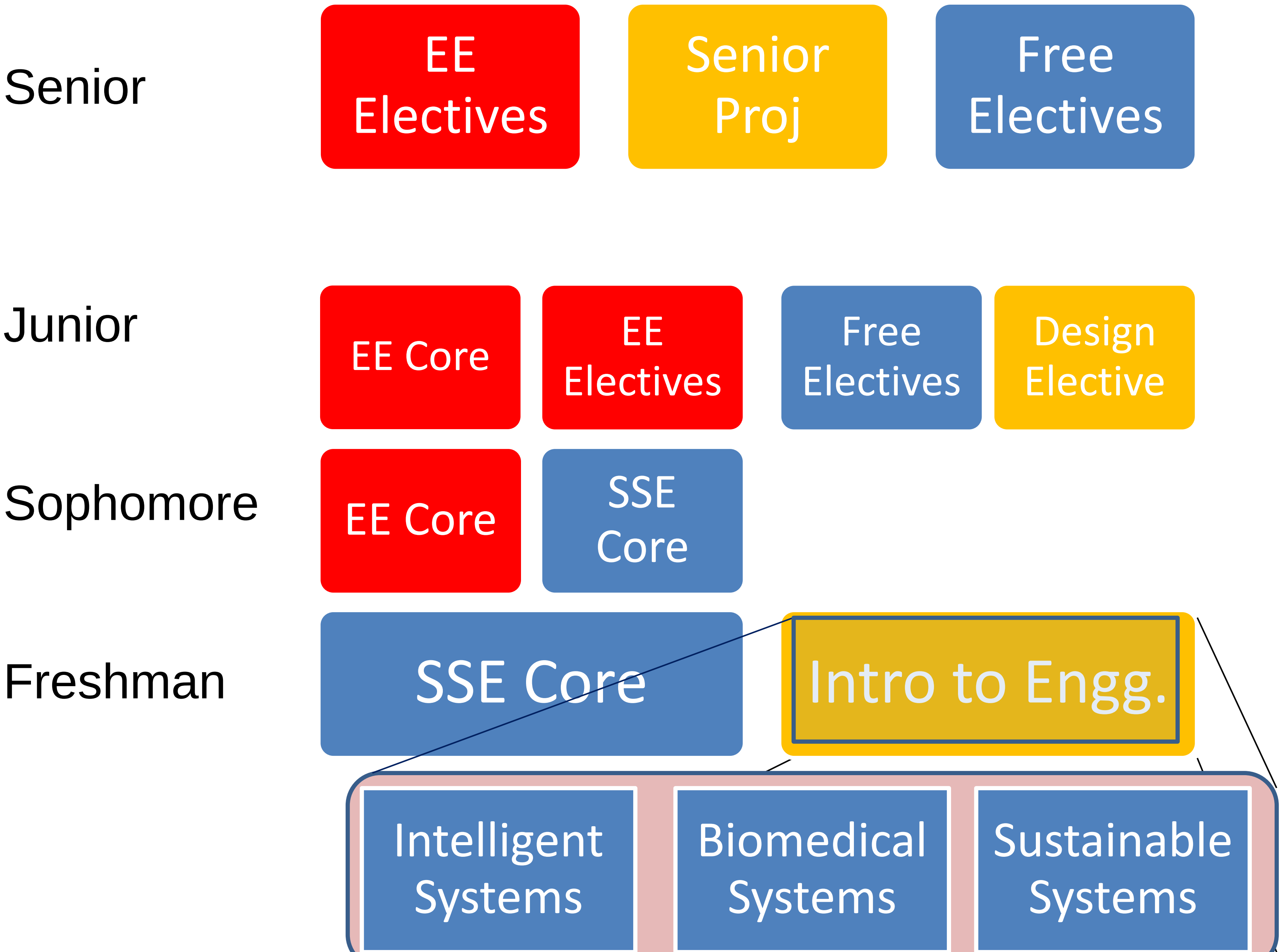
Each kit contains micro controllers, LED matrix, programmable chips, digital-to-analog converters, an oscilloscope, power distribution core, a complete tool set, a multimeter, speed controllers and motors.

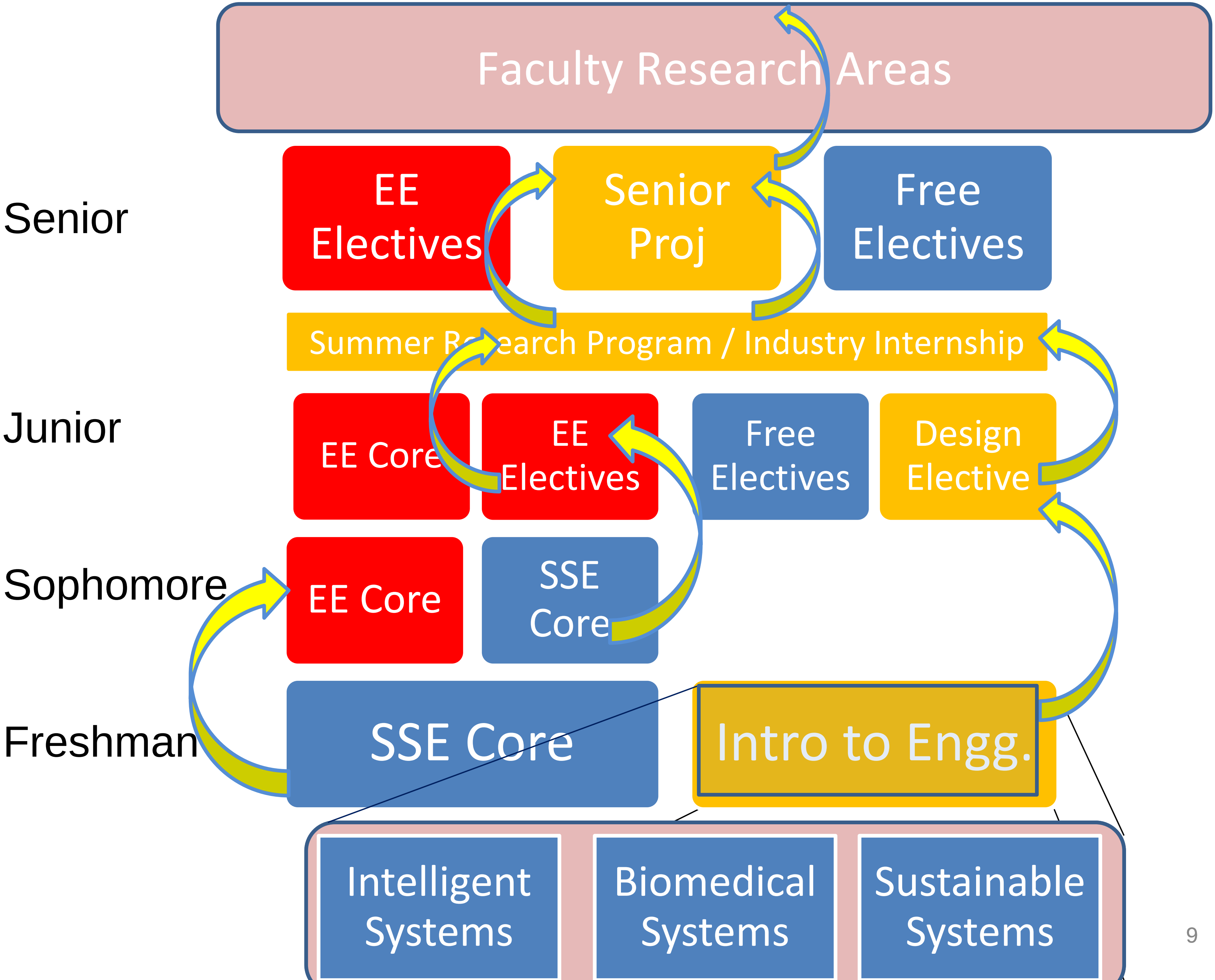
Dr Jahangir Ikram's team developed & shipped **50+ lab kits** indigenously for EE-324.

Heroic effort by ALL EE faculty throughout 2020.
Minimal damage to teaching & research programs.

# Portable lab kits for online-leaning

# EE100. The Revolution Begins!





Faculty Research Areas
Senior
EE Electives
Senior Proj
Free Electives
Summer Research Program / Industry Internship
Junior
EE Core
EE Electives
Free Electives
Design Elective
Sophomore
EE Core
SSE Core
Freshman
SSE Core
Intro to Engg.
Intelligent Systems
Biomedical Systems
Sustainable Systems

# EE-100 Fall 2020: Instructors & TAs

**Dr. Momin Uppal**

**Dr. Abubakr Muhammad**

**Dr. Muhammad Tahir**

**Dr. Awais Bin Altaf**

**Dr. Hassan Jaleel**

**Dr. Nauman Butt**

**Dr. Hassan Mohy Ud Din**

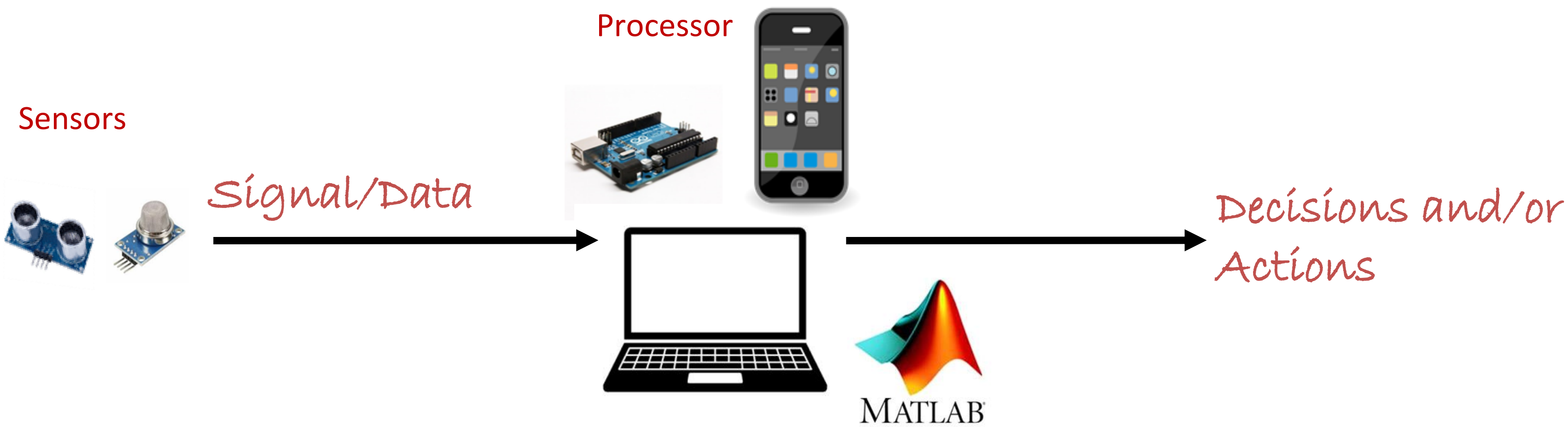
**Eesha Atif**
**EE Senior**

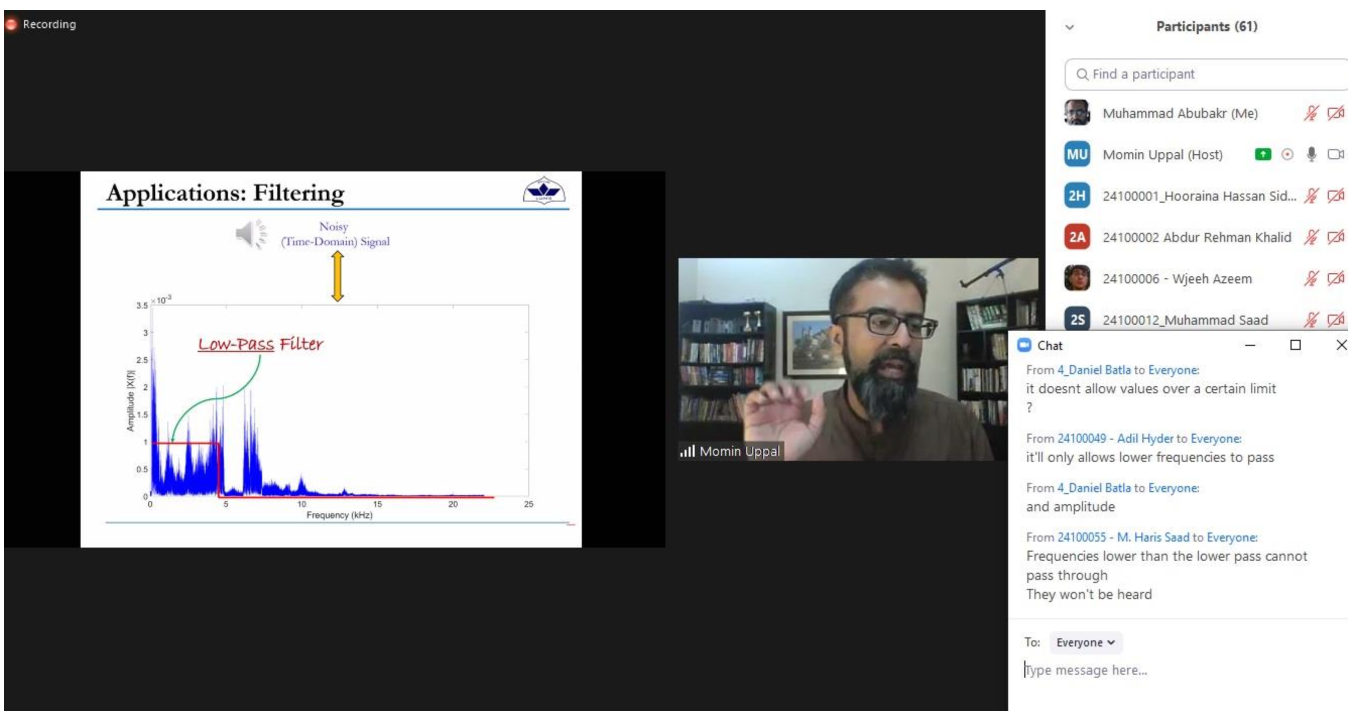
**Hamza Ather**
**2020 graduate**

**Nouman Arshad**
**Senior Lab Engineer**

**Syed Hasan Amin Mahmoo**
**2020 graduate**

# Content Overview



# Student participation


One student group beat a classification accuracy target set by faculty and TAs in their final course project.

# Outcomes & Way Forward

- Lab Tasks: Trickle-down of departmental research into freshman teaching
  - Radio Frequency sensing
  - Biomedical signal acquisition
  - Lab-on-a-chip and cell counting
  - Acoustic event detection and localization
  - Intelligent decision-making in agriculture and irrigation
- Spring 2021: Two flavors being offered for EE-100 (1-CH)
  1. Intelligent systems (Full flavor)
  2. Sustainable systems (Full flavor)

  - Biomedical system (invited lectures)

# Transdisciplinary Pedagogical Partnerships


**EE 5612 / SCI 302 (WIT Center)**

**SOCIO-ECOLOGICAL SYSTEMS & SUSTAINABILITY**

**Dr. Talha Manzoor**

**EE 557 (Energy Institute)**

**ELECTRICITY MARKETS**

**Dr. Hassan A. Khan, Dr. Fiaz Chaudhry**

**EE 212 (Continuing Education Studies)**

**MATHEMATICAL FOUNDATIONS FOR MACHINE LEARNING & DATA SCIENCE**

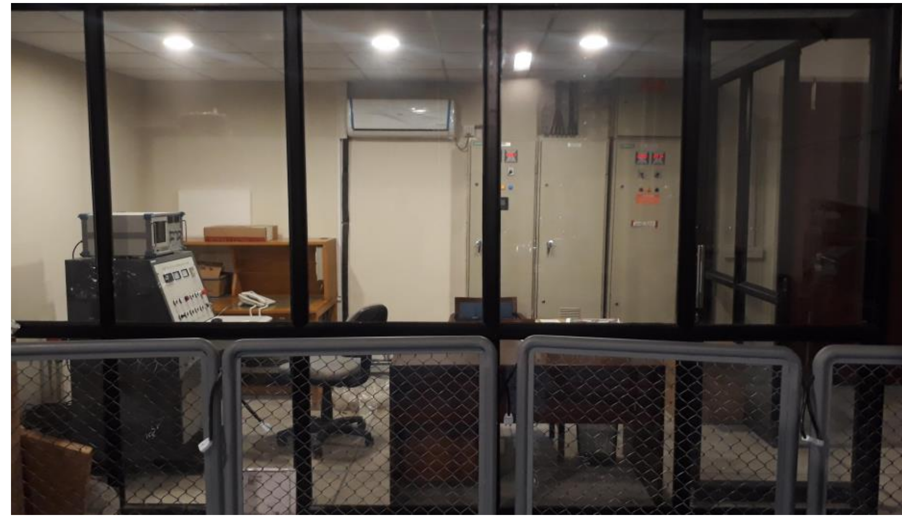
**Dr. Zubair Khalid**

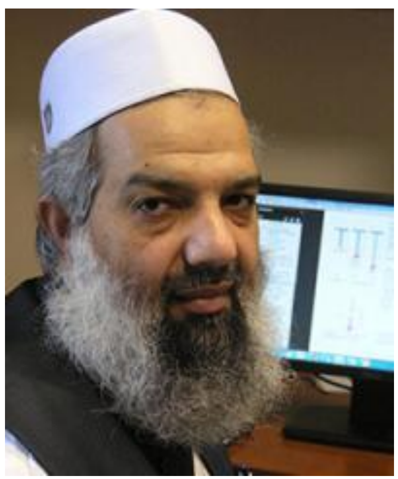
**EE 5213 / CS 623 (CS Dept .)**

**HARDWARE ARCHITECTURES FOR AI**

**Dr. Rehan Hameed**

# High Voltage Laboratory Commissioned!

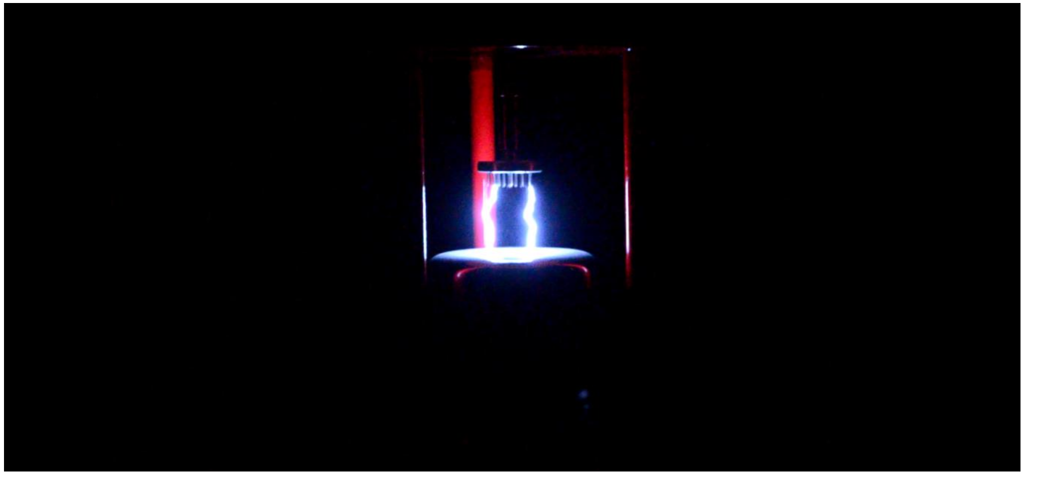


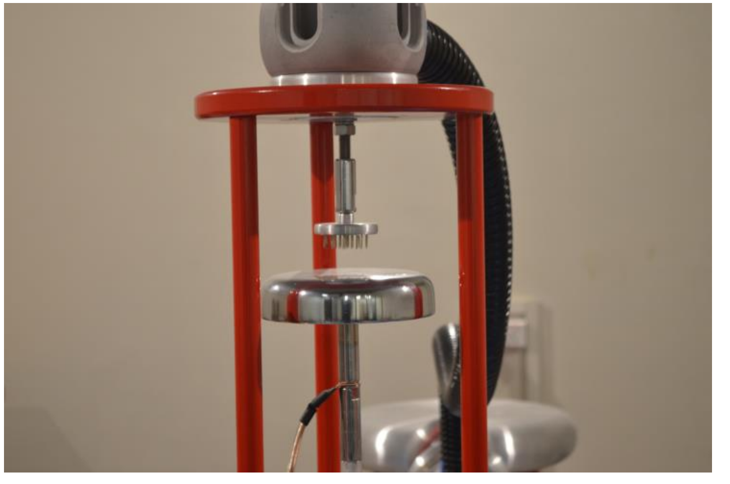


Conceived and designed by:

Dr Iqbal Qureshi and Dr Tariq Jadoon

# High Voltage Laboratory Commissioned!



EE 553

**HIGH VOLTAGE ENGINEERING**

**Dr. Iqbal Qureshi**

# Industry Partnerships

Prof. Nauman Zaffar    Dr Wasif Khan    Dr Awais bin Altaf    Dr Adeel Pasha

EE External Relations Committee

# Industry Partnerships

Prof. Nauman Zaffar

Dr Wasif Khan

Dr Awais bin Altaf

Dr Adeel Pasha

EE External Relations Committee

- Negotiation with multiple organizations for tailored fully funded MS Programs
  - Digital IC Design
  - Intelligent systems
  - Space applications
- One organization has agreed to fund 10x MS students.
- Similar negotiations underway with two others.

# Industry Partnerships

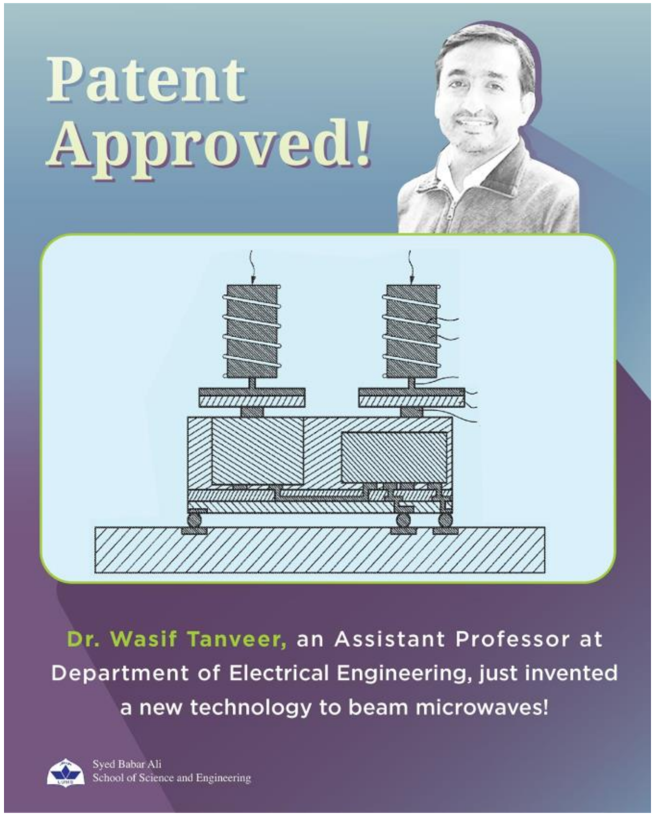



Prof. Nauman Zaffar   Dr Wasif Khan   Dr Awais bin Altaf   Dr Adeel Pasha

EE External Relations Committee

- An Electronics Hardware Accelerator / Technology Fund
  - Enabling productization and commercialization of basic research prototypes
  - Provide an income source to propel basic research
- ABL has agreed to support the initiative with PKR. 3M for first year.
- Many others have shown interest.

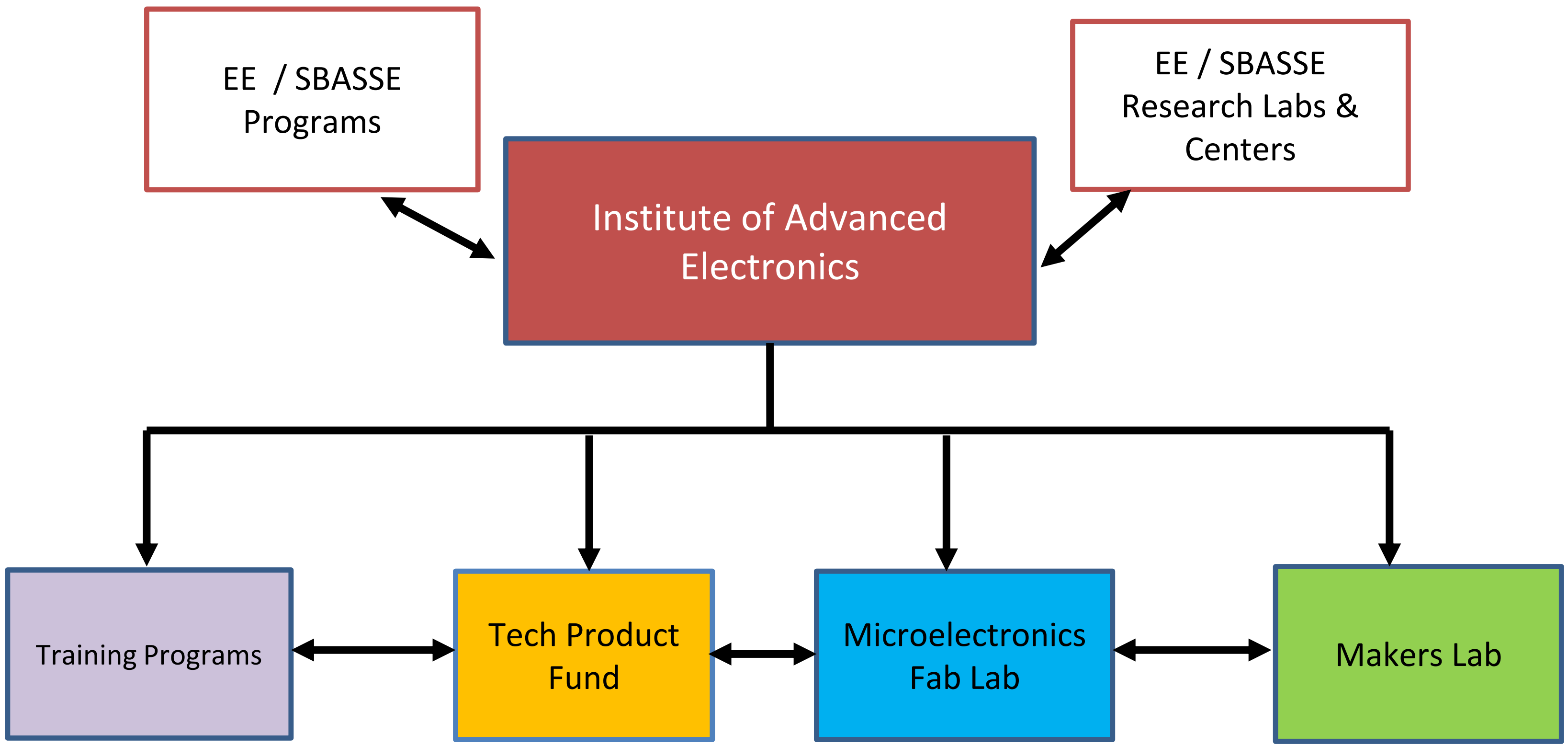
# Industry Partnerships


Dr Wasif Khan (lead) and several others from EE and CS Departments.

# Industry Partnerships

- Where are we going with this?
  - A future **Institute of Advanced Electronics**



# Student achievements

- Students got placed at **MIT two years in a row**
- **>25%** secured **funded PhD** positions @ top schools
- >80% acceptance rate @ top schools for batch 2020
- **1st Female PhD graduate** got **post-doc @ Stanford**
- No major COVID-impact on employment numbers
  - BS 92% placed after 6 months
  - MS 91% placed after 6 months

feature

# Battery-Free Subsea Internet of Things

**How a scalable underwater sensor network, which is entirely battery-free, has the potential to monitor the world's oceans.**

*By Sayed Saad Afzal*

DOI: 10.1145/3436203

Recently, there has been significant interest in low-power, low-cost scalable underwater networking systems for environmental, defense, and industrial applications. Driven by the need to address the impact of climate change, climatologists and oceanographers are interested in monitoring vital ocean signs such as coral reef conditions, biodiversity, and carbon balance. Similarly, the Defence Advanced Research Projects Agency (DARPA) launched the "Oceans of Things" program in 2017 to move toward their goal of achieving an energy-efficient underwater networking system for maritime situational awareness. On the industrial front, top companies, such as Google, Microsoft, and Honeywell, seek to deploy such networks to monitor underwater structures ranging from oil and gas pipelines to submerged data centers.

In spite of growing interest and potential in this domain, existing solutions for a low-cost and low-power distributed underwater sensor network remain largely inadequate. This is because today's underwater systems rely on point-to-point communication that is power hungry (consuming 50-100 Watts for transmission). As a result, batteries of underwater sensors get drained quickly. They would need to be recharged every time they run out of energy, which limits their lifetime. One workaround to this issue is to use duty cycling where sensors are powered up for only a fraction of the total time, and repeat this process to transmit data. However, this approach will severely limit our throughput to a measly ten bits per second.

So that leads to the following question: Is it possible to create a scalable underwater sensor network that is entirely battery-free, yet offers high data rates at a considerable operational range? The short answer is yes.

**COMMUNICATING WITH BACKSCATTER**

Student researchers at MIT have developed an underwater sensor design that employs "backscatter," which allows for communication with 1 million times less power (ranging from 120uW to 500uW) than traditional underwater communication systems (see Figures 1 and 2). Backscatter sensors communicate at near-zero power by simply harvesting energy from ambient signals in the environment and then reflecting them back for communication. This makes them an ideal choice for ultra-low-power networks. Unfortunately, existing backscatter systems work with radiofrequency signals and these signals quickly attenuate underwater, which means these systems cannot be used for underwater communication or power harvesting. Instead, our sensors rely on acoustic signals for backscatter,

Image by Cristian Palmer / Unsplash



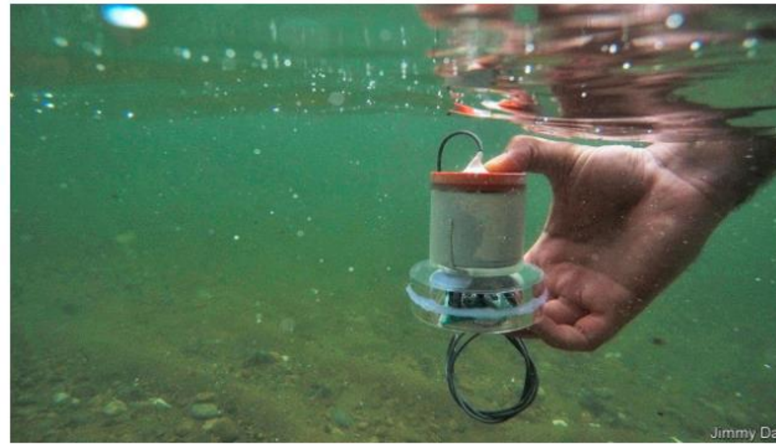
The Economist | Menu | Weekly edition | Search

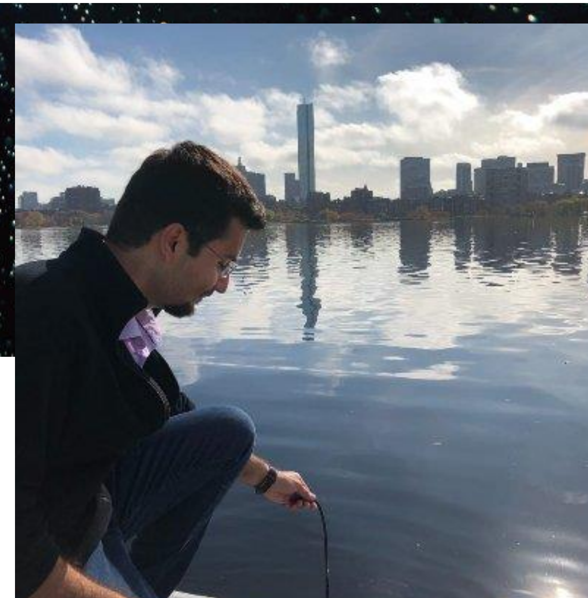
Science & technology
Oct 17th 2020 edition ›

Good vibrations

## How to send underwater messages without batteries

A new device extracts energy from ambient noise



## Sayed Saad Afzal

EE Graduate 2018 batch – Gold Medalist
PhD Candidate, Fall 2019,
Massachusetts Institute of Technology, USA

# Sample SPROJ – 2019 Batch :

## High Voltage Conversion, Bi-Directional DC Microgrid

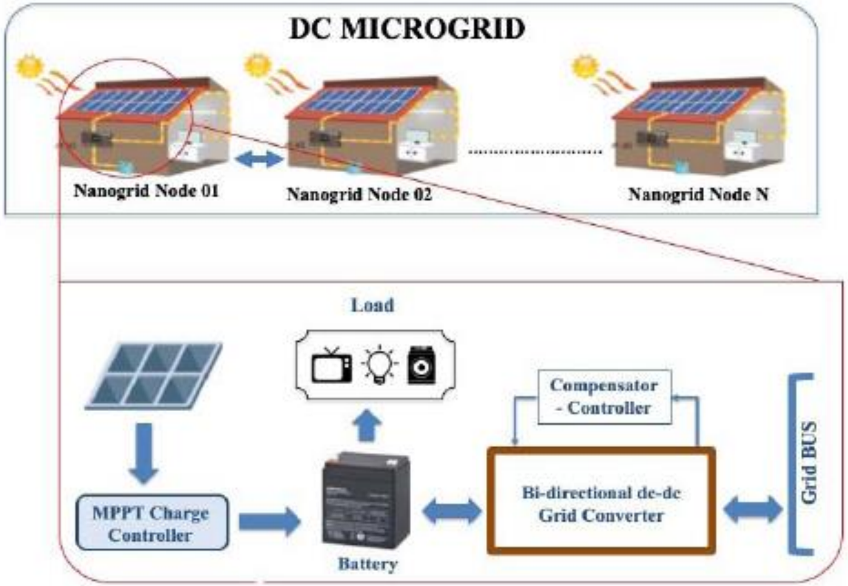

Awais Raza


Kashaf Jamshed

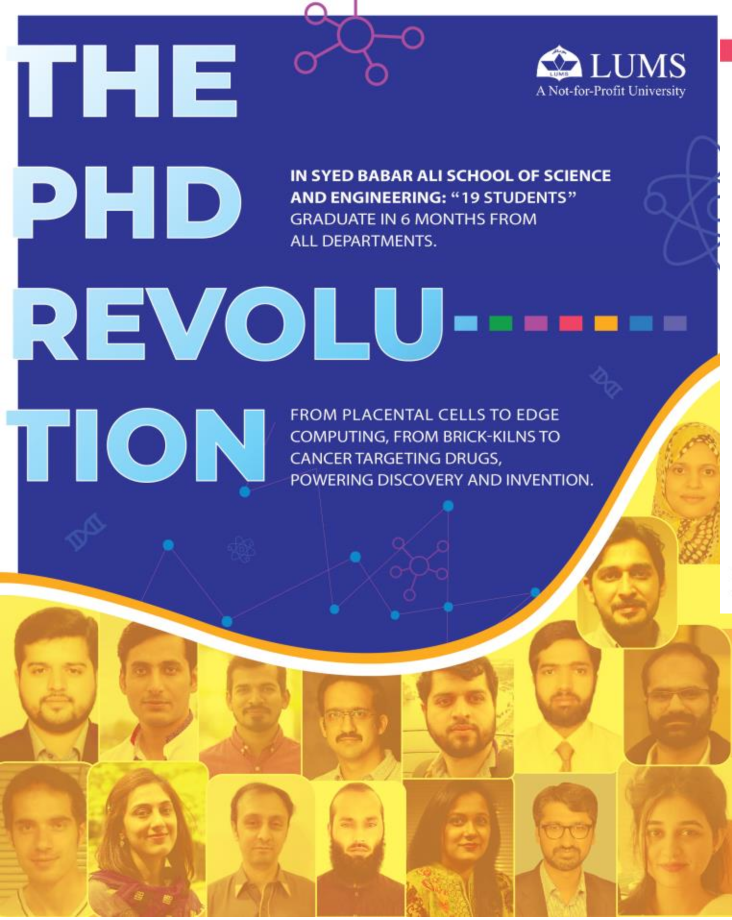

Maida Farooq

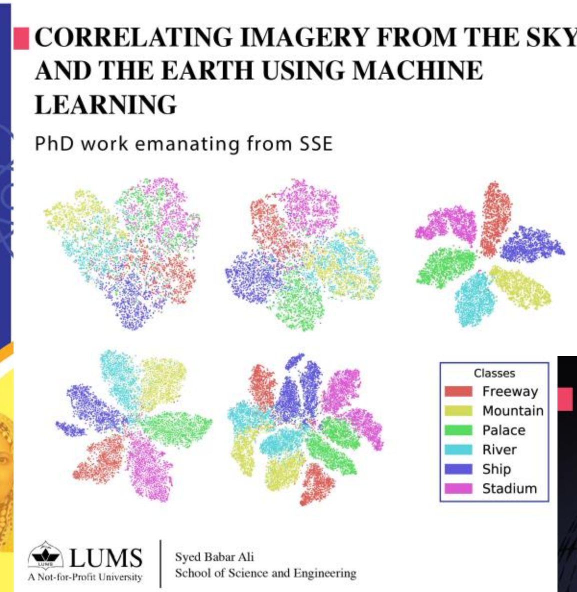

**Prof. Nauman Zaffar**

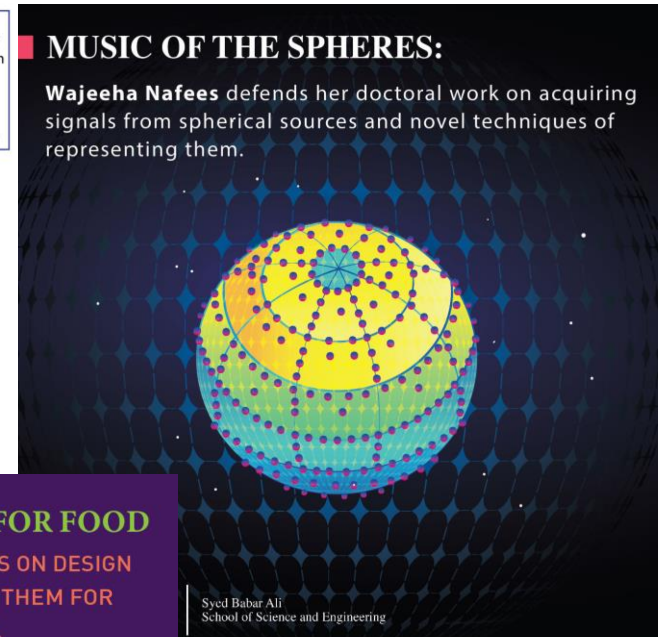

**Dr. Hassan Abbas Khan**

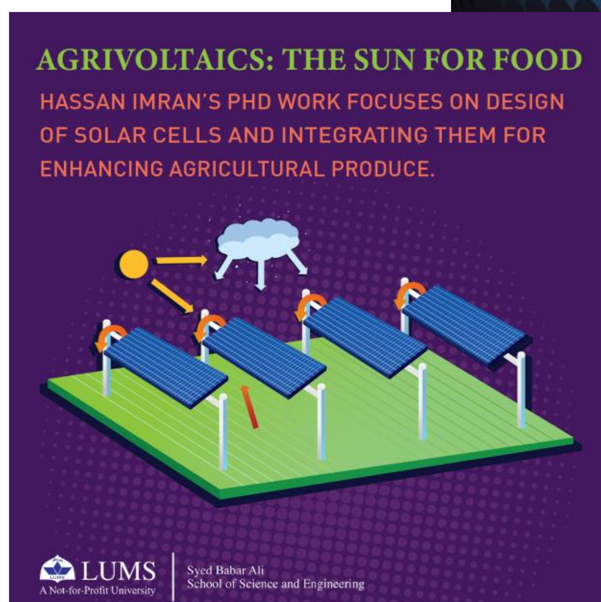



Simulation / Design (Diagram)




**EE PhD graduates in 2020**

Saad Zia Sheikh (Dr Adeel Pasha)
Muhammad Kamran (Dr Faryad)
Numan Khurshid (Dr Murtaza Taj)
Wajeeha Nafees (Dr Zubair Khalid)
Hassan Imran (Dr Nauman Butt)

# PhD student excellence

## Micro Doppler Signatures and Multi-Antenna Radars: Research Directions, Challenges and Opportunities

Dr. Ijaz Haider Naqvi (Associate Professor, LUMS) and
Dr. Faran Awais Butt (Assistant Professor, UMT, Lahore)

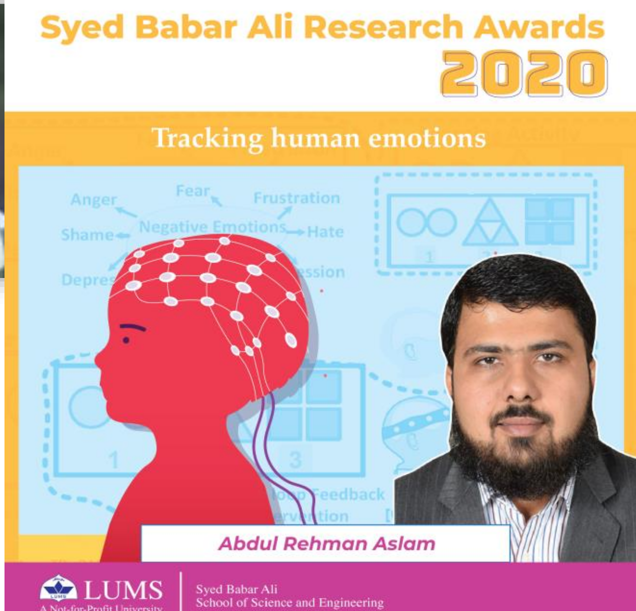
Seminar TalK (Online)
Dec 07, 2020, 05:30 PM
Pakistan Standard Time

LUMS | Department of Electrical Engineering
Syed Babar Ali School of Science and Engineering

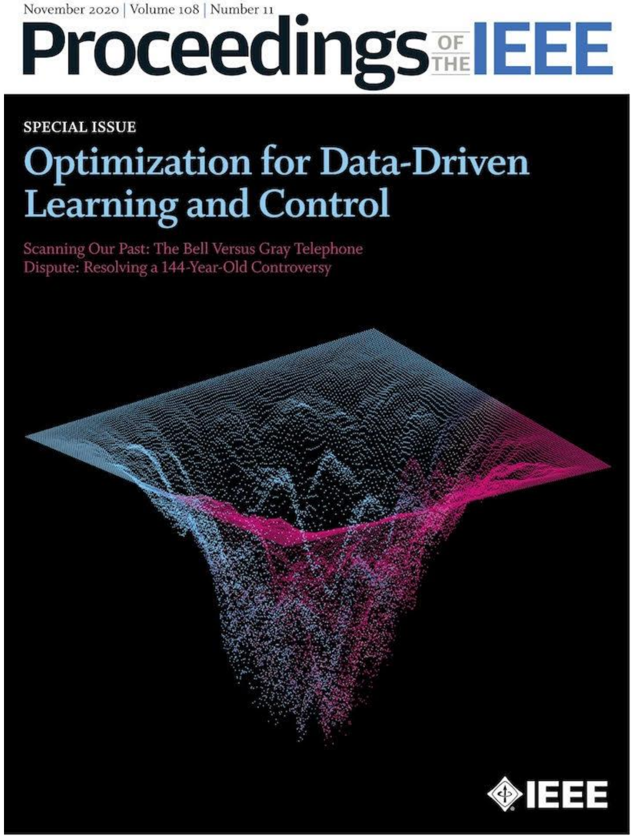
Dr. Zubair Khalid


Dr. Imran Cheema


Dr. Awais Bin Altaf



# Selected Research Highlights




INVITED PAPER

## Distributed Optimization for Robot Networks: From Real-Time Convex Optimization to Game-Theoretic Self-Organization

*This article presents a collection of state-of-the-art results for distributed optimization problems arising in the context of robot networks, with a focus on two special classes of problems, namely, real-time path planning for multirobot systems and self-organization in multirobot systems using game-theoretic approaches.*

By Hassan Jaleel, *Member IEEE*, and Jeff S. Shamma, *Fellow IEEE*

**ABSTRACT** | Recent advances in sensing, communication, and computing technologies have enabled the use of multirobot systems for practical applications such as surveillance, area mapping, and search and rescue. For such systems, a major challenge is to design decision rules that are real-time-implementable, require local information only, and guarantee some desired global performance. Distributed optimization provides a framework for designing such local decision-making rules for multirobot systems. In this article, we present a collection of selected results for distributed optimization for robot networks. We will focus on two special classes of problems: 1) real-time path planning for multirobot systems and 2) self-organization in multirobot systems using game-theoretic approaches. For multirobot path planning, we will present some recent approaches that are based on approximately solving distributed optimization problems over continuous and discrete domains of actions. The main idea underlying these approaches is that a variety of path planning problems can be formulated as convex optimization and submodular minimization problems over continuous and discrete action spaces, respectively. To generate local update rules that are efficiently implementable in real time, these approaches rely on approximate solutions to the global problems that can still guarantee some level of desired global performance. For game-theoretic self-organization, we will present a sampling of results for area coverage and real-time target assignment. In these results, the problems are formulated as games, and online updating rules are designed to enable teams of robots to achieve the collective objective in a distributed manner.

**KEYWORDS** | Convex functions; distributed algorithms; multirobot systems; optimization.

### I. INTRODUCTION

In multirobot systems, a group of individual robots seeks to achieve a collective objective [1]. Motivating applications include collaborative missions, such as exploration [2], area coverage and monitoring [3], [4], task allocation [5], transport [6], and pursuit evasion [7], [8], as well

Manuscript received December 22, 2019; revised May 3, 2020 and August 25, 2020; accepted September 17, 2020. Date of current version October 27, 2020. *(Corresponding author: Jeff S. Shamma.)*

**Hassan Jaleel** is with the Intelligent Machines and Sociotechnical Systems (IMaSS) Laboratory, Department of Electrical Engineering, Syed Babar Ali School of Science and Engineering, Lahore University of Management Sciences (LUMS), Lahore 54792, Pakistan (e-mail: hassan.jaleel@lums.edu.pk).

**Jeff S. Shamma** is with the Robotics, Intelligent Systems, and Control (RISC) Laboratory, Computer, Electrical and Mathematical Sciences and Engineering (CEMSE) Division, King Abdullah University of Science and Technology (KAUST), Thuwal 23955-6900, Saudi Arabia (e-mail: jeff.shamma@kaust.edu.sa).

Digital Object Identifier 10.1109/JPROC.2020.3028295

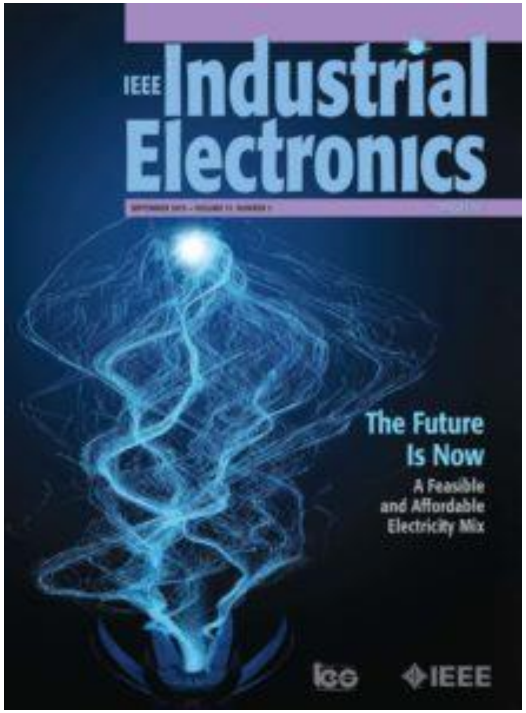






**Dr. Hassan Jaleel**

# Selected Research Highlights




## Blockchain Technologies for Smart Energy Systems

*Fundamentals, Challenges, and Solutions*

©ISTOCKPHOTO.COM/NICO EL NINO


NAVEED UL HASSAN, CHAU YUEN, and DUSIT NIYATO


In this article, we discuss the integration of the blockchain into smart energy systems. We present various blockchain technology solutions, review important blockchain platforms, and describe several blockchain-based smart energy projects in different domains. The majority of blockchain platforms with embedded combination of blockchain technology solutions are computing- and resource-intensive and, hence, are not entirely suitable for smart energy applications. We consider the requirements of smart energy systems and accordingly identify appropriate blockchain technology solutions for smart energy applications. Our analysis can help in the development of flexible blockchain platforms for smart energy systems.


*Digital Object Identifier 10.1109/MIE.2019.2940335*
*Date of current version: 23 December 2019*


### The Potential for Blockchain Applications

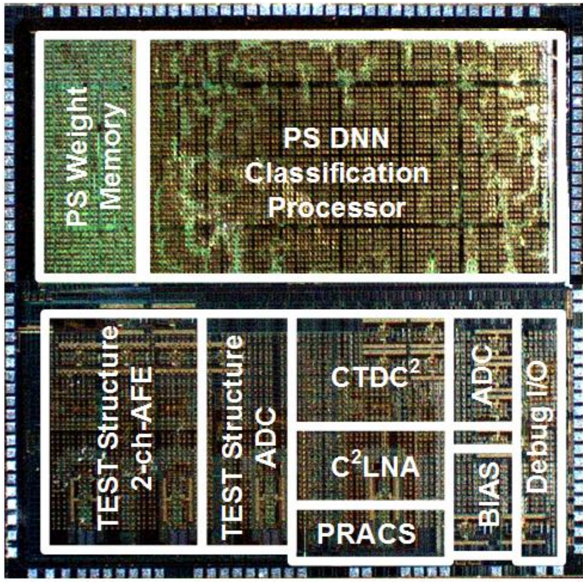
The continuous expansion of smart energy systems for industrial, commercial, and domestic applications presents several new challenges and opportunities [1], [2]. Smart infrastructure (SI), renewable energy sources (RESs), and electric vehicles (EVs) are becoming widespread [3], [4]; energy and carbon trading possibilities are increasing [5]–[7]; and energy management (EM) through demand-response management (DRM) programs is becoming more common



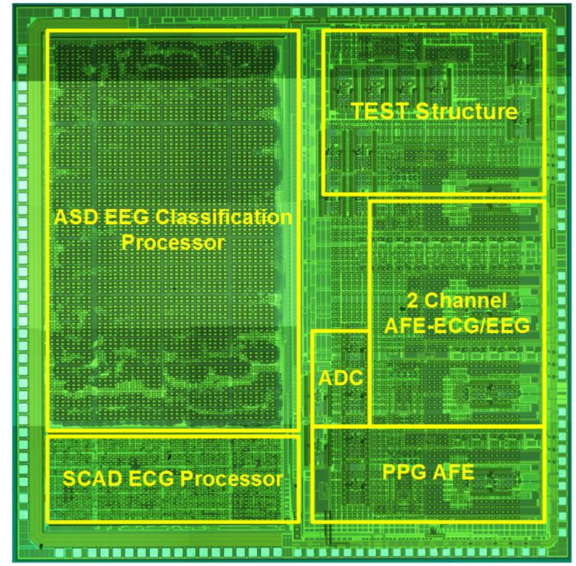
1932-4529/19©2019IEEE

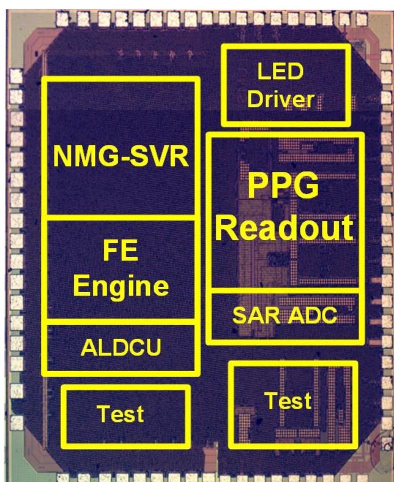

**Dr. Naveed ul Hassan**

# Selected Research Highlights

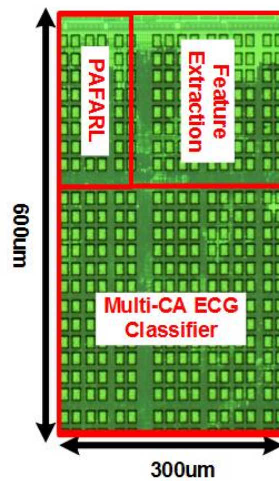



| Implemented Results | |
|---|---|
| Process | TSMC 0.18um 1P6M CMOS |
| Area | 4.0 x 4.0 mm |
| Supply Voltage | 1.0V (AFE) 1.0V (DBE) |
| NEF/channel | 2.71 |
| Classifier | DNN |
| Energy Efficiency | 10.13uJ/Class. |
| Accuracy | 85.2% |
| No. of Classes | 4 |
| PS Weight Memory | 16KB |




| Implemented Results | |
|---|---|
| Process | 180nm |
| Technology | NIR-PPG with NMG-SVM |
| Area | 2.0 x 3.0 $mm^2$ |
| Supply | 1.1V |
| Power | 186μW |
| Duty Cycle | 0.125% |
| $I_{in,\ maxDC}$ | 65μA |
| Integrated RTI Noise | 9.4$pA_{rms}$ |
| Gain | 120dB |
| mARD | 5.2% (200 Subjects) |




| | |
|---|---|
| Process | 0.18μm 1P6M |
| Active Area | 0.3 x 0.6mm |
| Supply Voltage | 1.0 V |
| # of CA | 8 |
| Power | 1.536uW @ 1KHz |
| Accuracy | 98.5% |

**First ever indigenous chip design and tape out from Pakistan.**

# IEEE Journal of Internet of Things

# ACM Transactions on Embedded Computing Systems

# IEEE LETTERS OF THE COMPUTER SOCIETY

# IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS EXPRESS BRIEFS

FOCUSING ON ALL MATTERS RELATED TO FUNDAMENTAL THEORY APPLICATIONS, ANALOG AND DIGITAL SIGNAL PROCESSING

## A Volunteer Supported Fog Computing Environment for Delay-Sensitive IoT Applications

Babar Ali, Muhammad Adeel Pasha, ... Houbing Song, *Senior Member*, ...

## A Dynamic Cache-Partition Schedulability Analysis for Partitioned Scheduling on Multicore Real-Time Systems

Saad Zia Sheikh, *Student Member, IEEE* and Muhammad Adeel Pasha, *Senior Member, IEEE*



## Energy-efficient Real-time Scheduling on Multicores: A Novel Approach to Model Cache Contention

SAAD ZIA SHEIKH and MUHAMMAD ADEEL PASHA, Lahore University of Management Sciences, Pakistan



## Optimizing Hardware Accelerated General Matrix-Matrix Multiplication for CNNs on FPGAs

Afzal Ahmad and Muhammad Adeel Pasha

## FFConv: An FPGA-based Accelerator for Fast Convolution Layers in Convolutional Neural Networks

AFZAL AHMAD and MUHAMMAD ADEEL PASHA, ... (LUMS), Pakistan

Dr Adeel Pasha

28

15

# Survived the Pandemic. Where to Next?

- Build on EE100 success.
- Industry partnerships for alternative funding streams.
- Space and HR constraints for major initiatives.
- BS and MS Student numbers
- Pedagogical partnerships
- Niche PhD and postdoctoral programs.
- Tenured faculty needs to think big!

| Session | BS Students |
|---|---|
| 2019 | 46 |
| 2020 | 43 |
| 2021 | 56 |
| 2022 | 46 |
| 2023 | 40 |

The EE revolution marches on!

Thank you.