2023 Issue 1 // Volume 119

THE BRIDGE

The Magazine of IEEE-Eta Kappa Nu

Applications of Lidar

Making Impact, Growing Connections
IEEE-HKN 2022 Year in Review

Ultrafast Lidar Based on Signal Time Stretch and Various Transduction Techniques

Ground-based Lidar for Historic Preservation, Increased Accessibility, and Virtual Tourism

Guiding Apollo to the Moon

IEEE-Eta Kappa Nu

IEEE

IEEE-HKN AWARDS PROGRAM

As the Honor Society of IEEE, IEEE-Eta Kappa Nu provides opportunities to promote and encourage outstanding students, educators, and members.

Visit our new website to view the awards programs, awards committees, list of past winners, nomination criteria, and deadlines.

ALTON B. ZERBY AND CARL T. KOERNER OUTSTANDING STUDENT AWARD (OSA)

Presented annually to a senior who has proven outstanding scholastic excellence and high moral character, and has demonstrated exemplary service to classmates, university, community, and country.
(Deadline: 30 June)

C. HOLMES MACDONALD OUTSTANDING TEACHING AWARD (OTA)

Presented annually to electrical engineering professors who have demonstrated, early in their careers, special dedication and creativity in their teaching, as well as a balance between pressure for research and publications.
(Deadline: Monday after 30 April)

DISTINGUISHED SERVICE AWARD (DSA)

Recognizes members who have devoted years of service and lifetime contributions to Eta Kappa Nu (or IEEE-HKN), resulting in significant benefits to all of the Society's members.
(Deadline: Monday after 30 April)

OUTSTANDING CHAPTER AWARD (OCA)

Recognizes chapters for excellence in activities and service at the department, university, and community levels. The award is based on the content contained in their Annual Chapter Report for the preceding academic year.
(Deadline: 31 July)

OUTSTANDING YOUNG PROFESSIONAL AWARD (OYP)

Presented annually to an exceptional young engineer who has demonstrated significant contributions early in his or her professional career.
(Deadline: Monday after 30 April)

IEEE-HKN ASAD M. MADNI OUTSTANDING TECHNICAL ACHIEVEMENT AND EXCELLENCE AWARD

Presented annually to a practitioner in the IEEE technical fields of interest who has distinguished himself or herself through an invention, development, or innovation that has had worldwide impact.
(Deadline: Monday after 30 April)

IEEE-Eta Kappa Nu (IEEE-HKN) was founded by Maurice L. Carr at the University of Illinois at Urbana- Champaign on 28 October 1904, to encourage excellence in education for the benefit of the public. IEEE-HKN fosters excellence by recognizing those students and professionals who have conferred honor upon engineering education through distinguished scholarship, activities, leadership, and exemplary character as students in electrical or computer engineering, or by their professional attainments. *THE BRIDGE* is the official publication of IEEE-HKN. Ideas and opinions expressed in *THE BRIDGE* are those of the individuals and do not necessarily represent the views of IEEE-HKN, the Board of Governors, or the magazine staff.

Get in touch with Eta Kappa Nu Twitter: ieee_etakappanu Facebook: IEEE-HKN

THE BRIDGE

The Magazine of IEEE-Eta Kappa Nu

2023 ISSUE 1 | Applications of Lidar

Features

Departments

Editor-in-Chief:
Jason Hui

Editorial Board Members:
Sean Bentley, Burton Dicht, Emily Hernandez, Marcus Huggans, Hulya Kirkici, Kevin T. Kornegay, Zahra Manzoor, Emmanuel Oyekanlu, and Steve Watkins

Managing Editor: Nancy Ostin

Assistant Managing Editor: Amy Michael

Advertising Sales: Nancy Ostin
n.ostin@ieee.org

Design Company: Tumbleweeds, LLC

IEEE-HKN INTERNATIONAL HEADQUARTERS

Editorial inquiries: IEEE-Eta Kappa Nu, 445 Hoes Lane, Piscataway, NJ 08854, USA
US Toll Free: +1 800 406 2590
Outside US: +1 732 465 5846
Email: info@hkn.org | www.hkn.ieee.org

Subscription address and email changes: IEEE Contact Center
US Toll Free: +1 800 678 4333 | Outside US: +1 732 981 0060 | Fax: +1 732 562 6380 | Email: contactcenter@ieee.org

Dr. Jason K. Hui

Epsilon Delta Chapter

THE BRIDGE, February 2023

Letter from the Editor-in-Chief

Dear IEEE-HKN Members and Friends,

Happy New Year and welcome to the first issue of *THE BRIDGE* for 2023! It is an honor and privilege to serve as the new Editor-in-Chief of this award-winning magazine. Over the past three years, I had the pleasure of serving on the IEEE-HKN Board of Governors as Regions 1-2 Governor and am pleased about continuing my affiliation with the society in this new role. I would like to express my sincere appreciation to Dr. Sahra Sedigh Sarvestani and Dr. Steve E. Watkins for their many years of dedication and leadership as co-Editors-in-Chief and invaluable support from Stacey L. Bersani, Assistant Managing Editor.

This issue features articles on the technology and applications of Lidar (Light Detection and Ranging) coordinated by guest editor, Dr. Watkins. It also contains the 2022 Annual Report, highlighting IEEE-HKN's year in review on awards, inductions, activities, community service hours, and chapters. Additionally, we look back at last October's memorable Student Leadership Conference at UNC Charlotte where participants gathered together for the first time in several years to learn and network, celebrate Founders Day, and recognize the accomplishments of our key chapters.

We have the pleasure of featuring several HKN colleagues who are serving in the esteemed role of "president": IEEE-HKN President Sampathkumar Veeraraghavan, former IEEE-HKN President and now ABET President Dr. S.K. Ramesh, and IEEE President and Chief Executive Officer, Dr. Saifur Rahman.

IEEE-HKN strives for effective communication through its various channels including our website, YouTube, Facebook, LinkedIn, and this magazine. The Editorial Board welcomes your ideas and content, and can be reached by email at info@hkn.org. And as always, *THE BRIDGE* is available on the IEEE App.

THE BRIDGE, February 2023
Introduction from the Guest Editor

Dr. Steve E. Watkins

Gamma Theta Chapter

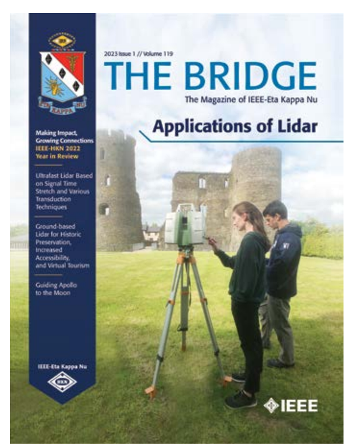
The features in this issue of *THE BRIDGE* magazine discuss Lidar which is an acronym for light detection and ranging. This technology exploits the monochromatic and directional nature of laser light. Wavelength choices allow systems to be highly adapted for the intended targets. Early Lidar systems were used for meteorological and terrain mapping. More recent developments have expanded these systems as versatile tools for mapping, ranging, and sensing. Applications include such diverse fields as surveying, archaeology, navigation, and spectroscopy.

Our cover shows the three-dimensional imaging of Ferns Castle in Ireland by the team of Dr. Michael "Bodhi" Rogers at the University of Colorado Denver. His work is further described in the feature titled, "Ground-based Lidar for Historic Preservation, Increased Accessibility, and Virtual Tourism" and demonstrates the use of Lidar to create high-resolution models of buildings, architectural elements, and archaeological artifacts. Our second feature is titled, "Ultrafast Lidar Based on Signal Time Stretch and Various Transduction Techniques" and explores Lidar techniques for ultrafast measurements for applications such as spectroscopy.

As noted in this issue's history spotlight, December 2022 marked the 50th anniversary of the last moon landing by Apollo 17. While a radar system was used as an altimeter for the actual landings, laser altimeters on the Command Service Module were used on Apollo 15, 16, and 17 to provide camera support, direct mapping, and altimeter information. This experiment led to instruments on later robotic missions that have made detailed maps of the moon, Mars, and Mercury. Retroreflectors delivered to the lunar surface by Apollo and Soviet spacecraft allow highly accurate laser ranging measurements of the distance between the moon and earth.

Other examples of Lidar technology are illustrated in the following images. Lidar can be applied as an altimeter for aircraft, satellites, and spacecraft such as the Garmin module used by the Mars Ingenuity helicopter. Lidar systems can monitor air quality in mines. Lidar sensors can provide environmental awareness for autonomous vehicles. Thanks go to the authors of the feature articles and to the contributors of the Lidar examples for providing a view of how engineers are "Advancing Technology for Humanity" (IEEE tagline).

(continued on page 6)



Students perform Lidar imaging of Ferns Castle in Ireland. Credit: M. Rogers, University of Colorado Denver.

SELECTED APPLICATIONS OF LIDAR

Architectural Documentation

Lidar structured-light scans documented the interior and exterior of the Philipse Manor Hall in Yonkers, NY. The interior scan shown produced three-dimensional images of this colonial-period building. The resulting three-dimensional models document the architectural elements as a means of preservation and understanding. For instance, a model of the 18th-century Rocco decorative papier-mâché ceiling in one room was used to produce molds for replicas in a restoration project.

Learn More: Michael "Bodhi" Rogers Laboratory

Philipse Hall Interior Image; Credit: M. Rogers, University of Colorado Denver

Mars Drone Image; Credit: NASA/JPL-Caltech

Flight Altimeter

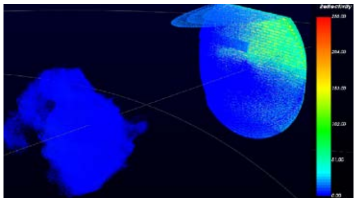
Perseverance rover and Ingenuity helicopter landed on Mars in 2021 (artist's concept). The powered, controlled flight of Ingenuity was a first on another planet. It was accomplished using a LIDAR-Lite-V3 module as an altimeter. This Garmin technology provided three-centimeter accuracy at a 50-Hz sampling rate in the extreme environment of Mars.

Learn More: https://mars.nasa.gov/technology/helicopter

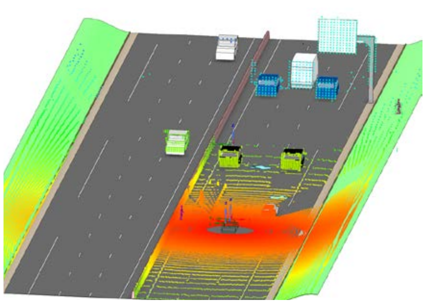
Mine Dust Monitor

A Lidar-based, portable monitor (left image) was developed to detect air quality for mine safety, i.e., detection of potential hazardous airborne particulate matter. This prototype was an undergraduate design project of Z. Osterwisch, A. Mauntel, N. Nisbett, and D. Barua with supervision of Dr. Ahmad Alsharoa at Missouri S&T. A dust plume (right image) is imaged and can provide information on plume location, particle size, and particle concentration.

Learn More: Ahmad Alsharoa Laboratory



Mine dust monitor & results images; Credit: A. Alsharoa, Missouri University of Science & Technology



Autonomous Vehicle

Lidar technology can provide information on the environment for autonomous vehicles. Moving and stationary objects throughout the surrounding three-dimensional space must be detected with Lidar in conjunction with other technologies, e.g., cameras. Simulations are used to understand and develop Lidar systems. A traffic simulation using ANSYS simulation software is shown.

Learn More: ANSYS Engineering Simulation Software

Former HKN President Ramesh is now ABET President

S. K. Ramesh, 2022-2023 President of ABET

ABET has been an integral part of my professional life since I began my career in the California State University system over three+ decades ago. Today, ABET accredits over 4,500 programs worldwide in Engineering, Technology, Computing, and Applied and Natural Science and the number of programs and countries we serve continues to grow. This includes over 1,000 programs outside the United States. Every year, over 175,000 students graduate from ABET accredited programs. ABET's member societies are critical to our success. We continue to proactively engage our 35 member societies to diversify and strengthen our global volunteer base in support of ABET's mission: promoting and improving the quality of technical education worldwide. Every day ABET's 2,200+ volunteers donate their time and expertise in helping ABET achieve this mission. I have personally witnessed the enormous transformative impact of ABET accreditation on the programs we accredit globally, and on the students and graduates from those programs. Speaking of adapting, I still find it hard to believe that we completed our past two accreditation visit cycles 100 % virtually!

Access, Inclusion, Affordability, and Quality are arguably the most important issues in higher education today. The challenges from the pandemic have brought these issues into sharp focus. Healthcare, climate change, food security, and sustainability, are among the critical global challenges confronting us. We have a great opportunity to educate students to find innovative solutions to these global challenges that confront society, and prepare them for participation in a global and diverse society. For higher education these are challenging times as well, with proposals for radical changes in the way in which we deliver educational programs, assess, and evaluate the impact of new pedagogies and technologies to enhance and improve student learning. We need to be focused and resilient – innovating in the face of adversity.

ABET has a rich history of global engagement with its member societies in support of our mission. As a testament to these efforts, ABET volunteers are working diligently to incorporate principles of diversity, equity, and inclusion (DEI) in program accreditation criteria. Treating one another with respect and courtesy is a fundamental element of inclusion. Looking ahead, how do we attract, inspire, and engage students to create a better, diverse, inclusive, more sustainable world? Clearly, this is at the heart of what we do in ABET. How can we engage students in curricular practices that strengthen systems thinking and sustainability, teamwork, and collaboration, cross-cultural sensitivities and professional skills, for diverse environments? Evidence is emerging that shows that changing the way we teach, with culturally enhancing pedagogy, broadens participation and makes education globally accessible and transformative.

Dr. S. K. Ramesh is welcomed as ABET President by out-going President William J. Wepfer (Georgia Tech)

ABET

ABET is a consensus-based organization. Continuity, Collaboration and Communication are vital. Only things that are well socialized and supported will get done. We will look at our past for lessons learned but focus on the future for what we need to change. I look forward to working with all of you to serve ABET's diverse tapestry of member societies and our profession in the exciting times ahead with an unwavering focus on our strategic goals and inclusive excellence.

S. K. Ramesh is the 2022-2023 President of ABET. He served on the ABET Board of Directors. He is an experienced IEEE Accreditation Program Evaluator (PEV) and is a fellow of IEEE. Dr. Ramesh served as 2016 IEEE-HKN President and 2016-17 Vice President of IEEE Educational Activities. He is a professor and former Dean at California State University, Northridge. He was inducted into HKN by the Lambda Beta Chapter.

Ultrafast Lidar Experimental Setup at Missouri S&T

Ultrafast Lidar Based on Signal Time Stretch and Various Transduction Techniques

Behzad Boroomandisorkhabi and Mina Esmaeelpour, Department of Electrical and Computer Engineering, Missouri University of Science and Technology

Abstract

This article discusses light detection and ranging (Lidar) techniques based on time-to-wavelength mapping and real-time fast Fourier transformation, as well as its application in spectroscopy. Different signal transduction techniques for Lidar data acquisition and processing are also discussed, including direct optical detection, detection of the microwave signals extracted from the interferometric measurements, and imaging based on the spectro-temporal encoding of various optical bands of the input signal.

I. Introduction

Light detection and ranging, known as Lidar, use the transmission and return of light as a remote sensing technology. A variety of wavelengths and pulse lengths are used. The use of ultrafast lasers with pulse lengths less than a nanosecond has been a topic of interest for scientific and commercial applications. Ultrafast Lidar technology has the advantages of noncontact and remote operation and immunity to electromagnetic interference. Optical ranging and Doppler Lidars, as well as composition analysis of complex materials and molecular evolution in chemistry and biomedicine, are some of the applications of this technology [1,2]. Ultrafast range detection is possible on a large dynamic range with nanometer accuracy by using dispersive Fourier transformation known as "Time-stretch" [1,3]. It requires an analog-to-digital conversion with a high sampling rate where short-time data storage and time-consuming post-processing may cause issues. These issues can be addressed through continuous detection and real-time feedback. Microwave photonics can also be applied to overcome these problems and realize real-time signal processing with integrated functionality [4].

The "Time-stretch" ultrafast Lidar technique has applications in ultrafast single-shot spectroscopy, imaging, ranging, ultra-wideband, and chirped microwave pulse generation for high-speed communications and radars. However, because of the high insertion loss of the adopted dispersion device, it has the disadvantage of a low signal-to-noise (SNR) ratio, which can be improved by incorporating heterodyne detection by mixing the weak signal with a strong local oscillator. However, the spectral information encoded in the envelope is hard to acquire because of the narrow-band radio-frequency (RF) spectrum. The amplitude-modulated interferometry (AMI), frequency-modulated interferometry (FMI), and spectrally resolved interferometry (SRI) are the most notable interferometric techniques for high-resolution ultrafast optical ranging to extract this decoded information [5]. Each of these techniques comes with certain drawbacks. For instance, in an AMI system, the ranging information is extracted from the phase shift of the interferometer's reference and object signals, so to avoid ambiguity problems, it is required to know the ranging information beforehand with sub-wavelength accuracy, and SRI needs equalization of the geometrical path lengths in dispersive elements to avoid ghost steps in the measurement. Here we will provide an overview of various techniques used for "time-stretch Lidar" data acquisition and transduction.

II. Background

In conventional Lidar, narrow-spectrum laser pulses are transmitted, and the return signal is monitored for the time-of-flight and amplitude measurements. The laser pulses are spatially scanned to create a mapping of the target objects. The wavelength used is tailored to the intended target. The conventional approach has limited performance for targets that are present on short time scales, or which require fast measurements, especially those with transient or weak return signals. If a broad-spectrum, ultrafast laser signal is used, the wavelengths can be spread out through dispersion to allow interferometric detection of the wavelength-dependent signal modulation. For instance, various wavelengths in a broad-spectrum pulse will travel at different speeds in a dispersive optical fiber. For spectroscopic applications, the target could be components of a liquid or gas which will encode the pulse wavelengths.

Time-stretch Lidar requires a broad-spectrum pulse or time-to-wavelength mapping of a narrow-line ultrafast laser pulse. Time-to-wavelength mapping is a process that consists of two steps, including (i) stretching the laser pulse and (ii) modulating it via beating with a reference signal through a modulation process, such as in a Mach-Zehnder interferometer (MZI). Differences arise when the order of these steps is switched in an experiment. Stretching of a narrow-line ultrafast pulse train can happen either through kilometers of fiber providing linear group velocity dispersion (GVD) such as dispersion compensating fiber (DCF) or linearly polarized fiber Bragg grating (LC-FBG).

In this section, three time-stretch Lidar systems are investigated based on the positioning of the dispersive element and their respective transduction techniques used to retrieve the information of the device under test. All these techniques use ultrafast laser pulses and dispersion elements to generate a temporal and spectral response that will eventually allow us to resolve tiny changes in the parameters of interest, including distance, shape, etc. Figure 1 describes the three Lidar systems to detect the small displacements of a mirror. The optical circulators direct the incident signal to the targets and then pass the modulated signal to the detection elements. The optical delay lines (ODL) and the polarization control match the signal and reference paths.

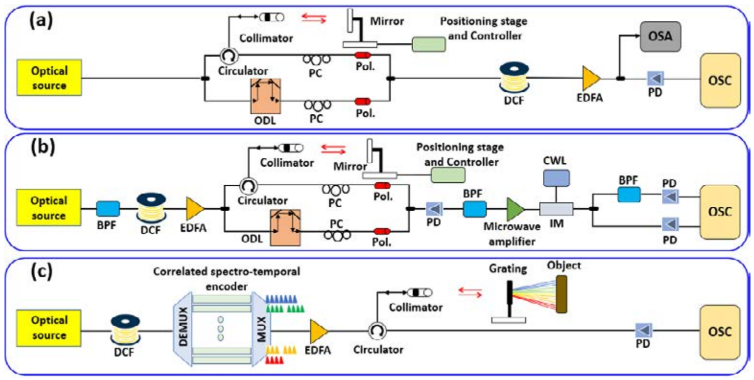


Figure 1: (a) Time-stretched Lidar with direct optical transduction, (b) time-stretched Lidar with microwave processing transduction, (c) ultrafast Lidar with correlated spectro-temporal encoding and wavelength division multiplexing. PD: photodetector, Pol.: in-line polarizer, IM: intensity modulator, PC: polarization controller, EDFA: erbium-doped fiber amplifier, (DE)MUX: (de)multiplexer, ODL: optical delay line, OSC: oscilloscope, OSA: optical spectrum analyzer, BPF: bandpass filter, CWL: continuous-wave laser.

A. Time-stretched Lidar with direct optical transduction

Figure 1a shows a real-time ranging Lidar based on direct optical detection and Fourier transformation post-processing [1,6]. The ultrafast laser pulse train is divided into the probe and the reference arms using a fiber splitter to generate two intrinsically coherent copies of the same laser. The two signals then recombine through a circulator into a fiber-based MZI, after which their beat signal (this pattern due to interference is called an interferogram) is guided into a DCF to provide multiple orders of magnitude broadening in the temporal and spectral profile. A tunable optical delay line is incorporated in the reference arm of the MZI to allow for beat signal tunability. The beat signal frequency of the MZI is proportional to the time delay between the two arms of the MZI, which is the delay introduced by the tunable optical delay line. A high-precision delayer with a large overall delay is needed to achieve both high sensitivity and a large dynamic range, both of which are limited by the speed of the photodetector and the oscilloscope. Therefore, for continuous measurement and data processing for high sensitivity and large dynamic range, a fast oscilloscope or analog-to-digital conversion is required, which will result in very large amounts of data being generated and stored.

Using a 50:50 splitter, both the temporal and spectral interferograms of the signal can be measured simultaneously to which optical data processing such as fast Fourier transform will be applied. Examples of the generated interferograms are provided in the next section, cf. Figures 4a and 4b. Temporal interferogram data is mapped to the frequency domain by using a polynomial fit function that relates the peak centers of temporal and spectral interferograms to each other. The ranging data, which is the distance of the mirror in Figure 1, is encoded in the temporal interferogram's frequency. An inverse Fourier transform is applied to the frequency domain data. By fitting each main sideband that is associated with a time delay difference to a Gaussian function with the center of each fitted result, the time delay difference and, consequently, the displacement of the object (mirror) is calculated. Using this technique, a range detection of 16 cm with an accuracy of 334 nm is demonstrated [1].

B. Time-stretched Lidar with microwave processing transduction

Time-stretched Lidar with direct optical transduction, which uses optical-to-electrical conversion of the detected signal through a photodetector, usually requires an analog-to-digital converter with a fast sampling rate. The measurement data set size is also large for this case. Since the displacement data is encoded in the frequency of the time-domain (temporal) interferogram, instantaneous microwave frequency measurement will bypass the challenges of the previous technique. In microwave processing transduction, instead of direct optical detections of the temporal interferogram, a frequency-to-intensity mapping known as amplitude comparison function (ACF) through intensity modulation of a secondary laser could resolve the issue. This technique allows for a real-time femtosecond ranging Lidar based on all-optical signal processing with few-micrometer resolution incorporating dispersive Fourier transformation and instantaneous microwave frequency measurement without the need for a fast ADC [4]. Figure 1b shows the schematic diagram of this technique.

The main difference between this and the technique depicted in Figure 1a is the optical transduction technique used to retrieve the signal information such as displacements. For this technique, the ultrafast laser pulses are first stretched by passing through the dispersion element (DCF) [7]. The stretched amplified signal, then, passes through an all-fiber MZI similar to the previous technique. The displacement is encoded in the frequency variation of the temporal interferogram, and optical signal processing of the microwave pulse generated on a photodetector is applied to address the challenges in storage and real-time processing of the interferogram data. By an intensity modulator, a carrier wave is modulated by the time-domain interferogram signal detected by a fast photodetector, and then the frequency variation of the microwave pulse is encoded to the first-order sidebands of the intensity-modulated signal of the secondary laser. By applying a symmetric-locked frequency discriminator, the frequency shift of the sidebands is mapped to a transmission change. Finally, a programmable optical filter realizes a real-time ranging system with adjustable dynamic range and detection sensitivity. In summary, using a fast Fourier transform interferometer, the displacement is encoded to the frequency shift of microwave pulse that is uploaded into first-order sidebands of carrier wave under intensity modulation. The displacement is extracted from sideband frequency shifts by applying optical frequency detection. A 15 mm and 45 mm detection range with a mean error of 19.10 μm and 36.63 μm, respectively, have been reported using this technique [4].

C. Spectral Lidar with direct optical transduction

Another ultrafast Lidar technique that incorporates time-stretch is known as spectral Lidar [8,9]. Current autonomous Lidar technologies are single-wavelength and use geometric or spectral beam scanning to generate a map of the surroundings. The acquisition time of such a Lidar technology, known as time-of-flight imaging-based Lidar, is affected by the speed of beam scanning and the maximum measurable time-of-flight. Using an ultrafast broadband source and a spatially dispersive element such as a grating, we can either eliminate beam scanning or increase the speed of the Lidar image acquisition for applications such as driverless cars. This technique uses time encoding of the different spectral bands of the time-stretched signal, which is adapted from the time and wavelength multiplexing techniques in optical communication systems [9]. The spectrally broadened time-stretched laser pulses are divided into various spectral bands, and each band is delayed differently (fiber-based encoding) and detected simultaneously. The combination of the fiber-based encoder with wavelength-division multiplexing is used to achieve parallel detection and fast spectral scanning. To obtain parallel detection of all the wavelength bands, optical code division multiplexing is obtained using a fiber-based, all-optical, temporal encoder in each wavelength multiplexed channel. Correlated spectro-temporal modulation with a high degree of freedom enables parallel time-of-flight and, consequently, a significant increase in the detection speed. A maximum 75 m detection range with a 4.4-fold speedup was obtained [9]. Figure 1c shows the schematic of an ultrafast Lidar with a correlated spectro-temporal encoding system.

D. Time-stretched molecular spectroscopy

A time-stretch Lidar technique can also be applied to detect and characterize molecular properties of the materials, such as trace gases at ultralow concentrations through absorption profiles. Fast acquisition time, high sensitivity, high resolution, and broad spectral bandwidth are topics of interest. Existing techniques, such as Fourier transform spectroscopy (FTS), provide a broadband spectrum and well-resolved data in nonintrusive diagnostics of molecular structures in various media but suffer from slow spectral acquisition rates. Wavelength-swept spectroscopy has the advantage of better SNR but suffers from repetitive measurements. Time-stretch has been demonstrated to improve these techniques and address their shortcomings through high-resolution parallel detection [10]. One of the techniques that incorporate time-stretch and time-to-frequency mapping is known as femtosecond imbalanced time-stretch spectroscopy (FITSS) [2] where the optical frequency domain signal is converted to a microwave or radio frequency domain comb. The resulting temporal interferogram and its Fourier transform will demonstrate a frequency comb from which material properties can be extracted. Time-stretched femtosecond laser pulses enter an MZI as shown in Figure 2. The reference arm of the MZI includes an optical delayer followed by a second dispersive element. The probing arm includes the material under test. The Fourier transform of the beat signal between the two arms of the MZI demonstrates a frequency comb in the radio frequency domain with a comb spacing the same as the laser repetition rate [2,11]. The RF comb structure

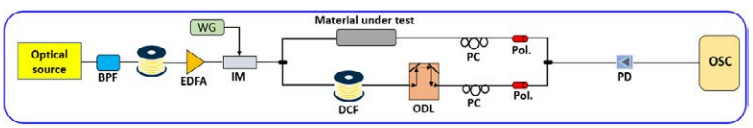


Figure 2: Time-stretched spectroscopy for ultrafast material (gas, solid, and liquid) characterization.

includes the molecular spectrum from the optical frequency comb. The advantage of such a technique over the existing techniques is fast acquisition time and high-resolution detection.

III. Experimental Results

We used the time-stretch ultrafast Lidar technique explained in the previous section to detect the small displacements of a mirror. Figure 1a demonstrates the schematic of the optical ranging based on dispersive frequency-modulated interferometry using 120 km of dispersive optical fiber. A picosecond laser source is used in the experiment with a repetition rate of 10 MHz, a center wavelength of 1550 nm, and a pulse width of 7 ps. The reflected signal from the mirror passes through the same circulator to combine with the reference signal and is set to have parallel polarization with the reference arm using polarization controllers and in-line polarizers before they are combined with each other. The beat signal is then amplified and passed through 120 km of DCF with a total dispersion of 2048 ps/nm to generate high-frequency interferograms. We use a 45 GHz photodetector and

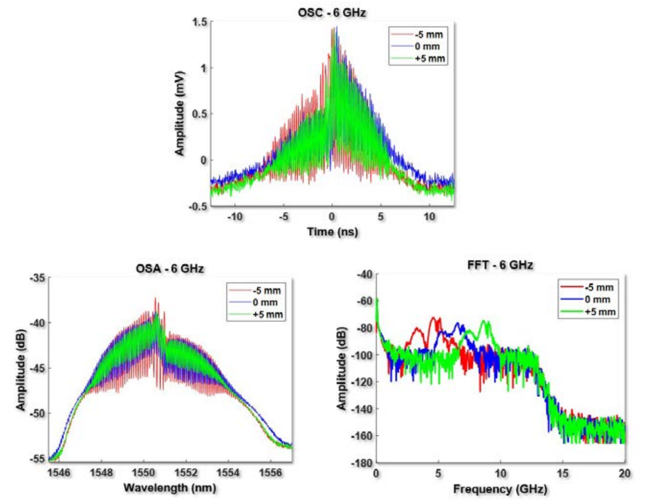


Figure 3: Temporal (top) and spectral (bottom left) interferograms, and fast Fourier transform of the temporal interferograms (bottom right).

a 12 GHz oscilloscope, as well as an optical spectrum analyzer to detect the temporal and spectral interferograms. Figure 4 demonstrates the interferograms and fast Fourier transformation for various locations of the mirror. Both reference and probe signals go through the dispersive element, are stretched in the time domain, and divided into two parts: one enters the photodetector and then connects to an oscilloscope, and the other connects to an optical spectrum analyzer. The former forms the temporal interferogram, and the latter forms the spectral interferogram. The optical delayer is adjusted to generate a temporal interferogram with a frequency of 6 GHz (half of the maximum oscilloscope frequency) as the initial frequency at x=0. By moving the positioning stage (mirror), the interferogram signal frequency changes. The displacement value can be extracted from frequency variations. The results for three different mirror positions of –5 mm, 0, and

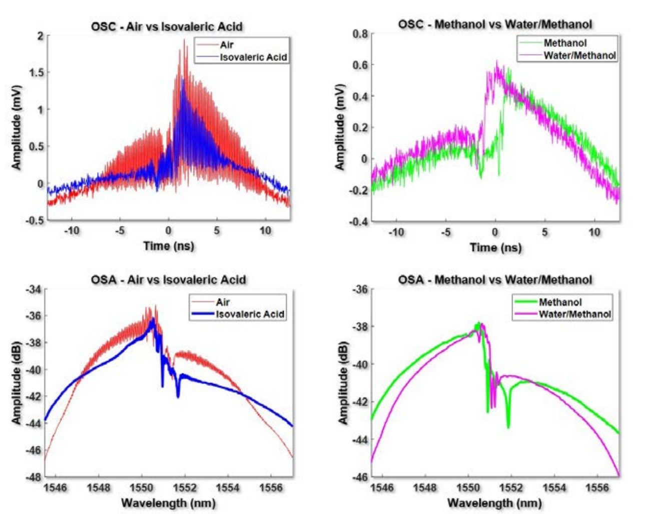


Figure 4: Measured temporal (left) and spectral (right) interferograms

5 mm are shown in Figure 3. A range resolution of 1 μm over a detection range of 14 mm is obtained.

Moreover, we have also demonstrated material characterization by applying the technique shown in Figure 1a. The material under test is put between the collimator and the mirror, and the interferograms are analyzed by time-stretching them via a 120 km DCF. This experiment was done with two different materials (100% methanol, 100% isovaleric acid, and 50% methanol/water solution). The result of this experiment is shown in Figure 4. Graphs on the left demonstrate the difference between isovaleric acid and an empty sample holder (made from glass material), and the graphs on the right show the difference between the interferograms of 100% methanol and a 50/50 water-methanol solution. The results demonstrate single-pulse, high-resolution absorptions in time and frequency space. Spectral data demonstrates multi-species detection in a 50:50 ratio of methanol/water mixture.

IV. Summary

Ultrafast time-stretch Lidar is a novel and powerful technique that can be adapted for various applications, from autonomous vehicles to spectroscopy, imaging, and sensing. Various transduction techniques exist to acquire and process a large amount of data which is a byproduct of continuous monitoring. The technique is limited by the laser pulse width, and dispersion-limited time-stretch power loss. However, it can be used for different spectral bands of interest in telecommunication, visible and mid-infrared, upon the availability of the dispersion element and amplification methodology within that spectral band.

REFERENCES

[1] H. Xia and C. Zhang, "Ultrafast ranging Lidar based on real-time Fourier transformation," Optics Letters, Vol. 34, No. 14, pp. 2108-2110, July 2009.

[2] Z. Zhang, H. Xia, S. Yu, L. Zhao, T. Wei, and M. Li, "Femtosecond imbalanced time-stretch spectroscopy for ultrafast gas detection," Applied Physics Letter, 116, 171106, 2020.

[3] A. Mahjoubfar, D. V. Churkin, S. Barland, N. Broderick, S. K. Turitsyn and B. Jalali, "Time stretch and its applications," Nature Photonics, Vol. 11, pp. 341-351, June 2017.

[4] Lijie Zhao, Haiyun Xia, Yihua Hu, Tengfei Wu, Zhen Zhang, Jibo Han, Yunbin Wu, and Tiancheng Luo, "Real-Time Femtosecond Ranging Lidar Based on All-Optical Signal Processing," May 2020.

[5] J. M. Payne, D. Parker, and R. F. Bradley, "Range finder with fast multiple range capability," Rev. Sci. Instrum. 63(6), pp. 3311–3316, February 1992.

[6] H. Xia, C. Zhang, "Ultrafast and Doppler-free femtosecond optical ranging based on dispersive frequency-modulated interferometry," Optics Express, Vol. 18, No. 5, pp. 4118-4129, March 2010.

[7] Y. C. Tong, L. Y. Chan, and H. K. Tsang, "Fiber dispersion or pulse spectrum measurement using a sampling oscilloscope," Electronics Letters, Vol. 33, No. 11, pp. 983–985, May 1997.

[8] Y. Zhou, J. C. K. Chan, and B. Jalali, "A Unified Framework for Photonic Time-Stretch Systems," Laser & Photonics Reviews, Vol. 16, No. 8, 2100524, June 2022.

[9] Z. Zang, Z. Li, Y. Luo, Y. Han, X. Liu and H.Y. Fu, "Ultrafast Parallel Lidar with Time-encoding and Spectral Scanning: Breaking the Time-of-flight Limit," Environmental Science, 2021.

[10] A. Kawai, K. Hashimoto, T. Dougakiuchi, V. R. Badarla, T. Imamura, T. Edamura, and T. Ideguchi, "Time-stretch infrared spectroscopy," Communications Physics, Vol. 3, No. 152, 2020.

[11] G. Herink, F. Kurtz, B. Jalali, D. R. Solli, and C. Ropers, "Real-time spectral interferometry probes the internal dynamics of femtosecond soliton molecules," Science 356, pp. 50-54, April 2017.

Dr. Mina Esmaeelpour has been an Assistant Professor in the Department of Electrical and Computer Engineering at Missouri University of Science and Technology since September 2019. Dr. Esmaeelpour holds a Ph.D. degree in physics from Lehigh University. Before joining Missouri S&T, she completed postdoctoral training at both Stanford University Medical School and Stanford University Engineering School for three years. She has extensive experience in fiber optics and fiber sensors.

Behzad Boroomandisorkhabi is a Ph.D. student in the Electrical and Computer Engineering Department at Missouri University of Science and Technology. He joined Missouri S&T in 2019. Before joining Missouri S&T, Behzad Boroomandisorkhabi got his Master of Science in electrical engineering from K. N. Toosi University of Technology in Iran. His research area is optical fiber and biomedical sensors.

DJI Matrice 300 Pro with a Zenmuse L1 Lidar package on a test flight at Chatfield State Park model airplane airfield, Colorado

Ground-based Lidar for Historic Preservation, Increased Accessibility, and Virtual Tourism

Michael Rogers, Department of Physics, University of Colorado Denver
Ekaterini Vlahos, Department of Architecture, University of Colorado Denver

I. Introduction

The first visible light electronic distance measuring (EDM) instrument, the Geodimeter, was created in 1953 [1]. While EDMs are an important surveying tool, it wasn't until the late 1990s when the time-of-flight Lidar scanning instruments were developed with the resolution and data gathering speeds sufficient for "as built" documentation and applied to historic preservation [2]. The Heritage Documentation Programs (HDP) within the U.S. National Park Service is one segment of the preservation field that engages Lidar to create a permanent record through drawing. The U.S. government created the Historic American Buildings Survey (HABS) in 1933 as one of three HDP. The other two include the Historic American Engineering Record (HAER) and, most recently, the Historic American Landscape Survey (HALS). All three documentation programs focus on diminishing the adverse effects of rapidly disappearing built environments and architectural resources. The documentation process and outcome include creating accurate measured drawings, interpretive drawings, photographs, written descriptions, and written histories of American historical buildings to be filed in the Library of Congress archives [3]. The Secretary of the Interior's Standards and Guidelines for Architectural and Engineering Documentation create the criteria for inclusion in the HABS/HAER/HALS collections [4].

A key component for inclusion in the Library of Congress collections is identifying the historical significance of the site, structure, or object. While hand measuring methods complement technology, the measured drawings submitted to the Library of Congress must be printed using ink and on an archival medium such as Mylar or Vellum. Photographs must be taken with a large-format camera with negative sizes of 4″ × 5″, 5″ × 7″ or 8″ × 10″ with the negatives submitted to the collection. These guidelines ensure the highest quality of documentation and guarantee that the documentation is in the public domain and accessible in the future.

The first portable Lidar scanners used for historic preservation had a limited field of view (40º x 40º) and limited range (50 m) and gathered about 1000 points per second. The Leica scanners used by our team have a field of view of 360º x 290º. The instrument on a tripod does not scan the area beneath. It can range from 120 m out to 1 km, gather 1 million points per second, and have onboard cameras for capturing true-to-life color [5]. We currently use the Leica ScanStation P40 for interior and exterior scans, which has a range accuracy of 1.2 mm + 10 ppm over the entire range, an angular accuracy of 8″ horizontal; 8″ vertical, and a 3D position accuracy of 3 mm at 50 m; 6 mm at 100 m. The Leica P40 is set up similarly to how one sets up a total station by placing the device on a tripod and leveling the instrument using a tribrach. Depending upon the selected data-gathering mode, the instrument may be set up over a known point on the ground. Ground-based Lidar technology, used for historic preservation and many other applications such as forensic investigations, bridge repair, and interior design to name a few, continues to improve in speed capture and accuracy. We will discuss some of the newest instruments in Section V, A Scanner for Every Task.

II. Common Field Methods for Historic Preservation

Free, Traverse, and Resection are three standard techniques for gathering data with the Leica P-series scanners. When scanning in Free Mode with no known points, orientation, or scanner height, the scanner is positioned in the desired location to gather the maximum data with minimal hidden features. This point is also selected with the next survey location in mind to ensure at least 30% overlap of the two scans to facilitate registering the scans to each other post-acquisition. The scanner is leveled, the scan and photographs acquired, and then the scanner is moved to another unmarked location with no azimuthal orientation. The following scan is initiated after leveling is completed. This mode minimizes field time but requires additional time post-acquisition to register all scans to make a single point cloud.

Traverse mode uses marked points on the ground (or on the floor) and targets to link all points together while acquiring scans. While using this mode, the first scan location is identified as a primary site datum, a location unlikely to move. Surveyor pins or markers are ideal, but metal access covers, edges of sidewalks, or other fixed features will work. Along with leveling the scanner, it is aligned over the marked point using a laser plummet, and the scanner height from the known point is entered into the system. The primary site datum may have a known coordinate such as latitude, longitude, or Universal Transverse Mercator (UTM) used for the project. A local survey grid system is established by assigning 1000.000 m x 5000.000 m x 500.000 m for Easting, Northing, and Elevation. This local grid system can be converted to a universal system post-acquisition if GPS data are collected for these points. A second point is then chosen to define the azimuth of the local survey grid. A target is placed over the second point and leveled. The P40 acquires the target similar to how one would use a total station and after the acquisition, the instrument sets the azimuthal angle for point one and records the location of point two in the local or universal grid system. After acquiring the scan and photographs at the first location, the scanner is moved to the second location and the target to the first. Once leveled and over the second point, a backsight to the first location is conducted to align the scanner back into the survey grid. Scan, photograph, set out the next location, move, backsight, and repeat. This field work is shown in Figure 1 at Trim Castle, Ireland.

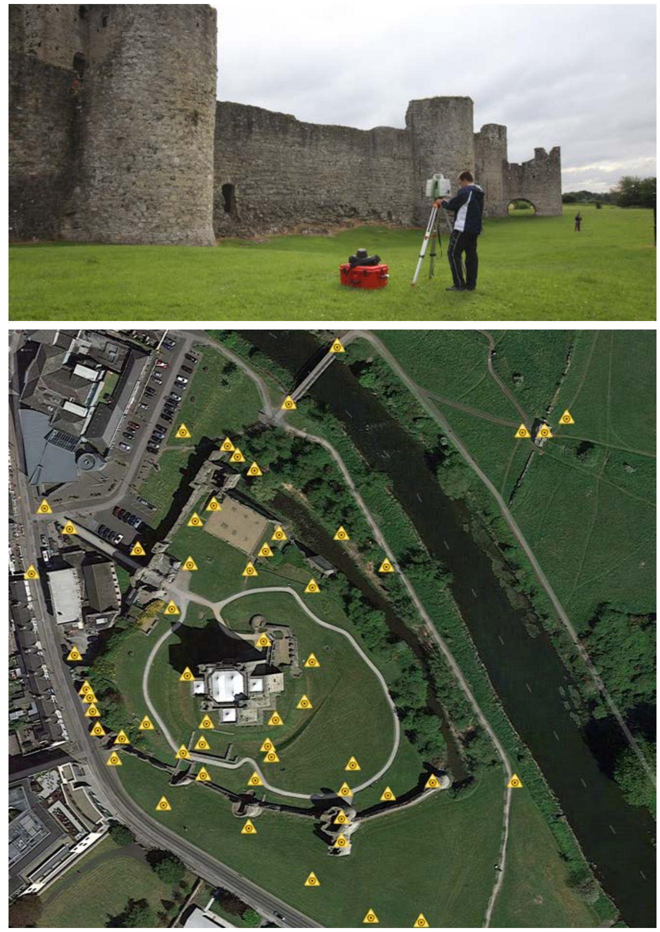


Figure 1: The Leica P40 in traverse mode backsighting to a prior point using a target outside of the curtain wall at Trim Castle, Ireland [6].

In Resection Mode, multiple targets are set up over known points. The scanner is placed over an unmarked point, leveled, scanner height is measured, and the various targets are selected and scanned to determine the scanner's location in the local grid system. Recording targets while in the field allows the scanner operator to know the level of precision of the scanner's locale. The P40 has options for four parameters, six parameters, or auto resection. Alternatively, a scan can be conducted without resection, and the multiple targets captured during scanning are used post-acquisition as part of the registration process.

The two main workflows involve taking the time in the field to register each scan location to the local survey grid with very little processing post-acquisition or spending less time in the area and registering each scan location back in the laboratory/office. With recent improvements in Leica's registration software (Leica Registration 360), the time to register post-acquisition is dramatically reduced, making No Orientation a more viable option. Registering while in the field allows for control over uncertainty levels and catching errors much easier, but planning and understanding how Leica's software registers the data makes the No Orientation option comparable to in-field registration, which comes with time and cost savings.

III. Detailed Scan versus Context Scan

A. Scanning Inside of a Building

Scanning resolution is based on project intent. The team typically records positional information every 0.005 m at the furthest distance of the object for detailed scans. For detailed scans, the Leica P40 measure distance option determines the furthest visible distance of the object being scanned. That distance is rounded up to ensure that the size of the sphere is larger than the scanned object to ensure that the lowest resolution in detailed scan mode is no more than 0.005 m. When scanning inside a building, all scans are detailed scans. Interior scan distances are much shorter than 50 m, so the 3D position accuracy of 3 mm at 50 m results in positional accuracies smaller than 3 mm.

Because the scanner moves using an angular increment, the scanning resolution is defined by the distance between points on a sphere of a radius set by the distance. Objects closer to the scanner will be in higher resolution, and objects further away will be in lower resolution. Once the distance and resolution are set, the scan is started and takes approximately 2-5 minutes for a standard room. Acquiring photographs takes 5-10 minutes, depending on whether one uses an external camera or the P40's internal camera.

Each interior space is documented using one or more scan locations to ensure complete coverage and minimal 'shadows.' When recording Old Fort Johnson, a historic house that was part of the American Revolutionary War located in Fort Johnson, NY, 43 interior scan locations were needed. Old Fort Johnston is a two-story, central passage stone house with four rooms on the first floor with the central hallway and staircase, four rooms on the second floor, and an attic and basement. President Lincoln's Cottage, located in Northwest Washington D.C., is where President Lincoln and his family resided during the hot and humid D.C. summers and where he drafted the Emancipation Proclamation (Figure 2). President Lincoln's Cottage is larger with a more complex interior than Old Fort Johnson and required twice the number of interior scans.

B. Scanning Outside of a Building

While scanning the exterior of a building requires a detailed scan (a reading every 0.0005 m or closer) of the building, we also want to record the context around the building. After positioning the scanner at a location to ensure detailed coverage of the building, the first scan is a Context Scan, where the scanner is set to record points every 0.250 m at a 100.000 m distance. After acquiring the scan and photographs, the building region to be scanned at the higher resolution is selected using the computer screen on the P40. The measure distance option is used to determine the furthest distance. This distance is rounded up and entered into the instrument. The context scan is then displayed, a stylus is used to select the region of interest, and the Detailed Scan is initiated.

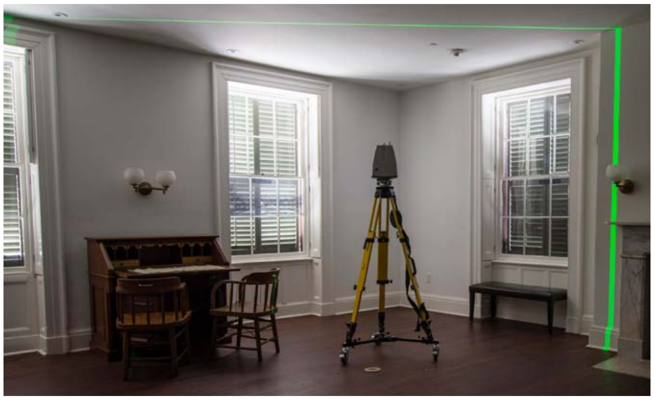


Figure 2: Long-time exposure while scanning the room of President Lincoln's cottage where Lincoln is thought to have drafted the Emancipation Proclamation; the desk is a reproduction with the original located in the Lincoln Bedroom at the White House. The scanner is an older Leica model, the C10, that uses a 532 nm wavelength laser whereas the P40 uses a 1550 nm wavelength laser.

A detailed exterior scan of a selected region can take a few minutes to a few hours to capture data, depending on the scanner's location and the size of the object being scanned. Figure 3 shows the Leica C10 scanning Ferns Castle in Ferns, Ireland. The C10 records 50,000 points per second compared to the P40. The context scan with photographs took 11 minutes, and the detailed scan took 49 minutes using the C10. This same scan with the P40 would take about 10 minutes for the context scan with photographs and seven minutes for the detailed scan. Because the detailed scan is taken from the exact location as the context scan without moving the scanner, there is no need to take a second set of photographs.

IV. Phototexturing

Assigning color (phototexturing) point clouds generated by the Leica C and P series scanners can be done with the onboard digital camera or an external digital single-lens reflex (DSLR) camera. After scanning, the onboard digital camera captures 274 1920 pixel by 1920 pixel images in approximately 10 minutes. The RGB color from these images is then automatically assigned to the XYZ coordinates in the point cloud by the Leica software. An alternative method to capturing images is to remove the scanner from the tribrach and mount a DSLR camera at the nodal point of the scanner. Using a wide-angle lens, four to six images are captured at the camera's highest resolution using a high dynamic range. These photographs are then

Figure 3 shows the resultant point cloud of Trim Castle in Trim, Ireland

merged into a spherical panorama using a program such as PTGui and then exported as Cubed-faced images for import into the Leica processing program, Cyclone. Common points are manually selected in the point cloud and photographs to give the software enough control points to orient the Cubed-faced photographs with the point cloud. Once oriented, the software assigns RGB values to the XYZ points in a fashion similar to the onboard camera method.

Using the onboard camera takes longer in the field, with less control over the image quality. However, it saves time post-acquisition with the Leica software auto-registering the images with the scan data. Taking photographs with an external camera allows one to use a high-resolution DSLR, a high-quality lens, and control all camera settings. The resulting images may produce a noticeably better colored point cloud, but the real advantage is the photographs themselves. Along with the point cloud data, the photographs are part of the documentation and can be used to create 3D views displayed on websites for virtual tourism. Note that digital photographs are currently not acceptable for submission to the Library of Congress as part of HABS documentation. Conversely, color digital images of the documented resource are accepted and included in the field notes accompanying documentation project materials.

V. A Scanner for Every Task

To understand the timeline of improvements to ground-based Lidar instruments, Leica's 2006 release of their HDS6000 is a good starting point [7]. With a range of 79 m at 90% reflectivity, a field of view of 360 x 310, and an integrated computer with a control panel, the HDS6000 phase-shift scanner looks similar to today's scanners. The real breakthrough was the incorporation of tilt compensators, which allowed for survey-grade data similar to data captured with a total station. The C10's release in 2010 improved upon the HDS6000 by moving to a pulsed, time-of-flight system that achieved distances of 300 m at 90% reflectivity but came with a decrease to 50,000 pts per second. The P40 was released in 2015 with an increase in operating temperature range, a distance of 270 m at 34% reflectivity, and achieving 1,000,000 points per second, dramatically decreasing scan times. In 2017, the P50 increased the P40's maximum distance of 270 m out to 1 km at 80% reflectivity.

In 2016, Leica released the BLK 360, and in 2018, the RTC 360, to complement their P-series scanners. These scanners are designed to be fast, lightweight, small, have a scan distance of only a few tens of meters, and improve onboard image quality. Scans are acquired through a one-touch onboard screen or via a wirelessly connected tablet. The RTC360 uses a Visual Inertial System where internal sensors monitor the movement of the scanner from one location to the next, with the software auto-locating the scanner in a local grid system with no need to set out and backsight points. The RTC360 has tilt compensation for one axis and is limited to a 10-meter range.

A scan at Detailed Scan settings takes about two minutes, and HDR images take an additional two minutes. Once the first scan is complete, the scanner is moved to the next location and set up without the need to level, measure instrument height, or locate over a distinct point within the local grid. The movement of the scanner can be monitored on the tablet. The tablet displays the scans after automatic transfer at the end of each scan and can be used to further refine linking two scans together. This process is accomplished by visually rotating and moving the scans. The software then runs a registration algorithm to link the two scans. The RTC360 brings improvement to the hardware along with improved software.

Each scanner has its application, with a combination of scanners ideal for historic preservation. While documenting an entire city block in downtown Denver in the summer of 2022, the team used the P40 for exterior scans where the precision of the two axes tilt compensation was needed out to a distance of 130 m to document a 50 m tall apartment building. Over seven days, the two scanners captured 660 scans for a total of 0.63 terabytes of data.

A recently acquired DJI Matrice 300 RTK with a Zenmuse L1 Lidar scanner payload would have been ideal to operate during the summer of 2022 to document a site with buildings spread out in a larger landscape. The team did not have the drone-based Lidar at the time, and it took four days and 155 scan locations to document the buildings and landscape. The first test flight of the Matrice 300 covered an area approximately an eighth the size of the summer project. The total flight time was about eight minutes, with three minutes of laser scanning time. In the future, what took us four days on the ground will be replaced by 30-45 minutes of drone flight time.

We also have a suite of structured light scanners that range in resolution from 0.5 mm to 0.05 mm. These are used for documenting fine architectural details, such as the papier mache decorative ceiling at the Philipse Manor Hall historic site in Yonkers, NY. These scanners are designed to document small to medium-sized objects such as a desk. This scanner and an RTC360, and a DJI Matrice drone are shown in Figure 4.

(a) (b) (c)

Figure 4: (a) The Leica RTC 360 scanning inside of the mercantile at Sakura Square [photo credit: Jesse Kuroiwa], (b) DJI Matrice 300 Pro with a Zenmuse L1 Lidar package on a test flight at Chatfield State Park model airplane airfield, Colorado, and (c) Artec Eva structured light scanner at Philipse Manor Hall, New York.

VI. Increased Accessibility and Virtual Tourism

Point clouds generated by structured light, ground-based Lidar, and drone-based Lidar can be combined into a single, unified point cloud or broken into separate, distinct architectural elements. The point cloud(s) will follow different workflow paths based on project needs, with the original point cloud always available to meet future yet-to-be-defined requirements. For example, when developing a set of HABS drawings, the point cloud is divided into manageable architectural elements that will be used to create the measured drawings. In the workflow, the desired portion of the point cloud (e.g., commercial, residential, worship, landscape) is exported and then imported into programs such as AutoDesk CAD or Revit. The tools in AutoDesk can snap to the point cloud and reduce it to a measured drawing in a plan or profile view.

Another workflow path is to mesh the point cloud into a mesh or watertight model using programs such as Leica 3DR, Blender, or MeshLab. These meshed models can be 3D printed or phototextured and displayed in Augmented Reality (AR) or Virtual Reality (VR) using devices such as a web-based WebXR viewer, an Oculus, or a Microsoft HoloLens (to name just a few available viewers). The structured light surveys of the papier-mâché ceiling at Philipse Manor Hall were inverted and used to create 3D-printed molds. The molds were used to make papier-mâché replicas of the 53 distinct elements in the ceiling that were then installed on a ceiling at the Schuyler Mansion.

Beyond creating a high-fidelity digital record for historic preservation, our research addresses accessibility and virtual tourism. Historic places open for visitation often have inaccessible areas to the public and other sites not accessible based on mobility. Interpretive signs can aid in bringing some experience to these hard-to-access spaces, but 3D point clouds and meshed models with photorealistic texture can bring these spaces virtually to the visitor. Adding a kiosk with a monitor, an augmented reality device, virtual reality device, or all three gives visitors a chance to explore all areas while visiting a historic site. These devices can also reconstruct missing elements and even provide visitors with views of the site through time. Visitors to the General Schuyler House in Schuylerville, NY get to tour the house and walk the grounds around the house. Missing from such a visit, is experiencing all of the mills, barns, and quarters of enslaved people and workers, all of which no longer exist on the landscape. All of these elements can be digitally reconstructed and geolocated in a WebXR viewer, where visitors with a tablet or phone can view these structures while walking the property. Experiencing augmented and virtual reality while physically visiting an historic site can bring a deeper understanding of the physical context; however, virtual visitors can also visit these sites from afar.

REFERENCES

[1] Cox, Ronald, "Distance-Measurement, Electromagnetic," pp. 177–180 in Robert Bud and Deborah Warner, eds., *Instruments of Science* (New York and London, 1998).

[2] Spring, Adam P. "A history of laser scanning, part 1: space and defense applications." *Photogrammetric Engineering & Remote Sensing* 86.7 (2020): 419-429.

[3] Burns, John A., ed. Recording historic structures. John Wiley & Sons, 2003.

[4] https://www.nps.gov/hdp/standards/index.htm

[5] https://scantech-international.com/blog/timeline-of-3d-laser-scanners

[6] Rogers, Michael 'Bodhi, Ryan Bouricius, Denis Shine, Stephen Mandal, and Scott Stull. "Laser-Scanning Trim Castle." *Archaeology Ireland* 32, no. 3 (2018): 34-39.

[7] https://www.geospatialworld.net/news/leica-geosystems-launches-leica-hds6000-scanner/

Michael "Bodhi" Rogers is a Professor and Chair in the Department of Physics at the University of Colorado Denver. Along with being a Ph.D. physicist he is also a registered professional archaeologist. He specializes in below ground imaging such as ground-penetrating radar, magnetometry, and earth resistance, and 3D model creation using photogrammetry, structured-light scanning, and time-of-flight scanning. His research includes the creation of 3D models of cadaveric arms to document efficacy for new wrist and elbow surgeries, documenting historic structures, and developing methods of viewing LiDAR data using a web-based viewer and WebGL.

Ekaterini Vlahos is a Professor of Architecture at the University of Colorado Denver. As a licensed architect and former Director of the Center of Preservation Research (CoPR), her research focuses on developing innovative methods using cutting-edge technologies to promote informed decision-making for preservation and sustainable design. She is the recipient of the Preservation Leadership Award and, in collaboration, the Stephen H. Hart Award for outstanding preservation projects. Professor Vlahos serves on the CIPA International Scientific Committee of ICOMOs and the National Council for Preservation Training and Technology Board.

Making Impact, Growing Connections

With the return to in-person activities post-COVID, 2022 was a banner year for IEEE-Eta Kappa Nu filled with growth, new initiatives and the implementation of many of the goals set forth at the January Board retreat. With a reinvigorated committee structure, strong leadership, hard work, and the dedication of superlative volunteers, we are proud to look back on some of the achievements of 2022.

Chapter Service Hours passes the 100,000 mark!

IEEE-HKN Chapters reported more than 100,000 hours of service in 2022.

Our members are filling a great need on their campuses, in their departments and communities. Service work includes: tutoring, STEM outreach, workshops, and plan.

Now more than ever, HKN students are helping other students succeed, making a difference as Universities return to on campus activities and bridge the learning gap created by COVID.

Chapters Reinvigorated through Donor-funded Grants Program

A generous donation from John McDonald, Beta Chapter, and his wife, Jo-Ann, provided the first gift in support of this dedicated Fund aimed at providing chapters with a US$250 grant to support community service, academic support, or Chapter-Building activities. Since March of 2022, the following eight Chapters received the grant through this program:

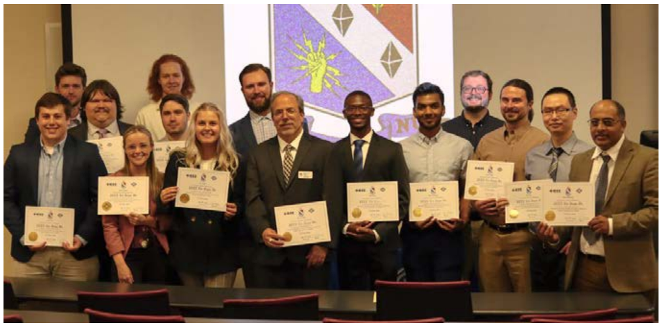
- Mu Chapter (University of California, Berkeley)
- Mu Iota Chapter (Seattle University)
- Delta Omega Chapter (University of Hawaii - Manoa)
- Epsilon Mu Chapter (University of Texas at Arlington
- Beta Chapter (Purdue University)
- Chi Chapter (Lehigh University)
- Lambda Xi Chapter (Hofstra University)
- Nu Epsilon (Kennesaw State University)

A video documenting the ways that Chapters have leveraged their funding can be found here. In addition to direct funding, Chapters can receive coaching from HKN volunteers and staff through this initiative. In 2022, 20 Chapters took advantage of this relationship which yielded the following results:

- 10 have reported one or more induction ceremonies
- 11 have reported new officers
- 7 have submitted at least one Activity Report
- 5 have submitted the 2021-2022 Annual Report
- 4 have regained Active Status

New Chapter Established at Kennesaw State University

On April 24, 2022, the Nu Epsilon Chapter was established at Kennesaw State University. Governor-at-Large Ryan Bales presided over the ceremony. Eleven charter members were inducted into the chapter.



Induction ceremony at the Nu Epsilon Chapter

The work continues! The IEEE-HKN Board of Governors has identified “Strengthening our Chapters” as a top priority in 2023. If you would like to be involved in the Chapter Support Initiative or donate to the Chapter Support Fund, please contact us.

HKN staff member, Sylvie Leal, was promoted to a newly-created position, Chapter Relations and Operations Administrator to facilitate the strengthening of Chapters around the world.

2022 Year in Review

	2021	2022	% Increase YOY ↑
Total **HOURS IN SERVICE** to HKN	65,778	100,000+	52% ↑
Service, Education, Outreach **HOURS**	29,492	39,113	14% ↑
Total Hours of **STEM OUTREACH EVENTS**	4,920	7,163	46% ↑

2,200 Number of Inductions

45 Number of Sponsors

765 Total Number of Conference Attendees

54 Total Number of Chapters Represented

Chapter activities in 2022

Building Alumni Relations with Four In-Person Receptions Across the Regions

The adage, "Once Eta Kappa Nu, always Eta Kappa Nu" was put into practice this year with four in-person receptions held across three regions connecting with close to 150 alumni. These receptions allowed for alumni to share memories, learn what HKN can offer them currently, and ways they can support current students. Below are the locations and dates of the 2022 receptions:

- 19 March at IEEE RadarCon in New York, NY
- 2 April at Region 3 SoutheastCon in Mobile, AL
- 19 July at IEEE PES General Meeting in Denver, CO
- 11 October at IEEE Phased Array Symposium in Waltham, MA

Speaking at the Alumni Reunion held in Denver, Jim Jeffries, former IEEE President related, "50 years after my induction, the HKN Alumni reunion reminded me again that I had joined as a professional and not just taken a job and was a chance to catch up on the expanding role of HKN's commitment to scholarship, service, and the Profession." More Alumni receptions are being planned for 2023. To learn more about how to reconnect as an HKN alum, visit: https://hkn.ieee.org/ieee-hkn-alumni-reconnect-form. If you would like to host an alumni reception, reach out to Nancy Ostin at n.ostin@ieee.org.

Funding for our Alumni Receptions was provided by a generous donation from Dr. and Mrs. Richard Gowen.

HKN Students at the SoutheastCon Alumni Reception

Alumni Reception at IEEE PES General Meeting in Denver, CO

Uplifting Graduate Students for Success

In 2022, a pilot Alumni - Graduate Student Mentoring Program was spearheaded by Joseph Greene, 2022 IEEE-HKN Student Board member, in an effort to forge closer ties between professional HKN members and graduate students, stating "Whereas advisors focus on your collegiate success, mentors are invested in you. By engaging with you in a broader context, mentors use their experience to help you set reasonable career expectations, set personal goals, as well as strive towards your personal and professional success."

The pilot program had the dedicated participation of nine mentors supporting 14 graduate students. Mentors and mentees formalized their goals by signing a contract which also included agreed upon meeting times and topics to cover which ranged from how to build a start-up while bonding to how to evaluate post-graduation job offers. John D. McDonald, IEEE Life Fellow and Member of National Academy of Engineering, who served as a mentor stated, "There's no greater feeling as a mentor than to use your experience to help others achieve success themselves. When they accomplish something they didn't think they could do, and they are so happy and confident, and they say that they couldn't have done it without your help, that's what it is all about." John's mentee, Sabrina Helbig, a graduate Electrical Engineering student at the University of Pittsburgh and President of IEEE-HKN's Beta Delta Chapter, is grateful for the help that she has received stating, "my mentor has helped me to reach for opportunities that I may not have otherwise been able to grasp, that I was maybe afraid to pursue, or that I hadn't even thought about. He has introduced me to new people, encouraged me to share my own knowledge

John McDonald and Sabrina Helbig

and experience to help others, and bolstered my confidence in myself. There are many things that we can achieve on our own, but we can achieve so much more with a mentor by our side."

Joe Greene looks forward to watching this initiative grow to encompass more HKN members in the future and would be thrilled to include any Alumni, Professional, and Graduate students members in our next round of mentoring. Any interested parties can contact info@hkn.org to get involved.

HKN Events, Podcast, Webinars and more!

HKN's greatest strength is its network of engineering professionals in all stages of their careers and education. 2022 saw the continued leveraging of this network to share expertise in a host of different formats including its online conferences, Pathways to Industry, HKN TechX, and innovative new podcast series entitled Career Conversations. Career Conversations has reached a combined audience of over 700 and covered relevant career topics, such as Career Planning, Effective Mentoring, Public Policy, Ethics, Workplace Conflict and Imposter Syndrome. Produced by members of the HKN Young Alumni Committee, the podcast series engages experts from throughout the HKN community in a conversational format that is informal, informative, and leading-edge.

To meet the specific needs of HKN graduate students two areas of content were developed: the Grad Labs webinar series and Graduate Student Spotlights in *THE BRIDGE* Magazine. Produced in partnership with Tufts University, Grad Labs helps graduate students navigate topics such as finding research topics, how to train your advisor, and how to manage interpersonal relationships. Graduate Student Spotlight showcases graduate student's research work and is made possible through the dedication of Dr. Katelyn Brinker, Chair of the HKN Public Relations and Communications Committee. In 2022, the BRIDGE's Graduate Student Spotlight Feature was honored with a 2022 APEX Award for Publication Excellence for Best Feature. The award was *THE BRIDGE* Magazine's 10th CONSECUTIVE AWARD OF EXCELLENCE and honored the work of Dr. Sahra Sedigh Sarvestani, Co-Editor-in-Chief, Dr. Steve Watkins, Co-Editor-in -Chief, Nancy Ostin, Managing Editor and Katelyn Brinker, Spotlight Editor.

IEEE-HKN Website Updated

Our new website featuring videos, photos, a members only area, and enhanced tools was launched in January. Take a TOUR, visit us at www.hkn.org.

With new Chapters, more services hours, new communications tools and new leadership, HKN is poised for even more success, learning, networking and support for a productive, dynamic 2023.

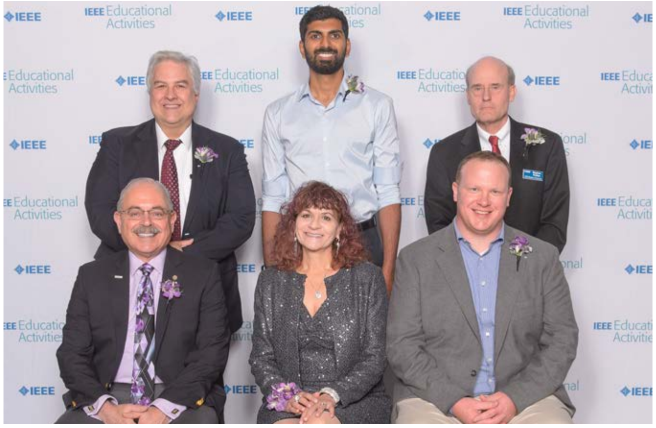
2022 HKN Awardees at IEEE November Meeting Series

IEEE-HKN Asad M. Madni Outstanding Technical Achievement and Excellence Award: *Dr. Albert Pisano,* Dean of Engineering, Jacobs School of Engineering at the University of California, San Diego

IEEE-HKN Distinguished Service Award: *Dr. Karen A. Panetta,* 2019 IEEE-HKN President and Dean for Graduate Education at Tufts University

C. Holmes MacDonald Outstanding Teaching Award: *Dr. Thomas D. O'Sullivan,* Associate Professor of Electrical Engineering at University of Notre Dame

Outstanding Young Professional Award: *Dr. Achuta Kadambi,* Assistant Professor at the University of California, Los Angeles Department of Electrical and Computer Engineering



2023 IEEE-HKN Awardees

Record Attendance for 2022 IEEE-HKN Student Leadership Conference

"Networking with alumni from the chapter and with IEEE as a professional after graduation," "the ideas for building community and leveraging our various networks," and "collaborate with local chapters" were just a few of the key takeaways expressed by students who attended the Student Leadership Conference (SLC) on October 28-30, 2022, held at the University of North Carolina at Charlotte. The conference broke attendance records with over 250 students, advisors, recruiters, IEEE Society members, HKN Board members, and staff gathered for two-plus days of learning, networking, and community building. As its first in-person gathering since 2019, the 2022 HKN SLC attracted participants from 54 chapters from five different countries. Funding generously provided by the Samueli Foundation helped offset registration and travel costs for chapters.

The 2022 HKN SLC provided Chapter officers and members a way to hone their leadership skills, connect with each other, and hear from industry experts on how to prepare for their future careers. Students had the option to attend workshops from four different tracks—Chapter development, Career development, IEEE Technical Societies, and Technology—giving them a wide range of learning opportunities. A robust recruitment fair offered students the chance to meet with over 26 potential employers, IEEE Societies, and graduate schools. The recruitment fair was a win-win, according to Cindy Tiritilli, Senior Member and Program Director for the IEEE Communications Society, who stated "Our partnership with IEEE-HKN has opened doors to new relationships and new opportunities to connect with the next generation of our community. Through HKN's events, we are able to showcase IEEE Communications Society (ComSoc) to some of the best and brightest students and alumni and learn about what they need to be successful in our industry."

Gamma Theta students learn about the IEEE Education Society from Russ Meier.

The jam-packed conference opened Friday afternoon with a Fox Hunt sponsored by Keysight and Test Equity in which student teams scoured the beautiful UNC Charlotte campus looking for hidden transmitters using handheld directional antennas. This activity provided the perfect way for students to engage with each other from the onset of the meeting. On Friday evening, conference participants were welcomed by UNC Charlotte Chancellor Sharon Gaber who oriented conference attendees to the city of Charlotte and UNC Charlotte. Another highlight of the opening session was the celebration of Founders Day which paid tribute to Maurice Carr and the eight other undergraduate students who founded Eta Kappa Nu on October 28, 1904. The event was live streamed on YouTube: https://www.youtube.com/watch?v=Yvzi5vwYfbA.

On Saturday morning, participants were treated to a talk by Brandi Burnett, Director of Strategic Planning - Tactical Space Systems Division for Northrop Grumman followed by an afternoon of workshops and panels. The conference offered 23 sessions on wide-ranging topics like "IEEE and Public Policy," "Engineering Topics that Impact Climate," and "From We Want Money to We Have Money: Chapter Finances and Grants." Regional meetings allowed chapters to connect and plan future collaborations. Also, the IEEE MOVE Truck, which provides victims of natural disasters with short-term communications infrastructure, computer, and power solutions, was on-hand to inspire students to think of ways they too can serve their local communities.

Students celebrate IEEE-HKN Founder's Day

After a full day of learning and bonding, conference participants headed to an awards dinner at the NASCAR Hall of Fame in downtown Charlotte. IEEE-HKN Board President and conference host, Dr. James Conrad, presided over the festivities where 42 Key Chapter Awards were presented, and board members and sponsors were thanked for their contributions, including OSA finalist Ashley Kuhnley, Eleanor Jackson, and long-time staff member, Stacey Bersani.

The conference closed out on Sunday morning with four labs and a TI workshop. For student attendee Silas Perry, a junior at the University of Nebraska studying computer engineering, "The IEEE-HKN conference was a life-changing event," summing up the impact the conference had on him by stating, "I would have never had the opportunity to meet such lovely people, nor such fantastic companies. I walked away from the conference with new friends, opportunities, and ideas for my chapter, Beta-Psi." Silas was not alone in seeing the value of attending the 2022 Student Leadership Conference. Close to 98% of students responding to a post-conference survey stated that they are highly likely to encourage other chapter mates to attend next year's SLC, which promises to make the 2023 SLC even better!

Dear HKN Members,

Greetings!

It is a pleasure to wish you all a happy new year! I'm excited to connect with you through this presidential message. I'm humbled and honored to serve as the global president of the 2023 IEEE Eta Kappa Nu Board of Governors (BoG) and for the opportunity to serve IEEE-HKN members globally this year. My mission is to serve the needs of HKN members and deliver unique member-enriching experiences at the grassroots. **"Members like you are the heart and soul of IEEE-HKN. I strongly believe that student members, chapter advisers, and alumni, are the pillars of IEEE-HKN. Without you, the story of HKN's progress, success, and growth is not complete".**

My top priority is to deliver an exceptional membership experience and address the key challenges faced by chapter leaders. To achieve this goal, the 2023 HKN BoG plans to launch a portfolio of high-impact, global programs that will promote career development, increase transnational networking opportunities, strengthen partnerships with industry and global organizations, and make IEEE-HKN one of the world's top trusted sources in technology and innovations. This year, the HKN BoG will focus on the following five top priorities:

1) Strengthen Chapters
2) Strengthen Committees
3) Build the Brand
4) Strengthen Collaboration and Partnerships
5) Scale up Development Efforts.

We are starting the year with a great team that will continue to grow the portfolio of impactful programs aimed at strengthening IEEE-HKN's position as a world leader in technology and science. The 2023 IEEE HKN BoG team is already working on defining a well-thought roadmap to make 2023 an impact year. To achieve that, we are meeting with key leaders from across IEEE to define joint partnership programs. Particularly, we plan to develop and deliver programs with major IEEE Boards, IEEE Societies, IEEE Regional Leadership, and Industry. IEEE-HKN will collaborate both within and beyond IEEE, to foster a community of technologists reflecting our core values of scholarship, character, and attitude.

HKN conference programs such as a) Pathways to Industry b) IEEE-HKN TechX c) IEEE-HKN Student Leadership Conference d) Pathways to Academia and d) IEEE-HKN Grad-Lab offer an exciting opportunity for our members to connect with world leaders in science and technology, and provide a great opportunity to support continuous learning and professional development. I would like to encourage our members to participate in these programs.

IEEE-HKN offers an exciting lineup of global awards and recognition programs designed to promote and encourage educational and professional excellence in electrical and computer engineering, computer science, and the IEEE fields of interest. These awards recognize outstanding accomplishments by students, professors, and industry professionals who make significant contributions to society, and who exemplify a balance of scholarship, service, leadership, and character. IEEE-HKN encourages chapters and individuals to nominate all eligible candidates in the upcoming 2023 awards cycle.

To increase our interaction with members, we are launching a fire-side chat program with the president this year. Through this program, I plan to regularly meet our members, chapter leaders, and alumni to learn about the fantastic work carried out by IEEE-HKN chapter leaders globally and also act on the key challenges faced by volunteer leaders.

I'm committed to launching impactful member engagement programs to advance the growth of HKN globally. Together as a team, I'm confident in building a vibrant, life-long global community that will inspire, connect, and engage IEEE-HKN members to advance technology for the benefit of humanity and deliver an inclusive and prosperous future for everyone.

I take this opportunity to thank your chapter leadership, chapter advisers, and alumni for your dedication and gift of time towards HKN activities. I look forward to traveling on this journey with you. Please feel free to reach me if I can be of any support.

Sincerely,

Sampathkumar Veeraraghavan
President, 2023 IEEE-Eta Kappa Nu

IEEE-HKN Welcomes New Members of the Board of Governors

The 2023 IEEE-Eta Kappa Nu (IEEE-HKN) Board of Governors welcomed five new members, and a 2022 Governor At-Large was elected President-Elect. They took office on 1 January 2023.

Sampathkumar Veeraraghavan, Epsilon Delta Chapter, will lead the society as President in 2023. He is best known for his technological innovations in addressing global humanitarian and sustainable development challenges. He has successfully delivered cutting-edge technologies in areas of conversational Artificial Intelligence (AI), Natural Language Understanding (NLU), cloud computing, enterprise systems, infrastructure technologies, and assistive and sustainable technologies.

Dr. Ryan Bales, Gamma Theta Chapter, was elected 2023 President-Elect. He served as IEEE-HKN Governor At-Large from 2020 to 2022. Dr. Bales is a Principal Research Engineer with the Georgia Tech Research Institute's Sensors and Electromagnetic Applications Lab and has 17 years of experience in applied research in embedded systems and electronic warfare. He has led the development of the digital signal processor for the Angry Kitten advanced electronic warfare program since its inception in 2011. He mentors junior engineers in the areas of embedded system design and signal processing and encourages service as part of their professional growth.

Dr. James M. Conrad, former IEEE-USA President and current Professor and Associate Chair of the Department of Electrical and Computer Engineering at the University of North Carolina, Charlotte, will serve as 2023 Past President. He is a member of the Beta Eta Chapter and previously served as President, President-Elect and the MGA Governor At-Large on the HKN Board.

Denise Griffin, Epsilon Delta Chapter, will serve as Region 1-2 Governor for a three-year term. She began her career in Systems Engineering with GTE Government Systems and then worked for startup companies. After one of the startup companies was acquired by Cisco Systems, she created and managed the Technology Partner Program, supporting companies as they integrated their products with Cisco. She then took time off to raise her family, during which time she volunteered extensively in both IEEE and SWE, creating many impactful programs and events. She successfully returned to work in industry in 2011 and credits volunteer work for helping her to regain employment. Since 2011 she has focused on Customer Success roles and currently works as a Customer Success Manager at Parlance.

Dr. Supavadee Aramvith, Eta Chapter, will serve as Region 7-10 Governor for a three-year term. She is an Associate Professor at the Department of Electrical Engineering, specializing in Video Technology. She has successfully advised 11 Ph.D., 27 Master's, and 36 Bachelor's graduates. She has rich project management experiences as the project leader and former technical committee chair to the Thailand Government bodies in Telecommunications and ICT. She has successfully spearheaded and delivered high impactful member engagement and global and regional initiatives on various IEEE boards and committees.

Amy Jones, Gamma Theta Chapter, will serve a three-year term as Governor At-Large. She began her career as a Project Engineer at Sachs Electric Company in St. Louis. In 2010, Amy joined John Deere full-time as a Software Verification and Validation Engineer in the Construction and Forestry

Division. In 2014, she became Senior Systems Engineer for the Excavators Outside the Americas product line and led a global team to define, develop, and implement electrical systems that meet the needs of a diverse customer base. Her team delivered 11 models to production in four years. Currently, she is the Display Product Manager. She has a driving passion for STEM (science, technology, engineering, and mathematics) outreach.

Matteo Alasio, Mu Nu Chapter, was elected to a one-year term as Student Governor. He is a Ph.D. student at the Politecnico di Torino in the Microwave and Optoelectronic group. As a member of IEEE-HKN, he organized events and participated in HKN's international events. He also led the Chapter's tutoring and study group efforts. Matteo said the university has given him the opportunity to work and study on the topics that are his passion, but also the chance to get in touch with many professionals and discover that a several of them are HKN members.

Elanor Jackson, Gamma Theta Chapter, was elected to a one-year term as Student Governor. She is pursuing a Ph.D. in Computer Engineering at Missouri S&T as a GAANN Fellow. She was inducted IEEE-HKN in Spring 2020 and served in a variety of chapter roles, including two terms as president. She received the Chapter's Advisors' Leadership Award and the IEEE St. Louis Section Outstanding Undergraduate Award. As an undergraduate, she participated in a research exchange with the University of Ljubljana in Slovenia, worked as a summer intern for Garmin, and conducted research on cybersecurity.

Congratulations to the 42 Key Chapter Recipients for 2021-2022!

IEEE-HKN is excited to announce that 42 Chapters have achieved Key Chapter status for the 2021-2022 academic year. Key Chapter recognition celebrates chapters that participate in activities identified as the best practices of successful chapters. Every Chapter has the potential to earn the Key Chapter recognition. Key Chapter banners were presented on 29 October 2022 during the Awards and Recognition Banquet at the Student Leadership Conference.

Congratulations to the members, officers, faculty advisors and department heads of the following Chapters:

Beta	Purdue University
Beta Delta	University of Pittsburgh
Beta Epsilon	University of Michigan
Beta Eta	North Carolina State University
Beta Gamma	Michigan Technological University
Beta Mu	Georgia Institute of Technology
Beta Xi	University of Oklahoma
Delta	Illinois Institute of Technology
Delta Omega	University of Hawaii, Manoa
Delta Xi	Air Force Institute of Technology
Epsilon	Pennsylvania State University
Epsilon Beta	Arizona State University
Epsilon Epsilon	University of Houston
Epsilon Eta	Rose-Hulman Institute of Technology
Epsilon Mu	University of Texas at Arlington
Epsilon Phi	California Polytechnic State University
Epsilon Sigma	University of Florida
Gamma Phi	University of Arkansas
Gamma Rho	South Dakota State University
Gamma Theta	Missouri University of Science and Technology
Iota Gamma	University of California, Los Angeles
Kappa Alpha	Northern Illinois University
Kappa Phi	University of North Carolina Charlotte
Kappa Psi	University of California, San Diego
Kappa Upsilon	University of Texas, San Antonio
Lambda	University of Pennsylvania
Lambda Beta	California State University, Northridge
Lambda Lambda	American University-Sharjah
Lambda Omega	National University of Singapore
Lambda Tau	University of Puerto Rico, Mayaguez
Lambda Zeta	University of North Texas
Mu	University of California, Berkeley
Mu Alpha	UCSI University – Kuala Lumpur
Mu Beta	Arab Academy For Science & Tech – Alexandria
Mu Kappa	University of Queensland
Mu Nu	Politecnico Di Torino
Mu Rho	Valparaiso University
Nu	Iowa State University
Nu Alpha	Univ Nacional De Educacion A Distancia
Nu Gamma	The College of New Jersey
Theta Lambda	University of South Alabama
Zeta Iota	Clemson University

HKN Chapters Foster Collaboration

Throughout 2022, HKN Chapters around the world planned events with other IEEE groups and with each other, demonstrating the value and importance of working together. Here are some ways they did it.

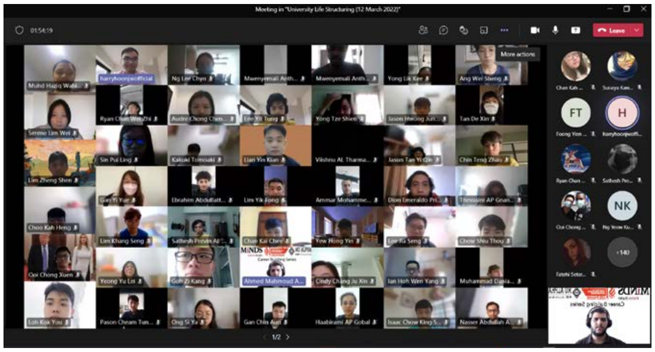
To honor Eta Kappa Nu's Founders Day, the Mu Kappa Chapter at the University of Queensland and the Mu Alpha Chapter at UCSI University – Kuala Lumpur came together for a virtual social gathering. Members of both Chapters showcased their keynote Chapter events of the past year in order to share ideas and celebrate each other's achievements. Socialization and online games, such as Skribbl, followed.

This inter-Chapter connection stemmed from unique circumstances. A Mu Alpha Chapter officer transferred to the University of Queensland and became involved with the Mu Kappa Chapter there, while keeping in touch with her Chapter of induction in Kuala Lumpur. This bridged the gap between two HKN Chapters that are over three-thousand miles apart.

Amtul Shaafi Hanaa, a Mu Alpha Chapter member, reflects on the event: "It was a fun experience… Such collaborations tend to be good learning experiences and can let us form better connections with other Chapters. We get to know more through their sharing sessions and learn from them about how they conduct their Chapter. It is especially useful for networking, as we meet new people through such events. Inter-Chapter collaborations thus prove beneficial for students. It also helps instill the spirit to do better for our future and conduct better activities. It also serves as a means of encouragement to each other as we honor each other's achievements."

The Mu Xi Chapter at the Indian Institute of Science (IISC) - Bangalore exemplified collaboration with its Membership Outreach Program. Members of the Mu Xi Chapter partnered with the sixteen other IEEE groups represented on their campus to welcome new university students. Presenters at the event, including faculty/advisors, alumni, and industry leaders, came together to educate students about the different IEEE technical societies and groups such as, IEEE Women in Engineering (WIE), IEEE Communications Society (ComSoc), IEEE Computer Society, IEEE Signal Processing Society, and others. Each group spoke about what it does and how IISC students can get involved. Over 50 participants attended the event, and many expressed interest in the Mu Xi Chapter.

Derick, an event attendee, shared that he would have never known about the work of any of these groups otherwise. "I also learned about the work IEEE does to help the community, like… outreach to school kids for STEM… This program helped me understand the various activities of IEEE and the support and help the organization provides to students like me."


Mu Alpha Zoom Event

Mu Xi 2022 Membership Event

Celebrating the Research Contributions of Our Graduate Student Members

Graduate students, an important and growing part of the IEEE-HKN global community, are performing groundbreaking research. We have developed this award-winning section in *THE BRIDGE* to celebrate and elevate their research contributions. The HKN Graduate Student Research Spotlight is a standing feature in *THE BRIDGE*. The profiles of the students and their work will also be shared on our social media networks.

Each profile will showcase the intellectual merit and broader impact of HKN graduate student members' research and provide information about the students' backgrounds and where people can learn more about them and their work.

We will spotlight these achievements while also showing potential graduate students what is possible!

Would you like to be featured?

Fill out our submission form. Submissions will be reviewed, assembled into a profile template, and posted on HKN's social media pages. A select number of profiles will also be featured in *THE BRIDGE*.

New Advertising Opportunity

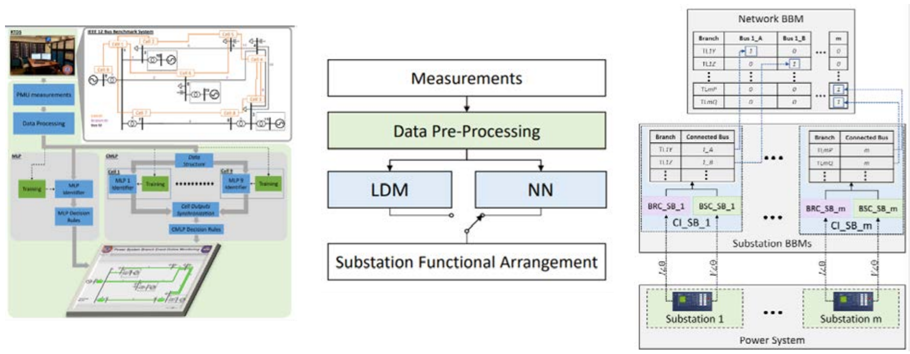
IEEE-HKN is the professional home to the world's top graduate students in electrical and computer engineering, computer science, and the allied fields of interest. Get your company or university in front of these students and HKN's undergraduate students who are considering their next steps by advertising in a special section in *THE BRIDGE*. Click here for more information and rates.

Dulip Madurasinghe

Zeta Iota
Clemson University, Ph.D. Student in Electrical Engineering

RESEARCH TOPIC
AI Based Power System Monitoring and Control Applications

My research is focused on applying intelligent algorithms to improve the power system monitoring and control. I have progressed through my research from the power system branch event identification to substation configuration identification to proposing a novel power system transmission network topology processing (TNTP) at energy control center (ECC). All three of these steps are to establish the foundation to propose novel real-time applications for power system control at the ECC. The research has already produced several publications. I'm motivated to propose a meaningful energy management system (EMS) application based on an artificial intelligence (AI) algorithm named real-time intelligent security constraint dynamic power flow approach.



Left to Right: Distributed Intelligent Branch Event Identification Approach, Substation configuration identification, Transmission Network Topology Processing based on Substation Configuration Identification and Branch Event Identification

LEARN MORE
https://scholar.google.com/citations?user=5YkcqEoAAAAJ&hl=en&oi=ao

CONTACT
www.linkedin.com/in/dtmadurasinghe/

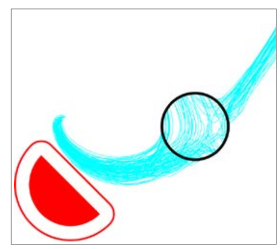
Jared Miller

Gamma Beta
Northeastern University, Ph.D. Student in Electrical Engineering

RESEARCH TOPIC
Convex Optimization, Nonlinear Systems, Control

Peak estimation is the problem of bounding extreme values of a state function along system trajectories. Examples of peak estimation include finding the maximum speed of a car, height of an aircraft, and proportion of infected people in an epidemic model. Peak estimates may be employed to analyze system behavior, evaluate controller performance, and design policy interventions. These peak estimation problems are finite-dimensional but nonconvex when optimizing over the initial condition/time that could generate the peak value along a trajectory. Measure-theoretic and algebraic methods may be applied to approximate these nonconvex problems by a sequence of convergent (under mild conditions) convex optimization problems in increasing complexity and accuracy.

Jared Miller has extended these measure-based peak estimation methods to extract near-optimal trajectories, to incorporate uncertainty in dynamics, and to quantify the safety of trajectories by bounding the distance of the closest approach to an unsafe set. Further research in this topic includes peak estimation and optimal control for systems with time delays (e.g., the incubation periods). Other work he has performed includes the data-driven stabilization and control of systems with input and measurement noise and the exploitation of sparse structure to improve the approximation quality of large-scale semidefinite programs. He is a member of the Robust Systems Laboratory at Northeastern University and was in part supported by a Chateaubriand Fellowship.



No trajectory (cyan) starting from an initial set (black-circle) following dynamics with uncertainty reaches a defined distance (red contour) surrounding the unsafe set (red half-circle).

LEARN MORE
https://jarmill.github.io/

CONTACT
www.linkedin.com/in/jared-f-miller

Aobo Zhou

Mu Kappa

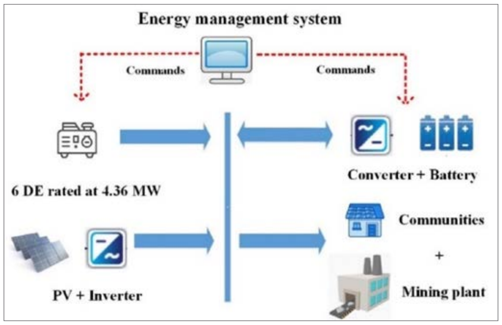
The University of Queensland, Ph.D. Graduate in Electrical Engineering

RESEARCH TOPIC

Renewable Integration into Isolated Microgrids

The power networks in most remote communities are self-sustained small-scale power systems, also referred to as isolated microgrids. These networks are usually equipped with multiple distributed energy resources (DERs) to supply the local load demands. However, with large-scale renewable deployment into the local microgrids, the system's operational stability and reliability are seriously challenged due to the uncertain and intermittent characteristics of the renewable sources.

Aobo's research mainly focuses on planning, control, and energy management in the isolated microgrids with large-scale renewable integration. He has proposed a series of solutions in terms of renewable components planning, comprehensive energy management, and dispatch algorithm, as well as dynamic software-based platform modeling for security and reliability validation. Aobo's work has been supported by the School of ITEE (Information Technology and Electrical Engineering) at the University of Queensland.



The figure shows a typical hybrid energy configuration of an isolated microgrid. In the future, with high renewable penetration into the local power networks, the energy management will be significant to keep the system operating efficiently and reliably.

LEARN MORE
https://ieeexplore.ieee.org/author/37087059224

Sabrina Helbig

Beta Delta

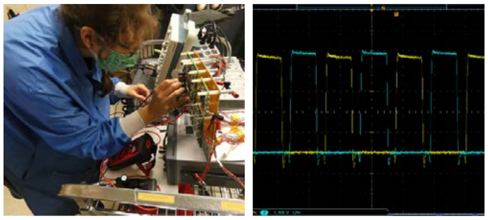
University of Pittsburgh, M.S. Student in Electrical Engineering

RESEARCH TOPIC

Power-Dense Design and Radiation Testing of Power Electronics for Aerospace

A huge trend in electronics is making circuits smaller and more power-dense while maintaining or improving efficiency. This trend is relevant across the realm of electronics applications, but it is especially pertinent in power electronics for space missions, where power conversion can occupy a significant footprint. Space electronics may encounter harsh temperature and radiation environments, which consequently means that, for protection, radiation-hardened components tend to be bulky and costly. Yet, space missions are striving for greater functionality in the same or smaller packaging, heralding a push for higher power density.

In partnership with the Johns Hopkins Applied Physics Laboratory (JHUAPL) by way of the SHREC IUCRC, Sabrina's research focuses on miniaturizing DC/DC point-of-load buck converters, particularly at the output specifications of 1.8 V, max. 15 A, and > 80% efficiency. By integrating transistors made with the wide bandgap material gallium nitride (GaN) rather than traditional silicon, implementing a multiphase topology to reduce current and ohmic losses in each phase, and using commercial controllers, diodes, and passives instead of radiation-hardened components, this research strives to shrink converter dimensions and assess the total ionizing dose (TID) irradiated performance of the converters, which subsequently determines what space missions could incorporate these commercial parts. As of August 2022, test results are being analyzed.



Left to Right: Sabrina testing converters after a dose in the high dose rate (HDR) radiation chamber; Voltage waveforms measured at one converter's switch nodes.

One of the designed converter boards with added legs for mounting.

LEARN MORE
https://scholar.google.com/citations?user=qe_DB-sAAAAJ&hl=en

CONTACT
www.linkedin.com/in/sabrina-helbig-41b478160/


17 MS programs to choose from, plus 4 new 100% online programs
Learn more:
go.tufts.edu/engmasters
PhD, certificate, and postbac programs also available
Tufts UNIVERSITY
School of Engineering
EARN A MASTER'S IN ENGINEERING
in as little as one year or at your own pace.


TEXAS INSTRUMENTS
NOW HIRING
We're changing the world one chip at a time
careers.ti.com

Dr. Saifur Rahman

Director, Advanced Research Institute, Virginia Tech

Chapter of Induction: Beta Lambda Chapter

Professor Saifur Rahman is the founding director of the Advanced Research Institute at Virginia Tech, USA where he is the Joseph R. Loring professor of electrical and computer engineering. He is a Life Fellow of the IEEE and an IEEE Millennium Medal winner. He is the 2023 IEEE President and CEO. He is the founding editor-in-chief of the IEEE Electrification Magazine and the IEEE Transactions on Sustainable Energy. Some of his IEEE awards include: IEEE Technical Activities Board Hall of Honor (2014), Outstanding Power Engineering Educator Award (2013) and IEEE Power & Energy Society Meritorious Service Award (2012). He was awarded a multi-million dollar grant by the US Department of Energy to develop the Building Energy Management Open Source Software platform, which has been commercialized. His bachelor's degree in electrical engineering is from the Bangladesh University of Engineering and Technology, his master's degree in electrical engineering is from Stony Brook University, and he has a doctorate in electrical engineering from Virginia Tech.

Why did you choose to study the engineering field (or the field you studied)?

I chose to study engineering because from a very young age (8 to 10 years) I was very interested to understand how things work and why machines are built the way they are built. I remember when I was about 12 years old, I built a copper coil and put it between two magnets to see if the coil will turn if electrified. The result was I blew the main fuse in the house because I short-circuited the line. The current did not flow in the coil long enough for it to turn.

What do you love about the industry?

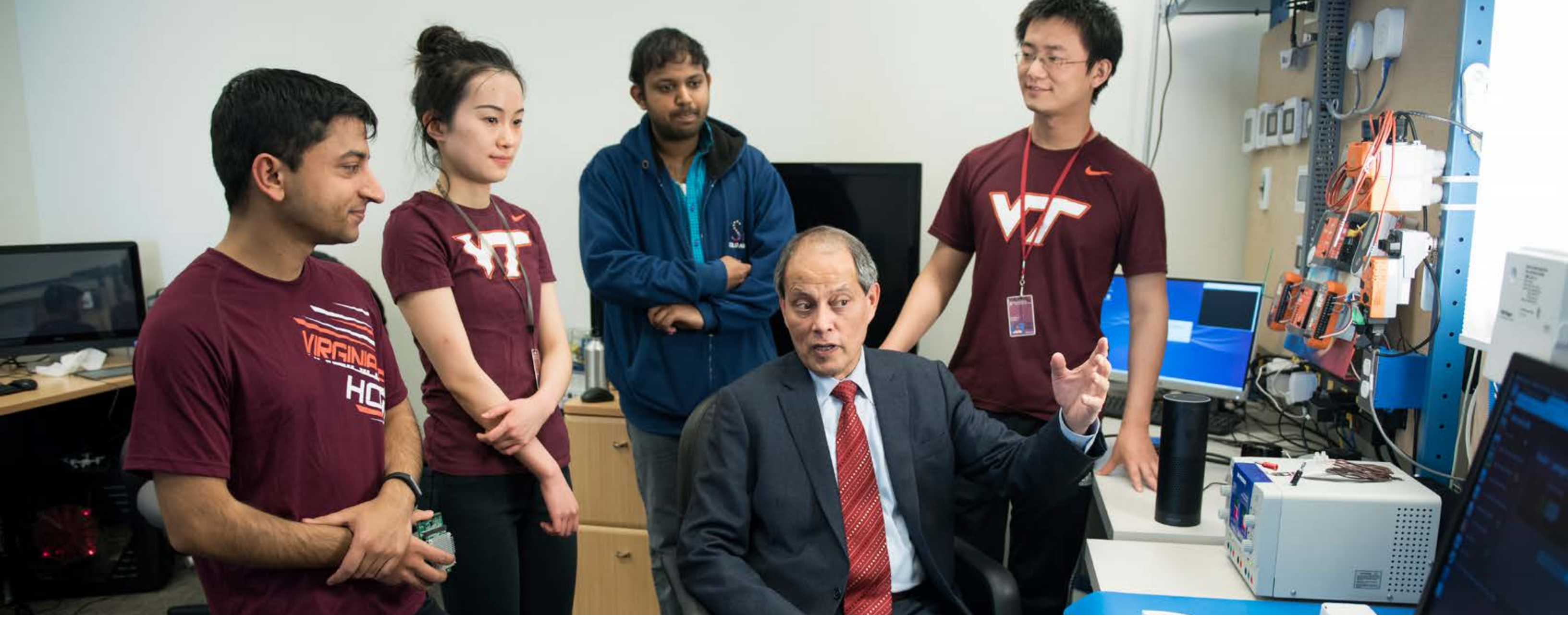
I work in the area of electric power, which is the lifeline of the modern civilization. Solar power, hydro power, wind power, biomass power, nuclear power, power from fossil fuel – all these are making living on earth more fulfilling and enjoyable. The generation, transmission and distribution of electricity provides ample opportunities for engineers to showcase their talent in advancing technology for humanity.

What don't you like about the industry?

Due to the heavy use of fossil fuel to produce electricity globally – and the resulting carbonization - there is a heavy pressure on the environment causing climate related disasters. While there is some awareness about this challenge, not enough serious efforts are being made to decarbonize the electric power sector.

How has the engineering field changed since you entered it?

When I was a freshman in college, in 1968, there were no personal computers, no smart phones, no electric vehicles, no robotics in our daily lives, and very little domestic air conditioning. In the 50 years since, the progressive developments in engineering have made such devices not only available, but also affordable to a large segment of the world population.



ARI Lab

In what direction do you think the engineering and other IEEE fields of interest are headed in the next 10 years?

There will be more automation, more AI applications, more autonomous vehicles, and more personal choices about how we live, how we raise our children, how we travel, and how we work. The concern is—such developments will not be equal across the globe, even within some countries there will be large disparities among various sections of their population.

What is the most important lesson you have learned during your time in the field?

The most important lesson I have learned during my travels in over 55 countries is – the young generation is very inquisitive, creative, and willing to do good in society. But they do not always get the opportunity or have the resources to realize their dreams. This is especially true among girls in developing countries. But with the widespread availability of internet and mobile phones, things are changing for the better.

What advice can you offer recent graduates entering the field?

Be innovative, set high goals, work very hard to achieve your goals, and work cooperatively. Do not be daunted by failures. You become a more effective person when you learn from your failures and find new and different ways to do things which can benefit others.

What is your favorite Eta Kappa Nu memory?

I was inducted into Eta Kappa Nu when I was a Ph.D. student at Virginia Tech. After the induction ceremony, I met with several undergrad students at the university (some HKN members, others not) and set up a team to help other undergrads who were having difficulty in their electric circuit courses. Electric circuits was my favorite subject in electrical engineering; the first theory course I taught at Virginia Tech was electric circuits.

Dr. Jane Tochukwu Ifediora

System Analyst/R&D Engineer, Independent National Electoral Commission of Nigeria Abuja

Kappa Delta Chapter

You can choose to directly support IEEE-HKN or any of the strategically identified IEEE initiatives that help meet the world's most pressing challenges and help us to realize the full potential of IEEE.

Dr. Jane Tochukwu Ifediora joined HKN in 2015 while studying for a Ph.D. at Atlantic International University in Miami, Florida. She is now a professor of material sciences there. She was inducted in the Kappa Delta Chapter in 2018 and has been an active member ever since.

Born into the family of the late Mr. Ogbuefi and Mrs. Daniel Ogbonnia Aneke, education has always played an important role in Jane's life, with her primary and secondary education putting her on a pre-medicine path. However, she discovered her love of engineering as an undergraduate at Enugu State University of Science and Technology, where she graduated with a dual degree in computer and chemical engineering. She completed service for the National Youth Service Corps at the Raw Material Research and Development Council (RMRDC) in Abuja, Nigeria, and was later hired in recognition of her good work. Always searching for ways to grow professionally, she is currently working as a system analyst with the Independent National Electoral Commission of Nigeria.

In 2017, she received the Sentinel of Science award in Mathematics and is a Senior Member of the IEEE.

Dr. Tochukwu became attracted to engineering education in order to have a good background of analytical and technological exposure as well as to tutor young scientists/engineers. She admires all scientists, educators, academicians, and professionals, but she especially admires the contributions of women scientists to global change. She anticipates rapid changes in the fields of information technology (IT), renewable energy, health, sustainable development, oil and gas, and housing over the next ten years. She supports IEEE-HKN because the society helps bring up young innovators in Science and Engineering fields with the scholarship, character, and attitude needed to tackle these challenges. She knows that her gifts to IEEE-HKN also honor the work of her late father, Ogbuefi D.O. Aneke, who made great contributions to the Bimodal Voting Accreditation System (BVAS), INEC Voter Enrollment Device (IVED), and the Android 9 operating system.

In her professional roles in the field, she has learned that "testing, experimentation, evaluation, and good technical and administrative reporting help the organization work for the future in times of difficulty and success." Her advice to new graduates entering the field is "to be dedicated, honest, and lay your hands mostly on experimentation / practical work." This will lead to what she sees as the greatest opportunity for IEEE-HKN over the next three years—to be the world's best technology innovators in science and engineering.

Guiding Apollo to the Moon

Burt Dicht

A spaceship landed on Earth after returning from an uncrewed 26-day, 1.3-million-mile trip around the Moon. On December 11, 2022, the Orion CM-002 spacecraft splashed down in the Pacific Ocean off Baja California. This closed out the Artemis I mission, NASA's first step to returning astronauts to the Moon later this decade. With a sense of symmetry, the splashdown occurred on the 50th anniversary of Apollo 17's landing on the Moon.

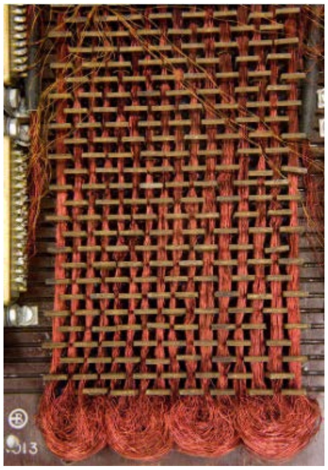
The Earth and Moon as seen from the Orion spacecraft (Image credit: NASA)

Apollo 17 (December 7-19, 1972) was the last crewed mission to the Moon, ending the monumental program that featured six lunar landings, 12 moonwalkers, 800+ pounds of moon rocks, and tremendous advances in science and technology. The Apollo program was born from President John F. Kennedy's bold goal, set on May 25, 1961, to land astronauts on the Moon and return them safely to Earth before the end of the decade.

For those of us who grew up as part of the Apollo generation, the successful Artemis I mission was a reminder of the technological prowess needed for the moon program. The Artemis program, including the Space Launch System rocket and the Orion spacecraft, incorporates the latest advances in technology, including electronics and computing. When comparing today's technology to that of the 1960s and what made the Apollo program possible, it's easy to ask, "How did we do it with what we had?" The Apollo astronauts relied upon rudimentary computer technology for guidance and control and slide rules for on-the-fly calculations.

The Apollo program utilized the talents of more than 400,000 engineers, scientists, and technicians and mobilized the resources of 20,000 companies and universities. IEEE's fields of interest were very well represented. As we celebrate the 50th anniversary of Apollo 17 and the end of the Apollo program, we also embrace the promise of Artemis and the return to the Moon. Let us now look back at one of the key contributions that achieved that "one small step."

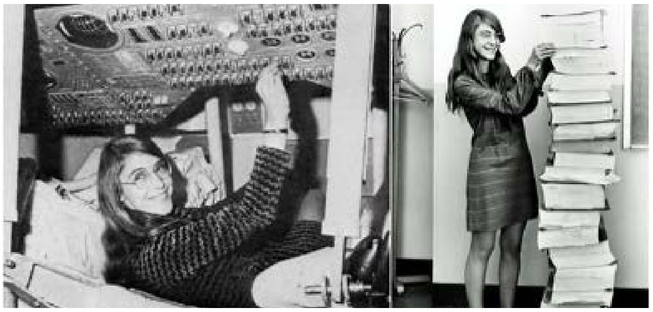
A critical component necessary for the moon mission was the Apollo spacecraft's guidance and control system. Only weeks after President Kennedy set the goal, NASA awarded the contract to the MIT Instrumentation Laboratory (now Draper Laboratory). NASA wanted to use an inertial measurement unit (IMU) like those found in submarines, ballistic missiles, and aircraft that had been pioneered by the lab's director, Charles Stark "Doc" Draper. While designing the basketball-sized IMU, which made use of three gyroscopes to measure changes in direction and three accelerometers to measure changes in velocity, was a challenge, the long pole was the digital computer that the astronauts would use to interface with the IMU.



Apollo Guidance Computer Core Rope Memory (Image Credit – Draper/Hack the Moon)

In the movie "Apollo 13", astronaut Jim Lovell (played by Tom Hanks) touts advances in technology by referencing computers "that can fit into one room." During the early 1960s, even the most compact computers required the space of several rooms. The designers of the Apollo Guidance Computer (AGC) were given an envelope of one cubic foot. The AGC was one of the first computers to use integrated circuits and prioritize computing tasks to speed up processing.

With a limited memory capacity of only 72 kilobytes, would that be enough to guide Apollo to the Moon? The memory was composed of copper wires woven in a specific pattern in what was called "Rope Memory." Expert seamstresses threaded the wires through magnetic rings (a wire going through the ring was a 1, and a wire going around the ring was a 0) to create the memory.



Margaret Hamilton inside the Apollo Command Module mock-up and posing with the AGC code. (Image credit: NASA/Draper Lab)

A major challenge in using rope memory was that once it was installed, it could not be changed. That meant the programming had to be right from the start. Margaret Hamilton, who led the team developing the programing put it into perspective: "When I first got into it, nobody knew what it was that we were doing. It was like the Wild West. There was no course in it. They didn't teach it." Her team of 400 engineers and programmers not only developed the AGC's programming, but their work also led to the creation of "software engineering" as a distinct discipline.

During all the Apollo missions, the AGC was the sole guidance system used as the spacecraft was on the far side of the Moon and during the lunar module's descent to the lunar surface. This AGC never failed throughout the entire Apollo program.

Burt Dicht is a member of IEEE-HKN's Editorial Board and the former Director of Student and Academic Education Programs for the IEEE's Educational Activities Department. He is also member of HKN's Eta Chapter.

To Learn More About the AGC and Rope Memory:

*IEEE Spectrum article **"Software as Hardware: Apollo's Rope Memory"***
29 Sept 2017 - https://spectrum.ieee.org/software-as-hardware-apollos-rope-memory and the
IEEE AGC Milestone: https://ethw.org/Milestones:Apollo_Guidance_Computer,_1962-1972

Past President of IEEE Education Society and Nu Beta Chapter Advisor Wins Prestigious Award

Edmundo Tovar, a professor at the Polytechnic University of Madrid (UPM) School of Computer Engineering, has been awarded the Ramón Llull Prize, which recognizes Computer Engineering professors who have made innovative and significant contributions in the teaching and development of computer science in the academic field.

Professor Edmundo Tovar

Professor Tovar has been awarded this distinction for his research career and promotion of open education through multiple national and international projects. He has been responsible for promoting open education at UPM as director of the UPM Open Education Office and as a member-at-large of the OpenCourseWare Consortium. In addition, he has been a founding member of several professional associations, including the Association of University Teachers of Informatics (AENUI).

At the IEEE Education Society, a worldwide society of professionals dedicated to ensuring high-quality education in science and engineering and one of IEEE's oldest technical societies, he began as co-founder of the Spanish chapter and President (2004-2006). Additionally, he has been a member of its Board of Governors for 10 years serving as Vice President of Educational Activities (2014-2018) and President of the IEEE Education Society (2021-2022).

Edmundo Tovar (middle) receiving award from Immaculada García Fernández (left), President of the Informatics Scientific Society of Spain and Rafael Pardo Avellaneda, Director of the BBVA Foundation (right)

Through his participation in different IEEE Educational Activities Board (EAB) Committees since 2008, he has contributed to the development of its programs, that include the monitoring of accreditation activities, the coordination of pre-university programs, the development and delivery of continuing education products, and activities. As a professional member of the IEEE-Eta Kappa Nu, he is a promoter and faculty advisor of the Nu Beta Student Chapter of the Universidad Politécnica de Madrid (2020).

These awards are granted by the Spanish Computer Science Society (SCIE) and the BBVA Foundation.

Tovar speaking at the Awards Ceremony

IEEE Aerospace and Electronic Systems Society

Marking 50 Years of Complex Systems for Space, Air, Ocean and Ground Environments

The IEEE Aerospace and Electronic Systems Society (AESS) focuses on the integrated electronic systems within complex systems for space, air, ocean, or ground environments. These systems include radar, navigation, avionics, aerospace communication, command and control, sonar, telemetry, and defense. AESS is concerned with the total system, including organization, systems engineering, design, development, integration, and operation.

IEEE AESS at IEEE Rising Stars Conference to enthuse and enlighten top engineering young professionals with IEEE Young Professionals and student leaders, includes 2019 IEEE President Jose Moura, 2019 Rising Stars Chair Ramesh Nair, and 2022 IEEE Radar Conference Chair Lorenzo LoMonte.

Stay Current

The society provides high-quality research, application, and news publications across its fields of interest and sponsors many more conferences that connect members and advance AESS technical interests. The monthly IEEE Aerospace and Electronic Systems Magazine provides articles on a range of applications of technology and research activities, along with future trends, news, and information. An example article in a recent issue considered resilient navigation in the face of GPS jamming. The January 2023 issue commemorated 50 years of AESS and its fields of interest in a special issue. Educational offerings that support professional development in applied fields are a key focus of the society, including distinguished lectures and webinars, tutorials, and short course offerings.

Inspiring and Connecting

The Society has a number of programs to better inspire, recognize, and connect students and Young Professionals to careers in AESS fields of interest. The Professional Networking and Mentoring Program pairs a young mentee with an individual, distinguished mentor in a designated field of interest to promote engagement and collaboration. Society-sponsored conferences have concentrated on developing multiple activities that include and showcase rising young professionals and students with competitions and challenges, industry panels, and tutorial programs. The 2021 IEEE/AIAA Digital Avionics Systems Conference (DASC) connected student teams to AESS through the autonomous drone competition. The 2022 IEEE Radar Conference in New York City, for example, offered both the experiential Radar Challenge and the weekend Radar Summer School with world-class professors.

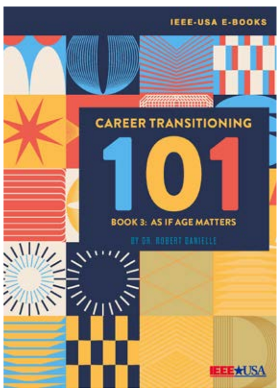
Garrett Hall, IEEE AESS and IEEE HKN-Kappa Upsilon former chair, presents award to student drone competition winners with his longtime paired mentor, 2021 IEEE AESS President Walt Downing.

Student Narayan Gossei, IEEE AESS and IEEE-HKN Kappa Eta, with his senior project team and Professor Kramer in May 2022. The project considered temperature regulation for airplane pods for General Atomics.

IEEE-USA's New, Free January E-Book for Members Takes On Ageism in the Workplace

Georgia C. Stelluto

"You now have more experience and wisdom than ever before. Age enhances your value." -Bonnie Marcus, Author



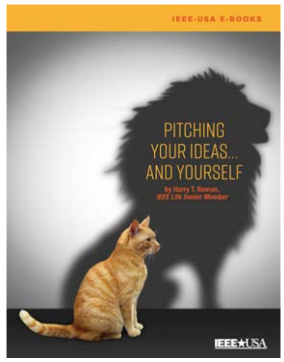
In his third IEEE-USA e-book, **Career Transitioning 101—Book 3: As If Age Matters,** Dr. Robert Danielle explores in-depth, the persistent problem of ageism in the workplace, and the different forms it can take. Using examples from his own life, as well as stories from friends, co-workers, and others, Danielle also discusses different ways to react to ageism, and help discourage it. The author explores ageism through multiple lenses, with the intent to raise situational and organizational awareness—as well as provide pathways to hope and prosperity-by sharing strategies to help combat the challenges facing older workers. He also examines age-related perceptions, some beginning in the 40s, that result in damaging, self-fulfilling prophecies—sabotaging any chance for workplace satisfaction or career success.

Members—Grab a copy of your free new e-book, by going to: https://ieeeusa.org/product/career-transitioning-101-book-3-as-if-age-matters/

Log in to your IEEE Web Account; add the book to your cart, and checkout! No promo code necessary!

IEEE-USA's January Free, New Audiobook Teaches How To Pitch Ideas Successfully

"From the CEO to the receptionist to the office manager, everybody should know that one-minute elevator pitch." -Timi Nadela, Author



In IEEE-USA's new audiobook, **Pitching Your Ideas... and Yourself**, author Harry Roman points out we hear pitches every day—from door-to-door salesman, cold call marketers, contestants on Shark Tank, or friends trying to convince us to change a point of view or political opinion. Roman focuses on the pitch at work in this book—for a new project, for an increased budget or staff, even for a promotion.

In the book, the author discusses what makes a good pitch: "Pitching is about stripping down your idea to its barest essentials; and then selling it with conviction, passion, and commitment."

He begins with a simple one—the elevator pitch. An elevator pitch is a crisp pitch you could give if you entered an elevator with an executive and only had a floor or two to explain what you did or what project you were working on. An elevator pitch's goal, Roman notes, is often to obtain an agreement to listen to a longer pitch later.

The author advises finding the balance between "a brutally honest presentation of the facts" and telling a story. Many engineers are hesitant to tell stories, but Roman points out, "Tales around the campfire are very powerful methods to convince people...even the most ardent number-crunchers love a good story."

Members—Download your free copy and enjoy it en route to your next destination—it is well worth the listen. You can download this audiobook by going to: https://ieeeusa.org/product/pitching-your-ideas-and-yourself/

The companion e-book is also available at no charge to members at the same URL noted above.

For Members Only: All IEEE-USA E-Books and Audiobooks Are Free to All IEEE Members

IEEE-USA's e-books and audiobooks help IEEE members advance their careers, work on their soft skills, learn about U.S. public policy, and even provide a fun distraction. And in 2023, IEEE-USA continues to offer the whole collection free to all IEEE members in the IEEE-USA Online Shop.

For a fun break: Check out IEEE-USA's newest e-comic book: The Tesla Twins--Rescue at the Speed of Light—and continue the adventures of IEEE-USA's dynamic young electrical engineering superheroes; IEEE-USA Coloring Books—one for kids and one for adults; and IEEE-USA's Crossword Puzzle Books—one for students and one for adults—all at: https://ieeeusa.org/shop/.

Download All of IEEE-USA's Free Audiobooks

IEEE-USA has many free audiobooks, on various career topics, all available for your listening pleasure. Download all the free IEEE-USA audiobooks, and collect them to add to your own personal audiobook library.

To download all free IEEE-USA Audiobooks—go to: https://ieeeusa.org/shop/audiobooks/.

IEEE Members—You can also search for the book titles, and get the companion e-books for these audiobooks at the product page—for free!

Go to https://ieeeusa.org/shop/.

Set sail with IEEE-USA on our 50th Anniversary Cruise October 16-20, 2023.

Book now for best availability: https://cruise.ieeeusa.org

Georgia C. Stelluto is IEEE-USA's Publishing Manager; Editor and Manager of IEEE-USA E-Books and Audiobooks; Department Editor of @IEEEUSA for IEEE-USA's flagship publication, Insight; and Co-Editor for IEEE-USA Conference Brief.

IEEE-Eta Kappa Nu Launches IEEE-HKN Career Center

IEEE-Eta Kappa Nu

LOG ON TODAY!

IEEE-Eta Kappa Nu is proud to announce its new IEEE-HKN Career Center–the premier resource to connect career opportunities with highly qualified engineering talent.

IEEE-HKN Career Center will allow you to:

MANAGE YOUR CAREER:

- Search and apply to more engineering jobs than in any other job bank.
- Upload your anonymous resume and allow employers to contact you through IEEE-HKN Career Center's messaging system.
- Set up job alerts specifying your skills, interests, and preferred location(s) to receive email notifications when a job is posted that matches your criteria.
- Access career resources and job searching tips and tools.
- Have your resume critiqued by a resume-writing expert.

RECRUIT FOR OPEN POSITIONS:

- Post your job in front of the most qualified group of Engineering talent in the industry.
- Promote your jobs directly to candidates via the exclusive Job Flash email.
- Search the anonymous resume database to find qualified candidates.
- Manage your posted jobs and applicant activity easily on this user-friendly site.

IEEE

ieee-hkn.careerwebsite.com