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# THE BRIDGE

The Magazine of IEEE-Eta Kappa Nu

## The Future of Renewable Energy

GENERATION:  
Photovoltaic Materials

TRANSMISSION:  
An Autonomous Energy Grid

CONSUMPTION:  
Grid-Interactive Efficient Buildings

# The Future of RENEWABLE Energy



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# THE BRIDGE

The Magazine of IEEE-Eta Kappa Nu

**2020 ISSUE 3 | THE FUTURE OF RENEWABLE ENERGY:** Generation, Transmission, Consumption

**4**

**Guest Editor**

Dr. Roderick Jackson

## Features

**6**

**THE FUTURE OF RENEWABLE  
ENERGY GENERATION:  
Photovoltaic Materials**

**12**

**THE FUTURE OF RENEWABLE  
ENERGY TRANSMISSION:  
An Autonomous Energy Grid**

**17**

**THE FUTURE OF RENEWABLE  
ENERGY CONSUMPTION:  
Grid-Interactive  
Efficient Buildings**

## Departments

**22**

**PROFESSIONAL PROFILE**

Dr. Paul Michael Grant  
Gamma Gamma Chapter

**24**

**SPONSORED CONTENT**

What Did You Do  
During the Pandemic?

**27**

**The HKN Experience**

**28**

**AWARDS SPOTLIGHT**

IEEE-Eta Kappa Nu Names  
Recipients of its Inaugural  
Madni Medal, Distinguished  
Service Award and Outstanding  
Teaching Award

**30**

**IEEE-ETA KAPPA NU ANNIVERSARY**

IEEE and Its Honor Society  
Eta Kappa Nu Celebrate  
10 Years Together

**34**

**HISTORY SPOTLIGHT**

*THE BRIDGE* Magazine of  
Eta Kappa Nu: Part I

**36**

**STUDENT PROFILE**

Lauren McDaniel  
Theta Lambda Chapter

**37**

**DONOR PROFILE**

Dr. Sarah Rajala  
Beta Gamma Chapter

**38**

**CHAPTER SPOTLIGHT**

Mu Theta Chapter President  
Participates on Panel  
Discussion on 'Role of Women  
in Engineering'

**40**

**SPOTLIGHT ON SMART VILLAGE**

A Goal for Safe and Reliable  
Off-Grid Communities

**41**

**SOCIETY SPOTLIGHT**

IEEE Power & Energy Society

**42**

**IEEE-USA**

New IEEE-USA E-Books

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## *THE BRIDGE*, October 2020 Letter from the Editors-in-Chief

Dear Eta Kappa Nu Members and Friends,

This issue of *THE BRIDGE* magazine has a theme of "The Future of Renewable Energy." Our features discuss different technologies in which renewable energy is generated, transmitted, and consumed. These technologies reflect the significance of the IEEE tagline "Advancing Technology for Humanity" and offer exciting career opportunities for engineers. We appreciate the contributions of our guest editor Dr. Roderick Jackson at the National Renewable Energy Laboratory (NREL) and of the authors of our three features. For more information on NREL, see <https://www.nrel.gov/>.

While the feature papers look to the future, IEEE-Eta Kappa Nu pauses to take a look back at the last ten years. After 106 years as an independent organization, Eta Kappa Nu merged into IEEE to become IEEE-HKN on 1 September 2010. The 10th Anniversary content highlights events since the merger. Our important emphasis on scholarship, character, and attitude has been maintained. Among the changes are the chartering of chapters outside the United States and the expansion of membership eligibility to all IEEE fields of interest. Our chapters are making an enormous impact in their academic communities through activities which promote excellence, provide service to others, and develop professional skills.

Chapters that excel in their administration and activities can earn annual recognition. The figure shows examples of the award plaque for 1954, 1981, and 2009. This Outstanding Chapter Award (OCA) program was the first award program for Eta Kappa Nu and the Gamma Chapter at Ohio State University was the first recipient for the 1932-33 year. Through 2004, a single chapter received the annual award with other chapters possibly receiving honorable mention. Since 2005, multiple chapters are recognized each year as co-recipients. For 2018-19, twenty-six chapters (approximately the top ten percent of HKN chapters) were honored. 



Outstanding Chapter Award Plaques Through the Years



# The Future of Renewable Energy

Imagine a world where energy is clean, reliable, resilient, and affordable. In this world, energy distribution is intelligent and autonomous. As a community, not only do we enable this future through our contributions to science and engineering, we reside on the front lines of leading the transition.

However, this will require a paradigm shift on how we make, use, and transmit clean energy. Taking this charge to heart, in this issue we will discuss three leading perspectives on pathways to this energy future. We will discuss the future of renewable solar energy through next generation materials, the future of energy consumption through grid-interactive efficient buildings, and the future of energy transmission through an autonomous energy grid. This special issue will provide readers a holistic view into this renewable energy future from experts who are truly leading the transition. Specifically, we articulate:



**Dr. Roderick Jackson**

Laboratory Program Manager for  
Buildings Research at The National  
Renewable Energy Laboratory

## ● The Future of Renewable Energy Generation: **Next-Generation Materials for Solar Photovoltaics**


Opportunities for materials innovation in conventional PV can be made through further science and engineering in III-V materials, CIGS, CZTS, and CdTe-based cells. Additionally, organic photovoltaics (OPV) and Pb Metal Halide Perovskites (MHP) have unique material tunability, low cost processing, and efficiency potential that can be exploited to usher in a new generation of PV. However, key material characteristics and durability must be established to realize true scale in the market.

## ● The Future of Renewable Energy Transmission: **An Autonomous Energy Grid**

Consider a large distribution system with approximately 4.5 million customers who each own a PV system, a battery energy storage system, an electric vehicle, a smart thermostat, and controllable lighting. The energy system would be comprised of approximately 10–20 million controllable devices capable of producing, storing, and consuming electricity. The operational framework would be required to monitor, control, and optimize large-scale grids with variable generation and DERs. A modernized electricity grid is needed, and autonomous energy grids will be discussed as part of the potential solution.

## ● The Future of Renewable Energy Consumption: **Grid-Interactive Efficient Buildings**

Because buildings consume 75% of electricity generated in our current system, leveraging energy efficiency, connectivity, advanced analytic capability, and the ability to dynamically adjust energy loads, grid-interactive efficient buildings (GEB) reflect a new paradigm of how buildings will enable a synergistic balance of energy demand and supply. Critical to achieving the potential of GEB, research and development are needed that integrate advancements sensing and actuation with computing and communications innovation. However, resulting GEB must be intuitive to operate, inexpensive to install, cybersecure, and interoperable across multiple vendors, equipment types, and buildings to monitor and control the physical environment.

The challenges are ambitious to transform our energy future to one that is clean, reliable, resilient, and affordable. However, with committed professionals like you, we can lead the charge. 



# THE FUTURE OF RENEWABLE ENERGY GENERATION: Photovoltaic Materials

*Annalise Maughan, Kai Zhu, and Joseph J. Berry*

## Intro to Photovoltaics (PV)

There are myriad ways to harness solar energy, including, but not limited to: solar thermal, solar fuels, and photovoltaics (PV). Across the portfolio of solar energy technologies, PV is unique in that collected photons are directly converted to electricity. Traditionally, the dominant materials in PV are also the dominant semiconductor and optoelectronic materials. The cost of solar energy from PV is a product of a complex combination of non-material related factors, known as soft costs, e.g., permitting, zoning, and of balance-of-systems (BOS) costs, like inverters or other components needed to utilize cells and modules. While the soft costs are due to administrative/regulatory concerns, BOS costs are

driven by details of cell/module fabrication, mounting, power electronics, and other concerns, which touch on a range of basic material science issues. There is some overlap of BOS and soft cost, as a lighter weight solar panel can reduce installations costs, as an example. At the PV-system level, the materials considerations span both electronic and structural components. The focus of this paper is the solar cell, which is the minimum operational unit device that converts light into electricity.

Typical solar cells are sophisticated stacks of semiconductors, as shown in Figures 1 (a) and (b), with an electronic structure, which is prototypically for a PV shown in panel (c). The primary absorber material that defines the various technologies must

have a critical combination of properties. The absorber must interact strongly with light, i.e., have high absorption, and have good transport properties to ensure that photogenerated carriers can be efficiently extracted before they are lost to internal nonradiative recombination. The broadband solar spectrum creates a premium on having the

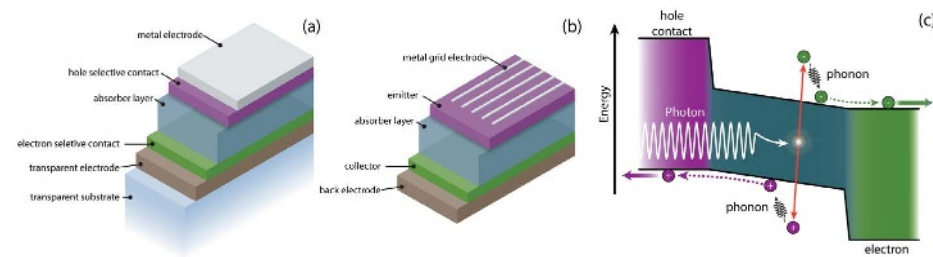


Figure 1: Typical thin film solar cell configuration is shown in figure (a). Panel (b) shows structure common to single crystal III-V or Si systems. In both cases, the orientation of electron and hole selective contacts can be changed. In the case of configuration (a), the device fabrication can be undertaken on glass/metal or metal foil rather than a transparent substrate. Panel (c) shows the energy band diagram for a typical PV device configuration, with phonon/thermal loss when photon energy is greater than the energy/bandgap. Other loss mechanisms associated with bulk or interface recombination are not shown.



appropriate bandgap to most effectively harvest solar irradiance. Given BOS expenses, there is a significant premium on solar cells having high efficiency as increases in efficiency provide an economic lever to reduce overall costs. We focus on 1-sun, i.e., unconcentrated, operation most typical to residential and utility-scale PV. (For latitudes of the United States, 1-sun is equivalent to 100 W/m<sup>2</sup>.)

## PV Challenges

From a semiconductor perspective, III-V materials, e.g. gallium arsenide (GaAs), gallium indium arsenide (GaInAs), are well matched for PV applications. These semiconductors interact strongly with light, have highly mobile carriers, and have direct, tunable electronic gaps. This last feature is critical to reaching the highest efficiencies, as it permits minimal thermal loss [1]. Additionally, III-Vs are lightweight, permitting a range of potential deployment options; however, III-V materials are not deployed terrestrially in most applications. Rather, the elemental semiconductor silicon (Si), which has relatively poor absorption and no real tunability of its electronic gap, dominates the existing PV material landscape. This discrepancy highlights the importance of high-volume and low-cost manufacturing as an additional requirement for designing PV materials. Si, which is an excellent semiconductor, is used in multiple technologies; and benefits from research relating to those technologies as well as their associated supply chains. This situation enables manufacturers to produce Si at scale, leading to reduced production cost.

Life cycle analysis (LCA) and fundamental aspects of energy input are also important aspects that should be considered in evaluation of sustainability and feasibility. Energy payback time (EPT) for a solar cell is simply an assessment of the energy input to produce a solar cell, versus the operational time required for that solar cell to harvest enough energy to enable its production. This concept of EPT incorporates the complexity of mining and refining the materials (which is often energy-intensive) as well as energy inputs to production of all components of a solar cell. When considering deployment of solar energy at terawatt scale, EPT can provide insight about manufacturing as well as recycling and reuse of materials. EPT

combined with LCA can provide important insight regarding the sustainability of a technology. Given that PVs are semiconductors, the resulting modules and systems at large scale could, if sustainability is not considered, represent a massive volume of electronic waste materials.

## Conventional PV

### SINGLE JUNCTIONS

The need for efficiency argues for tandems that are stacked semiconductor junctions with different bandgaps. The different bandgaps allow more photons across the spectrum to be absorbed. All tandem PVs are predicated on having efficient single junctions to pair. This reason, coupled with a marked increase in complexity, has prevented existing terrestrially deployed technology from leveraging tandems.

### Current PV Materials and Their Limits

We can assess key material characteristics for future PV materials based on established PV technologies. While Si dominates PV material based on EPT as well as LCA considerations, the next generation of PV materials will likely be thin films. While innovation in Si is possible to continue to reduce costs, there is little headroom in single-junction efficiency due to fundamental Si material properties. The remainder of this discussion will focus on thin film absorbers when looking to the future.

### III-V Materials

As indicated, III-V materials are impressive PV materials; however, to enjoy their remarkable efficiencies, they require single crystalline, highly pure, and highly perfect materials. More critically, they also require high embodied energy precursor materials, which demand extreme efficiency from resulting devices. To enable single crystal fabrication, bulk crystal substrates are required, which are energy intensive to produce. To achieve high-quality semiconductors, growth of the active layer material on these costly substrates occurs at relatively low deposition and production rates relative to polycrystalline thin films. There are active efforts to develop new processing approaches to address these limitations. Low deposition rates are addressed by enabling reuse of the bulk crystalline substrate.

Low production rates are improved through development of low-cost precursors and high-speed processes. If successful, these approaches could significantly reduce costs, but they involve multiple innovations and development of novel material processing technologies [2,3].

#### Thin Film Materials: CIGS, CZTS, and CdTe

Existing thin film technologies are based on a number of inorganic thin film absorbers. These materials all interact strongly with light, allowing them to be thin. copper indium gallium sulfide (CIGS) is a long-researched semiconductor. While boasting impressive champion efficiencies, the semiconductor properties rely on a balance between the four elements. This has represented a clear technical challenge in translating laboratory-scale efficiencies to large-scale, high yield production [4, 5]. A number of these hurdles were overcome, but the decreased prices of Si-based competitors undercut the cost advantage for terrestrial solar – an application where other aspects of the CIGS value proposition, e.g., light weight, flexibility, are less important. The inability to compete in terrestrial solar represents a significant barrier to entry, as losing the volume represented by this sector leaves companies difficult to sustain. A related technology, copper zinc tin sulfide (CZTS), targeted a set of materials that were abundant and lower in cost, but CZTS appears to have more issues with fundamental electronic defect structure. This precludes it from competitive efficiency [6,7]. The final inorganic absorber is cadmium telluride (CdTe)- arguably the most successful PV technology - with extremely high-speed production and very low cost. Relative to CIGS, the reduced materials complexity enables excellent manufacturability with reasonably high efficiency, culminating in excellent dollar per Watt value. However, CdTe has notable limitations. First, Cd and Te are both relatively scarce in the earth's crust. However, the real issue with the availability as it relates to scaling a PV material to terawatt levels is a combination of not only how much is present in comparison to what is needed for PV and competing uses, but also the relative accessibility along with the cost of access, e.g., refining it. In the case of Cd and Te, the elements' availability appears to place some

limitation on PV production [8]. However, scarcity concerns, along with the toxicity of Cd, have led to efficient recycling of CdTe PV materials, thus improving sustainability. All of these established thin films are subject to one common constraint: minimal ability to manipulate the bandgap.

### The Future of PV Materials

When considering the future of PV absorber materials in light of previous technologies, we can establish some critical characteristics:

- 1) Ability to be manufactured rapidly at scale (to reduce cost)
- 2) Strong absorption (to minimize material use and facilitate carrier extraction)
- 3) Tunable bandgap (to enable tandems)

The latter two criteria come from well-known fundamental materials considerations. The former criterion is a bit more elusive. Considerable efforts are being made in using computational approaches to identify the next PV material. These efforts seek abundant, readily forming materials with semiconductor properties that are defect tolerant, i.e., robust against disorder, either structurally and/or electronically [9,10]. In the context of a PV absorber, defect tolerance enables rapid manufacturing. Among next generation PV materials, that is, materials that have been explored seriously as PV absorbers only in the last 20 years, two have a degree of defect tolerance: organic photovoltaics (OPVs) and the even more nascent metal halide perovskites (MHPs).

#### Organic PV

The OPV approach is to tailor organic molecules to absorb light and produce long-lived carriers. In such molecular solids, care must be given to the details of the intermolecular packing and how it impacts the resulting film [11]. Specifically, the use of a molecular motif can negatively impact charge transport, often limiting the harvesting ability of photogenerated carriers. OPV materials have great tunability in their optoelectronic properties and their interaction with light can be tailored to be very strong in a specific range of wavelengths. However, absorption is typically more selective than inorganic semiconductors.





This selectivity provides unique opportunities for semitransparent applications, e.g., tinted windows or building integrated PV, but limits the overall efficiency. The selectivity of OPV can also enable tandems and multijunction configurations, but neither has been realized to date [4]. OPV has recently made significant gains in single junction efficiencies [4]. This indicates that the molecular motif can inhibit traditional electronic defects, but the challenge of controlling the microstructure to enable efficiency remains [12-15]. The vast space of molecular design, abundant atomic components, and amenability to a variety of process approaches makes efficient OPV an interesting path forward.

### Pb Metal Halide Perovskites

MHPs are perhaps the most promising and potentially transformational PV material in a generation. These halide-based compounds can be organic/inorganic hybrids or made with completely inorganic substituents [16]. In the last decade, Pb-based compounds have increased in champion cell efficiencies more rapidly than any other thin film technology and are now the most efficient polycrystalline device systems at the laboratory scale. Pb-based MHP materials have strong broad absorption and have a defect tolerant electronic structure that enables them to be readily manufactured [17,18]. MHPs are unique in their ability to address the manufacturability challenge, coupled with materials that have demonstrated the latter criteria of strong absorption and tunability. These attributes of MHPs also offer avenues to improve all older technologies. Specifically, MHPs have been demonstrated to improve Si and CIGS absorbers to exceed the efficiency they can achieve on their own [19-21]. Similar to III-V materials, all-perovskite tandems have also been demonstrated but have yet to exceed the high performance of single-junction perovskite devices. Given the rapid advances, we expect that this shortcoming will be overcome in the near future [22-26].


### Future Outlook

PV design is a demanding task, as it requires a complex multilayer semiconductor to operate outdoors for 30 years. The question of stability is tied to EPT, in that EPT sets the threshold for operational stability. A successful PV technology will operate at timeframes of one or more orders of magnitude greater than its EPT. While MHPs have very low EPTs relative to Si, no owner of a PV system, individual or utility, wants to deal with frequent maintenance. This makes stability and durability critical questions to address the technical challenge of stability is especially monumental [27]. Field test data is available for Si technologies, from real solar cells in real modules that have been in operation for extended times, e.g., 30 years. However, the evolution of Si PVs hampers the ability to predict stability based on established field data. This necessitates re-evaluation using understanding and insight, as well as knowledge of operational stresses. The prevalence of Si across technologies has been leveraged for determining the stability of Si PV. CdTe is a small fraction of deployed PV, but the approach to evaluating its stability also uses basic material insight. In the case of MHP, these materials were not comprehensively studied until approximately a decade ago, when they emerged for PV applications. To enable the use of these materials in deployed PV, the question of stability must be addressed. That in turn requires basic material understanding to make multidecade predictions for MHP devices [28]. This frames the challenge for next generation PV materials beyond the three criteria enumerated earlier.

Stability and durability challenges for PV materials are also critical to their sustainability. While MHP-based PV has yet to demonstrate multidecade stability, projections indicate that the dramatically reduced EPT of MHP-based PV could make even more modest lifetimes of 1.5 decades competitive with current PV technologies [29]. Lifetimes on these timescales are less than those of established Si and CdTe technologies, but they are of interest particularly if recycling or refurbishment can be carried out efficiently and at low cost. Despite the nascent state of MHP PV, investigations of how to recycle and





refurbish MHP solar cells are quite advanced and include promising laboratory-scale demonstrations of deconstruction, separation, and reconstruction [30–32]. This points to a path similar to that of CdTe and stands in stark contrast to Si-based devices. The stability challenge also requires that the range of materials that need to be considered, evaluated, and developed extend beyond the absorber. Critical needs include structural composites for PV racking, glass for packaging, and materials to enable their integration into a stable perovskite module that can readily be recycled, refurbished and whose components can be reused. There is little doubt that the future definition of PV materials will be extended by consideration of these aspects of PV systems to enable sustainability and lower cost. 

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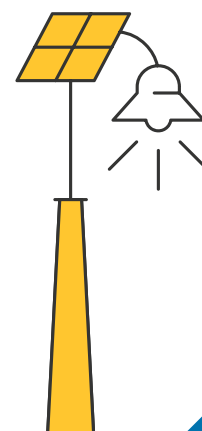
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# THE FUTURE OF RENEWABLE ENERGY TRANSMISSION: An Autonomous Energy Grid

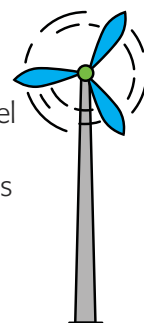
Benjamin Kroposki, Andrey Bernstein, and Jennifer King

**Note:** This article is a summary of “Autonomous Energy Grids: Controlling the Future Grid with Large Amounts of Distributed Energy Resources” by B. Kroposki et al. to be published in *IEEE Power and Energy Magazine*, November/December 2020. Listed as reference 2 in the bibliography.

## Background

The drastic price reduction in variable renewable energy, such as wind and solar, coupled with the ease of use of smart technologies at the consumer level, is driving dramatic changes to the power system that will significantly transform how power is made, delivered, and used. Distributed energy resources (DERs)—which can include solar photovoltaic (PV), fuel cells, microturbines, gensets, distributed energy storage (e.g., batteries, ice storage), and new loads (e.g., electric vehicles (EVs), light-emitting diode (LED) lighting, smart appliances, and electric heat pumps)—are being added to electric grids and causing bidirectional power flows and voltage fluctuations that can impact optimal control and system operation. Residential solar installations, customer battery systems, and EVs are all seeing rapid increases in deployments. With DER seeing such increased use, it is not unreasonable to imagine a residential electricity customer having at least five controllable DERs. In future electric grids, as more DERs are integrated, the number of active control points will be too much for current control approaches to effectively manage.

Imagine, for example, the San Francisco Bay Area, which has a large distribution system with approximately 4.5 million customers. What if each customer had a PV system, a battery energy storage system, an EV, a smart thermostat, and controllable lighting loads? This would amount to approximately 10–20 million controllable devices capable of producing, storing, and consuming electricity. Currently, no control systems are capable of ingesting 20 million data streams and making real-time operation decisions. In current large-scale grids, such as the Eastern Interconnection in the United States, central station power plants provide power to loads and have on the order of 10,000 points of control. Control systems work well when there are a limited number of active control points in the system, but to deal with the massive amounts of new DER technologies and the availability of grid measurements, a new control framework needs to be developed. The framework needs to monitor, control, and optimize large-scale grids with significantly high penetration levels of variable generation and DERs; it needs to process the deluge of data from pervasive metering; and it needs to implement a variety of new market mechanisms, including multilevel ancillary services. To handle this highly distributed energy future, we propose the concept of autonomous energy grids (AEGs).





## AEGs: The Concept [1],[2]

AEGs are multilayer, or hierarchical, cellular-structured electric grid and control systems that enable resilient, reliable, and economic optimization. Supported by a scalable, reconfigurable, and self-organizing information and control infrastructure, AEGs are extremely secure and resilient, and they can operate in real time to ensure economic and reliable performance while systematically integrating energy in all forms. AEGs rely on cellular building blocks that can both self-optimize when isolated from a larger grid and participate in optimal operation when interconnected to a larger grid. Figure 1 shows how a scalable approach to control can be built from the lowest level of individual controllable technologies (renewable energy, conventional generation, EVs, storage, and loads) and used to control hundreds of millions of devices through hierarchical cells. In the figure, the bottom level consists of individual technologies aggregated into small cells. Then, each upper level represents a collection of cells until the entire grid is covered. Within each layer, distributed controls are used to optimize energy production and use to meet system requirements. Minimal information is needed to be passed between layers, and this hierarchical approach enables control of hundreds of millions of devices.

To make this idea a reality, control algorithms for AEGs will need to be developed and implemented with the following characteristics:

### Operate in Real Time

A real-time optimization framework has been developed at the National Renewable Energy Laboratory (NREL) [3],[4] that can model well-defined objectives and constraints of DERs within each cell as well as consistency constraints for electrical quantities that pertain to the cell-to-cell connections. By using measurements in the system as a feedback mechanism and tracking optimal solution trajectories, the resultant feedback-based online optimization methods can cope with inaccuracies in the representation of the AC power flow and avoid having to measure all the uncontrollable resources. The algorithms enable DERs to track given performance objectives while adjusting their power to respond to services requested by grid operators and to maintain electrical quantities within engineering limits.

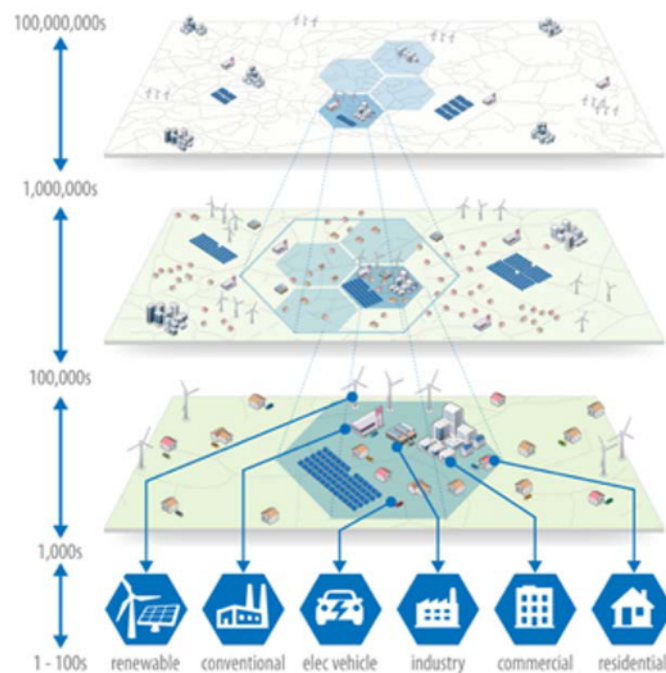


Figure 1. AEGs form a distributed hierarchical control system that integrates individual technologies in a cellular structure to the bulk power system. The scale on the left side indicates the number of controllable technologies seen along the bottom level. The lowest level shows locations of various generation, storage, and loads. [2]

## Hierarchical Communications and Asynchronous Data

To enable real-time optimization of AEGs with millions of controllable devices, a hierarchical communications architecture that includes cell-to-cell and cell-to-customer message passing can be formulated to manage these devices [5],[6]. Mathematically, to obtain consistency among cells, constraints are added to the optimization problem to ensure adjacent cells agree on the power flows from one cell to another. This is known as consensus-based optimization. Overall, the resultant feedback-based online optimization methods need to provably track the solution of the convex optimization problems by modeling well-defined objectives and constraints for each cell, as well as the consistency constraints for electrical quantities pertaining to the cell-to-cell connections. The feedback-based method also works for nonconvex problems; however, analytic proof of convergence for the feedback-based method is very tricky and not well established. These cell connections can be geographically co-located or based on aggregators such as smart home aggregators. In

this sense, it is worth emphasizing that the design of the distributed algorithm as well as the overall communications strategy will depend on the types of actors participating in the real-time optimization process (e.g., end customers, cell controllers, or aggregators).

## Robustness

In the context of AEGs, robustness includes both reliability and resilience. Reliability is the property to be tolerant to faults, and resilience is the ability to come back from a failure to an operational state. For reliable operation, stability analysis can be used at multiple timescales. Resilience to communications drops and asynchronous operation should be analytically established through pertinent input-to-state stability and tracking results. In other words, the AEGs should be able to continue operating even in the presence of these faults/errors. Mathematically, iterative optimization algorithms have been developed to operate with errors in their estimated parameters, such as gradients. In fact, it can be shown that a packet loss leads to the computation of primal or dual gradient steps with outdated information. Thus, cells that can switch from an islanded mode to a larger grid-connected mode may continue operating amidst faults and/or threats to the grid. These properties can be modeled as time-varying constraints in the underlying optimization problem. Similarly, flexible operation—wherein a cell (or a portion of a cell) switches to an autonomous control setting during a prolonged communications outage—should be enabled.

## Scalability

Figure 2 illustrates an architecture wherein communications among cells occurs when performing distributed and/or hierarchical control. As mentioned previously, distributed and hierarchical control algorithms are scalable and allow for the control of millions of devices in real time. When using distributed/hierarchical controls, the problem is broken up into smaller “cells,” and the interactions among cells can be reconciled using consensus to ensure consistency constraints for electrical quantities that pertain to the cell-to-cell connections. For example, adjacent cells must agree on the real and reactive power exchanges at the points of interconnection or overlap.

Real power and reactive power set points from the optimization are sent between levels in the hierarchy. Intracellular communications (on the same level) can be used to ensure that the set points of the DERs are computed to maximize the given operational objectives while ensuring that electrical limits are satisfied within the cell. Communications also take place between a cell-level control platform and individual customers; these are necessary to optimize customer-level objectives while respecting electrical limits within a cell. Message passing among cells to optimize the flow of power is based on economic and reliability targets. These levels of hierarchy allow for scalable distributed optimization algorithms to be designed and implemented in AEGs.

Figure 2 shows three levels of hierarchy. The top level, Level 3, aggregates neighborhoods to achieve an optimization objective, such as voltage regulation or power balancing. This level communicates to Level 2 (e.g., a single neighborhood) about the

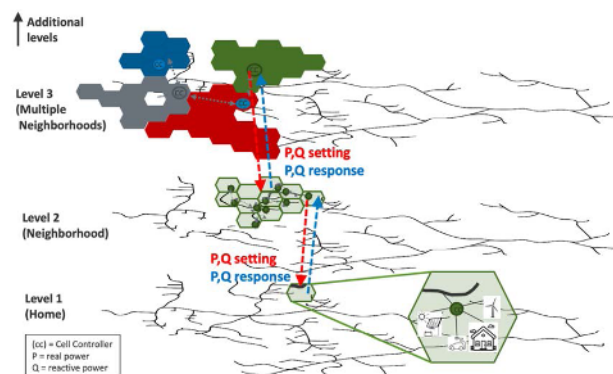


Figure 2. Communications architecture for distributed and real-time optimization of AEGs. In the figure, Level 1 would be at a home or business, Level 2 would be at a neighborhood, and Level 3 would be multiple neighborhoods on a single distribution circuit. [2]

aggregated power designated for that neighborhood. This information is passed from the neighborhood level down to the homeowner (Level 1) as a power set point to track. The homeowners might accordingly coordinate their own distributed wind or solar, smart home devices, and EVs to optimally balance the grid needs and their own usage preferences. Communications run in both directions, as indicated in Figure 2. For example, if the homeowner is unable to meet their power set point, information is passed



back up to Level 2 (e.g., via monitoring the aggregate power of the neighborhood) to indicate this, and the optimization is repeated until each agent in the cell has reached a feasible solution that achieves the global objective, as well as individual satisfaction.

## Evaluations in the NREL Energy Systems Integration Facility (ESIF)

To evaluate if the software algorithms would work when integrating many real controllable devices, we set up a large experiment at NREL's ESIF. NREL's work on the ARPA-E NODES program helped develop the first implementation of the algorithms in hardware and successfully demonstrate the real-time optimization of a single AEG cell. The experiment included simulation of a real distribution feeder from California with 366 single-phase connection points, more than 100 controllable assets at power (inverters, EVs, and batteries; see Figure 3 and Figure 4), and hundreds of simulated devices. The distributed algorithms were implemented in cost-effective microcontrollers that self-optimize and communicate to the central coordinator to attain system-wide goals (voltage regulation, frequency response).



Figure 3. Fleet of EVs under distributed control in the NODES experiment at NREL's ESIF.



Figure 4. Inverters under test in the ARPA-E NODES experiment.

## Real-World Applications

We have now started to move out of the laboratory to demonstrate the deployment of AEGs in the real world. The team has been working with Holy Cross Energy (HCE), a utility cooperative near Aspen, Colorado, to deploy the AEG technology in a group of smart homes in Basalt, Colorado. The smart homes in Basalt Vista

(Figure 5) are a pilot for an altogether new approach to the grid. These homes optimize energy for residents and their neighbors, but the principles behind Basalt Vista go much further. Within homes, each new connected device or energy resource—such as a residential battery, water heater, or solar PV system—can be controlled for unprecedented energy efficiency. At a larger scale, entire communities could rapidly share power, creating reliable energy for everyone.

HCE had been searching for a solution to managing new devices on its system. This has included a mix of customer energy technologies and bulk generation resources, since decreasing costs of connected customer-owned devices have made these systems much more affordable. HCE's grid has seen 10 to 15 rooftop solar installations per week, and it has been increasing its solar base for years, planning for a 150-MW summer peaking system through 2030.



Figure 5. Smart homes in Basalt, Colorado (USA).

## Conclusion

AEGs of the future will need to control and optimize millions of controllable devices in real time. A traditional central optimization approach to this problem is infeasible because of the computational cost; therefore, robust, scalable, and predictive hierarchical and distributed control algorithms with provable convergence are needed to optimize the grid in real time. NREL has developed these scalable algorithms to enable the proliferation of DERs on a massive scale.


A fundamental underpinning of AEGs is the ability to accurately model the cellular building blocks and their interactions with the rest of the systems so that control, optimization, and forecasting methods might be applied in operation. NREL has taken the preliminary





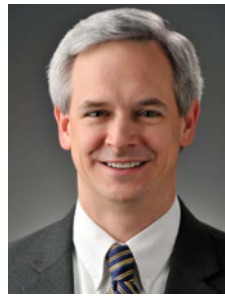
steps of demonstrating these algorithms in real time for real-world devices in the laboratory and now in smart homes. Additional work will be needed in controls, optimization, data analytics, complex systems, and cybersecurity to implement the AEG across the entire U.S. grid.

## Acknowledgments

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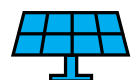
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# THE FUTURE OF RENEWABLE ENERGY CONSUMPTION: Grid-Interactive Efficient Buildings

*Nikitha Radhakrishnan, Erika Gupta, Karma Sawyer, and Monica Neukomm*

In the more than 100-year existence of the electric power grid, operators focused control on the supply of electricity, not the demand. Supply-side entities like utilities, grid operators, and large power plants match services to meet electricity demand. However, given growing peak electricity demand, transmission and distribution infrastructure constraints, and an increasing share of variable renewable electricity generation on the power grid [1, 2], there is rising interest in leveraging flexible demand-side entities to balance the demand with supply at different timescales and avoid transmission and capacity constraints. Flexibility in distributed energy resources (DERs)—such as customer-owned solar generation, battery storage, energy efficiency, and demand response—will be crucial in alleviating stresses on the grid and maintaining its resilience.

Buildings offer a unique opportunity for cost-effective demand-side management because they are the nation's primary users of electricity. They consume 75% of all U.S. generated electricity and drive a similar fraction of peak power demand [1]. The electricity demand from buildings results from a variety

of electrical loads such as heating, ventilation, air conditioning (HVAC); lighting; and appliances serving occupant needs. However, many of these loads are flexible to some degree. Energy efficiency and demand response are the two most common demand-side resources deployed today to provide benefits to building owners, occupants, and the grid. Demand response is realized by leveraging a building's demand flexibility, characterized by active load management on timescales consistent with utility system and grid needs. Demand flexibility is the technical capability associated with a building, to actively lower, increase, shift, or modulate energy usage in response to utility grid needs, compared to a baseline scenario reflecting the passive state of operation. For example, preconditioning building spaces can shift energy use away from more expensive peak hours. The thermal mass of a building's physical structure—parts made of steel, concrete, and masonry—have thermal inertia. It allows a building to deploy precooling or preheating strategies to shift HVAC energy loads to off-peak periods while maintaining comfortable temperature ranges for occupants. Research, led by the U.S. Department of Energy Building Technologies Office (BTO), helps buildings become smarter about the amount and timing of energy use through the Grid-Interactive Efficient Buildings (GEB) Initiative.



## What Are Grid-Interactive Efficient Buildings?

GEB is an energy-efficient building that uses smart technologies and on-site DERs to provide demand flexibility while co-optimizing for energy cost, grid services, and occupant needs and preferences, in a continuous and integrated way [3]. Four key features characterize GEBs:

- 1. Energy-efficient:** The ability to reduce net energy consumption and peak demand using high-quality walls and windows, high-performance appliances and equipment, and optimized building designs.
- 2. Connected:** Bi-directional communication capability to respond to time-dependent grid needs.
- 3. Smart:** Advanced analytical capability to manage multiple resources in ways that are beneficial to the grid, building owners, and occupants.
- 4. Flexible:** The ability to dynamically adjust and optimize building energy loads across behind-the-meter generation, electric vehicles, and energy storage.

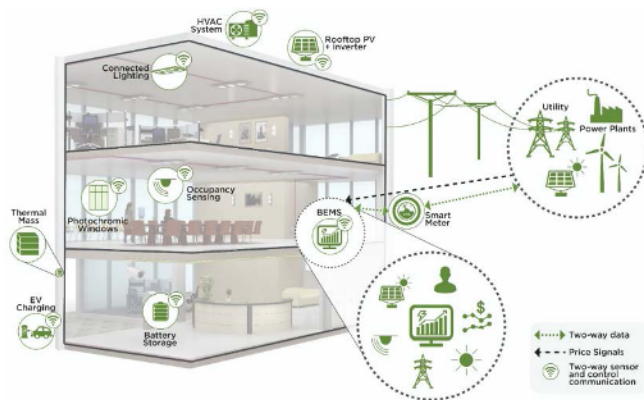


Figure 1. Example commercial grid-interactive efficient building. The GEB utilizes analytics supported by sensors and controls to optimize energy use for occupant patterns and preferences, utility price signals, weather forecasts, and available on-site generation. [3]

The GEB vision is the integration and continuous optimization of DERs for the benefit of the building owners, occupants, and the electric grid. A GEB optimizes energy use for occupant patterns and preferences, utility price signals, weather forecasts, and available on-site generation and storage. Sensors and controls can support analytics to optimize the operations

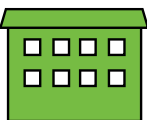
of a suite of advanced building technologies—including the HVAC system, connected lighting, dynamic windows, occupancy sensing, thermal mass, and distributed generation and battery storage. In many buildings, smaller sets of existing technologies could be integrated and controlled.

## Need for Advanced Control System Technology

A critical technical area of development necessary to harness building demand flexibility is integrating sensing and actuation with computing and communications to monitor and control the physical environment. Integrating state-of-the-art sensors and controls through most commercial buildings can save as much as an estimated 29% of site energy consumption. These savings are achieved through high-performance sequencing of operations, optimizing settings based on occupancy patterns, and detecting and diagnosing inadequate equipment operation or installation problems [4]. Furthermore, state-of-the-art sensors and controls can curtail or temporarily manage 10%-20% of commercial building peak load [5]. Moreover, building control strategies are necessary for implementing flexible, grid-interactive strategies to optimize building loads within productivity or comfort requirements.

Building control systems are a combination of local controllers and supervisory controllers. The local controllers manage a single component and respond to high-level settings (like temperature setpoints). Supervisory controllers manage whole energy systems, coordinate many local controllers, and implement high-level algorithms and strategies aimed at objectives like reducing energy costs. Coordination of multiple devices, coupling with building thermal mass, and mechanisms and processes that couple various in-building energy systems make it likely that building-level supervisory control approaches will outperform device-level approaches for providing demand flexibility [6].

Supervisory control algorithms typically involve preset rules, such as thermostat setpoint schedules for occupied and unoccupied hours. Various standards, such as ASHRAE Standards 90.1, 189.1, and IECC Chapter 4, specify building control rules. Many tuning parameters characterize rule-based controllers. They must be selected for each system and building and are often





reset during seasonal transitions. Rule-based systems are intuitive but do not necessarily lead to optimal operation due to their inability to anticipate or predict how the system will react. The ability to anticipate operational requirements is critical to the success of the GEB vision.

Model predictive control (MPC) has emerged as the most promising control algorithm to operate and plan building thermal operations and demand flexibility over a time horizon. It uses optimization over a sliding finite time horizon to find control strategies that optimize for selected criteria. It incorporates many inputs, including forecasts and measured data. MPC is attractive due to its conceptual simplicity and its ability to: (1) effectively control systems with complex time-varying system dynamics and multiple control inputs and constraints; (2) handle multiple objectives; (3) handle disturbances and uncertainty in predicted variables; (4) deal with inaccurate equipment models and load forecasts; and (5) optimize control decisions when faults are present in the system, provided that models capture their effects.

Some early experiments at building sites have shown that MPC can yield significant energy savings (up to 17%-65%) compared to the performance of installed control sequences [7, 8, 9]. Further, stochastic MPC algorithms can formally deal with inaccurate equipment models and load forecasts to find optimized control decisions when the predicted variables have uncertainty [10]. Distributed formulations of some MPC algorithms provide increased implementation scalability [11, 12].

The majority of MPC research has concentrated on implementation in large commercial buildings. The broad adoption of MPC in these buildings faces challenges like scalability, computational complexity, interpretability, and the need for expensive custom models, which are open areas of research. Development, training, and calibration of models that are sufficiently accurate and robust is another significant challenge, as is a lack of acceptance by building operators. These challenges lead to increased costs and long estimated periods for return-on-investment despite the demonstrated energy efficiency potential.

GEBs have taken advantage of the recent revolution in data science. Recent research efforts explore machine learning methods, such as reinforcement learning, to

learn energy efficiency control strategies. The methods learn the relationship between control variables (i.e., zone temperature setpoints and airflow rates), other variables (i.e., outdoor temperature, time of day, and day of week), and energy cost to represent them in structures such as neural networks [13]. Machine-learning-based building control may be competitive, especially when scalable and accurate control-oriented models are challenging to develop. Machine learning for energy consumption prediction [14] and MPC approximations for easier deployments [15] show immense potential to solve many of the drawbacks of traditional MPC systems.

## Barriers to Technology Adoption

Despite its significant role in the GEB vision, advanced building control systems face significant barriers to the maximum adoption of algorithmic innovation. Setting up building automation infrastructure is an expensive process, heavily relying on multiple contractors with varying expertise, time-consuming installation procedures due to a lack of standardized data taxonomy, and tailored modeling and control design for each building system. Moreover, cost-benefit trade-offs for advanced control strategies are difficult to assess due to existing technical challenges, uncertainty in guaranteed savings stemming from implementation and verification errors, and uncertainty in model or training data accuracy requirements and corresponding computational efforts compared to projected cost savings from performance improvements. Another significant obstacle for the penetration of autonomous building controls is the lack of standardized and interoperable hardware and software that can interconnect across multiple vendors, equipment types, and buildings.

Further, advanced control algorithms like MPC and machine learning may provide nonintuitive solutions, making it difficult for operators to interpret, tune, and adjust according to their needs. Lack of customer and operator education, interest, and awareness in new product development and implementation is a significant deployment barrier for new control technology, especially in small and medium commercial buildings. Additionally, comparison of performance features across products is difficult without an established baseline, especially for risk-averse owners and operators.




## Transforming Vision into Reality

The GEB vision heavily depends on various aspects of innovative control and automation technology. The development of interoperability standards for buildings and their systems is key to achieving the transformation of the vision into reality. One higher-level interoperability gap that has received recent attention is the need for standard semantic models of buildings and their systems. A semantic model is an overarching description of entities in a building, their capabilities, and their relationships to one another. With better interoperability, control systems can use smart sensors and actuators capable of self-documenting for communication with other building systems with minimal intervention. It would enable a control system to adapt from building to building and achieve expert-free commissioning, lowering installation costs. Standard semantic models allow applications such as advanced control, monitoring, and maintenance to automatically configure themselves to different buildings, allowing them to scale. Ideally, semantic models would also support interoperability between applications across different stages in the building life cycle from planning, design, and architecture, engineering, and construction to commissioning, maintenance, and operations.

GEB design depends on innovative predictive control algorithms for buildings. The algorithms should adapt to occupant/operator preferences, grid needs, changing weather conditions, and operational uncertainties. They should also proactively manage energy use ahead of time to accomplish the energy efficiency, demand flexibility, and occupant comfort goals of the buildings and DERs. They should be robust to uncertainties rising from sensing limitations, sensor measurement error, modeling errors, and weather and occupancy forecasts. These needs call for disruptive innovation in control technology that encapsulates the features mentioned above and is interpretable, scalable, and low-cost.

When buildings become critical grid assets, cybersecurity will become paramount. No longer will the security of building automation systems impact only the building and its occupants, but will also be a critical part of the electric grid. Recent investigations suggest that malware, phishing scams, or ransomware have targeted nearly 40% of building management system servers

[16]. Even without malicious attacks, the increasing complexity of smart building integrations increases the likelihood of disruptions and system failures due to faulty patches, user errors, and poor maintenance. If not adequately addressed, these threats could significantly slow the deployment of high-value connected technologies and future energy efficiency gains. As we realize the benefits of the GEB vision, we must also be cognizant of the risks and actively mitigate them.

BTO's GEB strategy aims to optimize energy use across DERs to advance the role of buildings in energy system operations and planning. The GEB strategy supports broader goals, including greater affordability, resilience, sustainability, and reliability; however, the concept of GEBs is nascent, and the research needs are quickly evolving. While many benefits and impacts have been defined, the full impact on the grid, buildings, and building occupants is still unknown. The central research needs include technologies and strategies, such as those described above, that allow for enhancing energy efficiency and demand flexibility and can ultimately lead to a fully optimized and integrated approach to demand-side management in buildings. 

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## THE FUTURE OF RENEWABLE ENERGY CONSUMPTION: Grid-Interactive Efficient Buildings

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**Dr. Nikitha Radhakrishnan**, is a Research Engineer at the Pacific Northwest National Laboratory (PNNL) and Technical Advisor for the U.S. Department of Energy Building Technologies Office with the Emerging Technologies program. Her work focuses on optimization and control methods for energy-efficient and demand-flexible building systems.

Prior to joining PNNL in 2016, she was a graduate student researcher at the Berkeley-Education Alliance for Research in Singapore (BEARS) and received her Ph.D. from Nanyang Technological University (NTU), Singapore. She is also a STEM Ambassador with PNNL's Office of STEM education and is actively involved in local STEM outreach events.



**Erika Gupta** is the Sensors and Controls Technology Manager at BTO with the Emerging Technologies program. Her work leverages her controls background, focusing on building energy management controls and projects supporting controls for grid-integrated efficient buildings. She first joined EERE as a technology development manager in the Fuel

Cell Technologies Office, managing projects that could lower the cost of hydrogen delivery. Under her management, the subprogram achieved its cost goal a year ahead of schedule through innovative control strategies, and several of her portfolio projects were recognized through R&D 100 awards. Prior to joining FCTO, she worked in the fuel cell industry as a systems reliability engineer and then as a lead control systems engineer on fuel cell battery hybrid systems for forklifts and distributed steam methane reforming systems at Nuvera Fuel Cells. She obtained her B.S. in mechanical engineering at Boston University and M.S. in mechanical engineering, with a focus on control systems, at Worcester Polytechnic Institute.



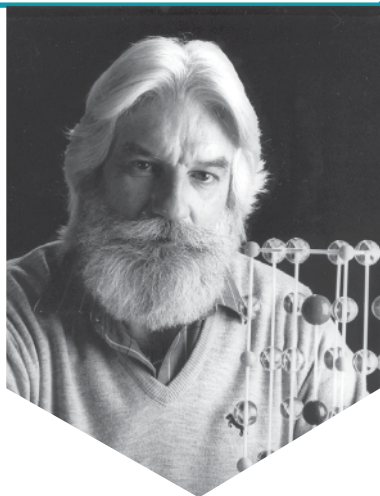
**Dr. Karma Sawyer** is the program manager for the Emerging Technologies (ET) program with BTO. She oversees a diverse portfolio of research and development program areas, with the goal of developing cost-effective, energy-efficient, flexible building technologies. Her team supports the development of innovative solutions and technologies

with partners across academia, national labs, small businesses and industry in HVAC, windows and envelope, sensors and controls, solid-state lighting, transactive controls, and building energy modeling. Prior to joining DOE, Dr. Sawyer worked as a postdoctoral scholar in the Department of Mechanical Engineering at the University of California, Berkeley. Dr. Sawyer was named an AAAS Science and Technology Policy fellow at ARPA-E (2010) and a fellow at the American Chemical Society-Petroleum Research Fund Summer School (2006). She received a B.S. with honors in chemistry from Syracuse University and a Ph.D. in chemistry from the University of California at Berkeley.



**Monica Neukomm** is the Grid-Interactive Efficient Buildings (GEB) Coordinator at BTO. She holds a master's degree in Public Policy, Energy, and Public Finance from the University of Maryland and a bachelor's in Business Administration from the University of Oregon.





### Dr. Paul Michael Grant, BSEE, AM, Ph.D.

Gamma Gamma Chapter,  
Clarkson University

Principal, W2AGZ Technologies

Paul Michael Grant was born in Poughkeepsie, NY, on May 9, 1935, the grandson of Irish immigrants, and grew up in the mid-Hudson Valley. In 2014, Grant obtained dual nationality status shared with the United States and the Republic of Ireland. His father worked for IBM and his mother for the local utility company, Central Hudson Gas & Electric, presaging what was to become a lifelong career filling both parents' shoes.

During the spring term of his senior year in high school, still only 17, he entered the employ of IBM, commencing what was to become a 40-year career with the company. In 1956, recognizing his work performance and abilities, the Corporation subsequently offered to underwrite his university attendance while he remained an employee, leading to a BSEE degree (summa cum laude, 1960) from Clarkson University and the AM (1961) and PhD (1966) degrees in Applied Physics from Harvard University.

While attending Clarkson (1956-60), Dr. Grant returned to work summers at IBM on thin magnetic film memory development, silicon epitaxial film growth and laser spectroscopy. During this period, he carried out research on magneto-resistive and Hall Effect thin ferromagnetic film devices, forerunners of today's spintronics technologies. The summer following his first year at

Harvard was spent back at IBM designing and constructing one of the first, if not the first, thin film evaporation chamber with the capability to measure in-situ reflection electron diffraction during film growth (RHEED).

Dr. Grant later organized and led IBM's Almaden Research Center's (San Jose, CA) effort in high temperature superconductivity, discovered five new superconducting materials, including the structure of the first superconductor above liquid nitrogen temperature followed by the world record Tl-2223 125 K material up to 1994, and is a co-inventor on the basic international patent on high temperature superconductivity in perovskite materials.

Dr. Grant retired from IBM in 1993 to accept a position as a Science Fellow at the Electric Power Research Institute in Palo Alto, CA. In collaboration with Chauncey Starr, EPRI's Founder, he developed the SuperGrid concept, a vision of an energy society based on a green, non-eco-invasive symbiosis of nuclear, hydrogen and superconducting technologies, supplemented by solar roof and urban biomass combustion renewables. He helped structure EPRI's US\$38 million Strategic Science and Technology program, particularly in superconductivity and advanced semiconductor materials to advance "Smart Grid" deployment.

He has written more than 130 publications in peer reviewed literature, more than 50 editorials, popular articles, commentaries and book reviews and holds more than 12 US and international patents and patent publications. He has appeared several times on television news network productions, e.g., Nova, Horizons and 60 Minutes.

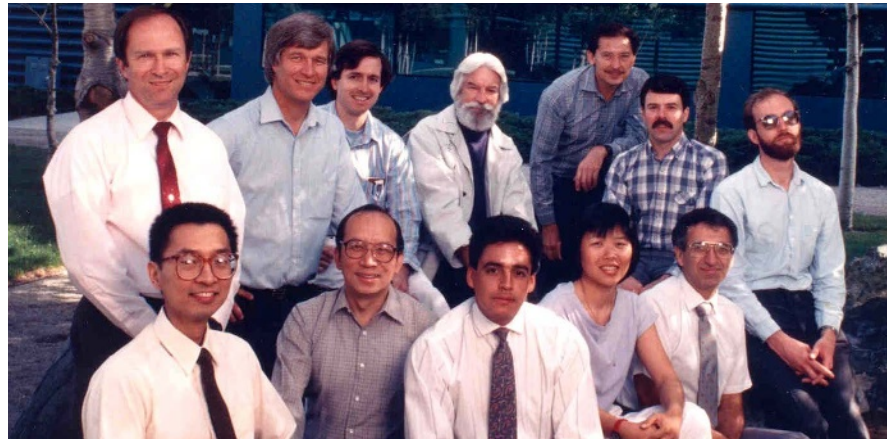
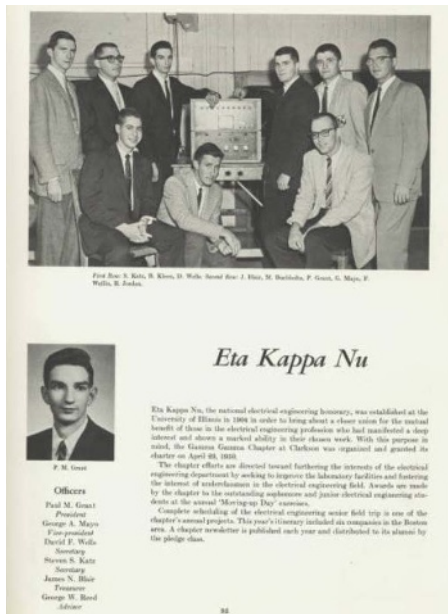
Dr. Grant continues to advance the [SuperGrid Vision](#) and employing modern computational physics to explore pathways to room temperature superconducting materials, as well as determining the pairing mechanism in high temperature superconducting copper oxide perovskites.

He is a freelance science writer for Nature, Physics World, Cold Facts, and Power Magazine.

He mentors science students all the way from elementary school to post-doctoral status with respect to future careers in industry and government.

Read more about Dr. Grant by clicking [here](#).





Summer, 1987 at IBM's Almaden Research Center, San Jose, CA. Front Row (Left to Right): Victor Lee, Ting Shen, Mike Ramirez, Grace Lim, Ed Nazzari. Back Row (Left to Right): Ed Engler, Jerry Torrance; Robbie Beyers, Paul Grant, Jose Vazquez, Rick Savoy, Stuart Parkin. This team was the first to find the atomic structure (shown in photo at far left) and optimal processing conditions for the original material found superconducting above the boiling point of liquid nitrogen. Paul Grant was Gamma Gamma Chapter President at Clarkson University, NY.

## How has Eta Kappa Nu (IEEE-HKN) impacted your life? Your career?

HKN at Clarkson taught me how to collaborate with and lead talented individuals, essential for my success on my future career.

## What inspired you to choose the engineering field?

My father was one of the pioneer "ham" radio operators who showed me as a kid how to design and build "neat" stuff, like radio controlled model airplanes. Isn't that what "engineering" is all about? (Dr. Grant's company, W2AGZ Technologies, is named to honor his father's ham radio call sign.)

## What do you love about engineering?

Solving and/or inventing practical solutions using physics and chemistry to improve human life and society.

## Whom do you admire and why?

The Four Thomases: 1) The Doubter (John 20). Ask questions. 2) Thomas Aquinas (1225-1274). Two paths to Truth: Faith and Reason. 3) Jefferson (1743-1826). Uncertainty Between the Press and History. 4) Edison (1841-1931). If you have an idea, go try it out!

## In your opinion, what has been the greatest change in engineering since you were a student?

I would say the evolvement of the Turing-Von Neumann programmable digital computer. With three instructions—subtract, store, branch on minus—and given enough time, you can solve any engineering idea/concept/design. Actually, the TvN machine matured when I was in high school, it just wasn't employed extensively until I was in college. I used an IBM 704 as a tool in producing my 1958 Senior Thesis at Clarkson.


## I wish I had known...

Richard Feynman. I came close on several occasions. I'm a fan of his thesis, "There's Plenty of Room on the Bottom." During my long career, I became acquainted with 12 winners of the Nobel Prize in Physics and/or Chemistry, one of whom I hired into my department at IBM San Jose.

## Best advice for new graduates...

Go for a career in industry, and, during your first week on the job, go out on the plant manufacturing floor, and seek what problems need solving.

## From your perspective, what's the next BIG advance in engineering?

Designing and manufacturing Life. We are already on the frontier of "Designer DNA," and now possess the microtools to engineer such. Such will present to humanity the most significant societal challenge over the upcoming decade. 





## What Did You Do During the Pandemic?

*Karen Panetta, Epsilon Sigma*

This is a question that will become an important interview question from prospective employers. The pandemic has created a unique generation of engineering graduates that have had to deal with extraordinary challenges. Thus, employers are going to want to know how young professionals managed to survive and thrive through this crisis.

An individual's response to this question reveals their ability to deal with unanticipated scenarios and their adeptness in overcoming adversity. The more successful candidates will show the impact they have made and the strengths they have gained from the experience.

Many young people are responding that they "took a gap year waiting for things to return to normal." Unfortunately, there will be no "normal" after the pandemic and a response like this shows naivete and a lack of economic realism. For instance, while hiring in many companies has ramped down or almost halted, students who assume they can just find a job until the germs go away and die, need to re-evaluate their plans. These students will be in competition with

millions of more experienced workers that have lost their jobs and are aggressively seeking permanent full-time opportunities rather than a short-term opportunity for someone to fill their time while they wait for life to return to the way it was.

Employers are seeking innovative and positive people that show that the individual is prepared for anything and will be resourceful.

They are also looking to see what personal actions and community involvement students participated in. For instance, in IEEE-HKN honor society, hundreds of HKN student members were the first offering online tutoring for kids whose parents needed help with home schooling their children while they struggled to balance working from home. Other great examples include the students who have engaged in using their engineering skills to 3d print PPE for local nursing homes and other at-risk populations through IEEE-SIGHT (Special Interest Group for Humanitarian Technologies) projects.

Every engineering student comes out with technical skills, but the ones that used them in ways that demonstrated their compassion for humanity will be the ones that companies will jump to hire.





### What's next?

Regardless of what engineering field an individual pursues, automation and robotics will become an intimate teammate throughout every discipline.


Robotics and technologies that help alleviate human contact to reduce the spread of disease will become commonplace. The most familiar applications of robotics include space exploration or manufacturing, but we will see more applications of specific application-based robots in our everyday lives. This includes disinfecting robots, health monitoring robots in schools and community spaces, delivery services and food production.

The pandemic has also renewed the importance for robust internet security, privacy and access to internet service. When the pandemic necessitated every social and educational interaction to move to virtual platforms, we became aware of just how inadequate and ill-prepared the world was to move online. Furthermore, it also highlighted how inequitable the availability of these services is throughout the world, despite living in a global economy.

### What will be the enduring impact of the pandemic on graduates?

Just like children of the great depression, who became very frugal and, reused and saved almost everything, we will see the behaviors of pandemic graduates change too. They will not take anything for granted and always be looking at scenarios of risk and alternative sources to ensure they have a plan of action in place when materials, supplies or even jobs are interrupted and lost.

As engineers, we know we must always keep learning, but now we must think of ways to execute innovative ideas when traditional assumptions of manufacturing and supplies are not readily accessible or cost-effective to obtain or transport.

This generation will also have more empathy and champion safety and resources for those individuals who have been essential to keeping food supplies and the agricultural pipeline functioning. These individuals have traditionally been the most underserved and invisible populations and now are the most vulnerable to virus exposure. Thus, the new engineers will not only be the architects of new technology but will be champions of social change. 



**Dr. Karen Panetta**

Epsilon Delta

Dean of Graduate Education for the  
School of Engineering, Tufts University

Professor, Electrical &  
Computer Engineering

IEEE Fellow

IEEE-HKN (Eta Kappa Nu)

Honor Society President 2019



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IEEE-Eta Kappa Nu

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# IEEE-Eta Kappa Nu Names Recipients of its Inaugural Madni Medal, Distinguished Service Award and Outstanding Teaching Award

*Recipients will be presented their awards at the IEEE-HKN Awards Ceremony to be broadcast live at 6 p.m. (ET) Saturday, 7 November 2020*

Dr. Ming Hsieh, Founder, Chairman and CEO of Fulgent Genetics, Inc. and Fulgent Pharma was named the recipient of IEEE-Eta Kappa Nu's highest honor, [IEEE-HKN Asad M. Madni Outstanding Technical Achievement and Excellence Award](#), for 2020, the first year the award has been given.



Dr. Ming Hsieh founded Cogent and Fulgent Genetics.

Dr. Hsieh was one of three individuals recognized by the Board of Governors for their outstanding contributions to IEEE-HKN, its members and to society at large.

All three will accept their awards at the IEEE-Eta Kappa Nu Awards Ceremony, to be held 7 November 2020 at 6 p.m. (ET). The program is the closing event of the [IEEE-HKN Experience](#). All three will participate in the live program.

2010 IEEE-HKN President Dr. Bruce Eisenstein, the Arthur J. Rowland Professor of Electrical and Computer Engineering at Drexel University, is the recipient of the [IEEE-HKN Distinguished Service Award](#)

for his exemplary volunteer service to the IEEE-HKN organization and its professional community. Dr. Eisenstein, IEEE President in 2000, was instrumental in the merger of HKN and IEEE in 2010.

Dr. Eisenstein, as the President of Eta Kappa Nu, was a major force behind the merger between IEEE and



Dr. Bruce Eisenstein lectures his class at Drexel University.

HKN, according to his nominator, Dr. Timothy Kurzweg, 2017 IEEE-HKN President. Dr. Eisenstein's vision developed a path to bring an honor society to IEEE and ensure a strong future for HKN.

"This contribution helped every past, current, and future member of IEEE-HKN," Kurzweg wrote.

The [C. Holmes MacDonald Outstanding Teaching Award](#) was awarded to Jennifer Marley, Assistant Professor of Electrical and Computer Engineering, Valparaiso University, Valparaiso, Indiana for her excellence as a teacher, her contributions to the scholarship of teaching, and her mentoring of undergraduate research students.

"Professor Marley is an exemplary teacher," wrote Douglas Tougaw, Professor of Electrical and Computer Engineering and the Richardson Professor of Engineering at Valparaiso University, in his nomination of Dr. Marley for this award. "She is brilliant, hard-working, and incredibly creative in finding ways to capture and maintain her students' attention."

Dr. Hsieh, who will receive a medal and an honorarium, invented a unique fingerprint modeling technique based on partial differential fluid dynamic equation and novel numerical representation for ridge flow characteristics of

a finger print, which could not be described by current pixel-based image representation. This significantly enhanced digital fingerprint features beyond traditional minutia points & pattern classification.

Dr. Hsieh also invented the Programmable Matching Accelerator (PMA) for high-speed fingerprint matching, which with novel image processing, recognition algorithms, and massive parallel and super pipeline dataflow hardware architecture, revolutionized the automated fingerprint identification system (AFIS). The AFIS combined with novel feature extraction



Dr. Jennifer Marley was recognized for teaching excellence and mentoring undergraduate research students.

algorithms and new non-heuristic search methods for matching of fingerprint features dramatically reduced computational complexity and implementation cost. The PMA achieved stellar fingerprint matching accuracy enabling an unprecedented performance of AFIS.

AFIS has had a worldwide impact: At the US Federal Bureau of Investigation, Cogent (another company founded by Dr. Hsieh), built a crime database, capable of capturing and searching a crime scene fingerprint of palm print from any part of finger/palm prints. London's Scotland Yard equipped its police force with Cogent's handheld finger print mobile phone, instantly identifying suspects. In Europe it supports Eurodac, the world's first and largest immigration control system. It has also been deployed worldwide to prevent voter fraud.

Fulgent's technology platform for genetic testing for cancer offers one of the broadest test menus in the market, with the ability to customize unique gene panels, according to Shrikanth Narayanan, Dr. Hsieh's nominator.


"This has created impact on cancer research, companion diagnostics across the oncology community on enabling personalized cancer treatments," Narayanan wrote.



This medal will be given to the recipient of the Asad M. Madni Outstanding Technical Achievement and Excellence Award.

The [IEEE-HKN Asad M. Madni Outstanding Technical Achievement and Excellence Award](#), is the honor society's first endowed award, made possible through a generous contribution from the IEEE-HKN Asad, Gowhartaj and Jamal Madni Family Fund of the IEEE Foundation.

The award is named for IEEE Life Fellow, IEEE-HKN Eminent Member, and member of the U.S. National Academy of Engineering Asad M. Madni.

The IEEE-HKN Board of Governors established the award in 2019 to recognize and honor Dr. Asad M. Madni's nearly 50 years of technical and philanthropic accomplishments and visionary leadership. 

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# 10

IEEE-Eta Kappa Nu



## YEARS TOGETHER

## IEEE and Its Honor Society Eta Kappa Nu Celebrate 10 Years Together

*Stacey Bersani, Project Manager, IEEE-Eta Kappa Nu*

With their merger on 1 September 2010, IEEE and its honor society, [Eta Kappa Nu \(IEEE-HKN\)](#), created a pathway for IEEE and IEEE-HKN to identify and develop future leaders in the IEEE fields of interest. Ten years, 48 new chapters, 26,000 inductees, and hundreds of thousands of community service hours later, IEEE-HKN is an engine for innovation and excellence.

"The leadership of IEEE realized the potential of this merger and many people worked tirelessly to make it happen," says Bruce Eisenstein, 2000 IEEE President, 2010 HKN President. "We can look with pride at the result today."

With 265 collegiate chapters in 19 countries, the honor society has provided IEEE a way to reach and bring

into its volunteer and leadership ranks the best and brightest students, industry professionals, and academics. Some 23 IEEE presidents—and every one since the merger—are HKN members.

IEEE-HKN also offers a strong feeder system for IEEE societies since HKN is populated with ready and willing volunteers for Science, Technology, Engineering and Math (STEM) education outreach, tutoring, humanitarian efforts, and committee and board-level positions throughout IEEE.

In turn, HKN gained the resources to grow and transform into a multi-faceted, vibrant, global society. All of HKN's international growth occurred since the merger: The honor society now

has 26 chapters in Regions 7-10. About 3,000 new members (from Regions 1-10) are inducted into IEEE-HKN each year.

"IEEE-HKN embraces its roots as an American university honor society, but it has grown into a global professional organization that brings professional development, career development, life skills development, and leadership skills development

The leadership of IEEE realized the potential of this merger and many people worked tirelessly to make it happen. We can look with pride at the result today.

BRUCE EISENSTEIN



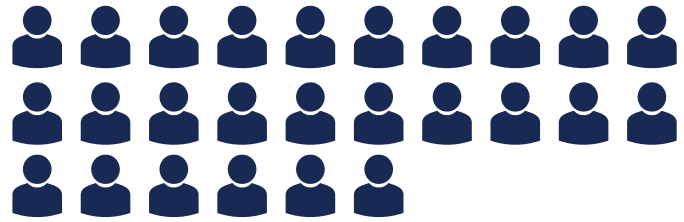
HKN Merger Handshake: Richard Gowen, IEEE Foundation; John Vig, IEEE President, and Bruce Eisenstein, HKN President (2010).



THE BRIDGE

2010-2020

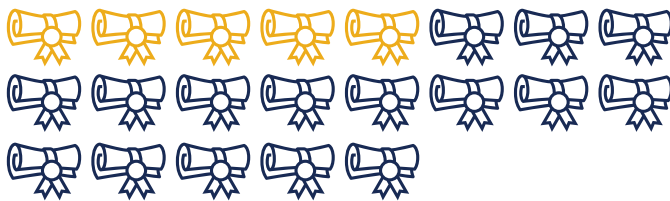
26,000  
INDUCTEES



17  
MEMBERS *elevated to eminent member*



48  
NEW Chapters

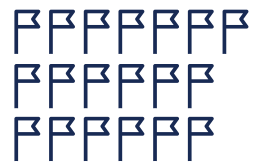


220  
ACTIVE Chapters

26  
INTERNATIONAL CHAPTERS in Regions 7-10



19  
COUNTRIES



27  
Issues of THE BRIDGE



7  
APEX Awards



#### FIRST ENDOWED AWARD

established in  
Asad M. Madni  
Outstanding Technical  
Achievement and  
Excellence Award

2019

#### NEW PROGRAMS

8+

Student Leadership Conference  
Founders Day Celebrations  
Key Chapter Recognition  
Pathways to Industry (*in-person and  
webinar series for professional development*)  
IEEE-HKN Experience  
Graduation Celebration  
Tetris World Championship  
Virtual Tutoring Center



Mu Nu Chapter members from Turin, Italy receive Chapter Awards in 2018.

to our members throughout their careers,” says [Edward A. Rezek](#), 2020 IEEE-HKN President.

Programs and services, such as the Student Leadership Conferences, the Pathways to Industry professional development series, the annual awards programs, and the electronic edition of *THE BRIDGE* magazine, have been added or improved to better meet the needs of its members and the communities they impact.

Leadership training, networking opportunities, a career center and chapter mentoring programs are offered to help develop “the complete technical professional,” says IEEE-Eta Kappa Nu Director Nancy Ostin, who recently celebrated her eighth year with IEEE and has led the society through a period of solid growth and transformation.



Balloons in the Air: Beta Eta Chapter Celebrates Founders Day.

The honor society is celebrating the anniversary of this successful partnership through the rest of 2020, encouraging all members—students and professionals—to raise the profile of IEEE-HKN through social media, coordinate service projects with IEEE Student Branches or within IEEE regions or sections, contribute to a

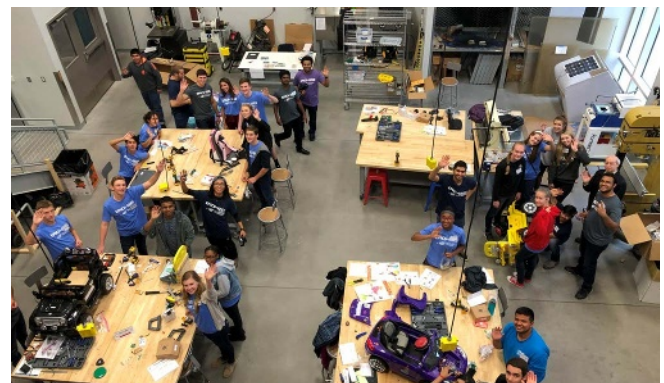
\$116,000 giving campaign (the honor society is 116 years old on 28 October 2020), and to give back in other ways.

At its core, IEEE-Eta Kappa Nu is an honor society dedicated to recognizing students and professionals who have proven themselves through outstanding scholarship, unimpeachable character and the positive attitude that propels them to serve others.

“IEEE-HKN is never given; it is earned,” Ostin says, who adds that the HKN designation is lifelong, and those who have earned it are expected to give of their time and talents for the betterment of their local and global community.

In 2019 alone, IEEE-HKN student members logged more than 85,000 of service to the society, their communities and others, Ostin says. The impacts of the Chapters are particularly great within the host educational institutions.

Projects have included The HKN Epsilon Xi chapter at Wichita State University partners with “Go Baby Go,” an organization that adapts ride-on vehicles for children with disabilities, to engineer and build customized cars for toddlers based on their specific needs. The Mu Eta Chapter and IEEE Student Branch at University of KwaZulu-Natal in South Africa organized “Women in Technology and Engineering Careers” talks for more than 200 local high school female students.



Go Baby Go Project by Epsilon Xi Chapter

The honor society has been tested in 2020 like never before: The global pandemic demanded that the primarily in-person business model that IEEE-HKN has used needed to be moved online so that Chapters could maintain operations, and members could live up to the promises they made when inducted. IEEE-HKN



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.



Legacy HKN Leaders (l-r): John DeGraw, Tom Rothwell, and Eric Herz.

did not just have to augment its offerings with online programming, it had to develop a new method of delivering resources and Chapter support.

By 5 April 2020, the society developed a new online Induction Ceremony, which holds fast to the 116-year-old ritual, and has been used by dozens of Chapters and a Virtual Tutoring Center Initiative. On 31 May 2020, IEEE-HKN held its first Graduation Celebration to recognize those who more than likely would not have in-person graduation ceremonies. HKN Eminent Member and Broadcom Founder [Henry Samueli](#) offered advice over a live broadcast.



The 2019 Student Leadership Conference attracted about 250 attendees to the program held at Tufts University.

Chapters have since shared best practices with one another on monthly calls, and the first-ever IEEE-HKN Tetris World Championship match was held, strengthening the sense of community among its worldwide membership.

A remote New Chapter Installation ceremony, which was used to add three new Chapters, was developed this summer. The Pathways to Industry program was transitioned into a series of online webinars, and the society's premier educational and networking event,

the annual Student Leadership Conference, is being reimaged as an 11-day, interactive online event that will be open to all IEEE-HKN members, students and professionals alike.


"Our students and faculty advisors built upon the resources we provided and used their creativity to mentor and tutor students, support their universities through hosting online classes for younger students, and came together for social events, such as online scavenger hunts and trivia games, to stay connected. Their commitment to IEEE-HKN and the brilliant way in which they responded to the crisis underscores the character these students possess and why they were invited to join IEEE-HKN in the first place," Ostin says.

Only the top 25 percent of undergraduate university juniors and the top 33 percent of university seniors are invited to join. Graduate students, doctoral candidates and professional members also are invited. As an honor society, IEEE-HKN emphasizes its ideals of scholarship, character, and attitude.

Many tech pioneers are members of IEEE-HKN, including [Vint Cerf](#) and [Bob Kahn](#), "fathers" of the Internet; [Martin Cooper](#), inventor of the first handheld cell phone; [Len Kleinrock](#), developer of the ARPANET; [Robert Metcalfe](#), inventor of the Ethernet.

They also include industry giants such as [Norm Augustine](#), former chairman and CEO of Lockheed Martin; [Larry Page](#), co-founder of Google, and [Steve Wozniak](#), co-founder of Apple.

[S. K. Ramesh](#), 2016 IEEE-HKN President and current Chair of its Development Committee, says: "The merger happened because of the vision and foresight of champions like [Bruce Eisenstein](#) (IEEE President, 2000 and IEEE-HKN President at the time of the merger), [Stephen Goodnick](#) (IEEE-HKN President 2011-2012), and [John Orr](#) (IEEE-HKN President 2013-2014), who guided us through the formative years to make IEEE-HKN what it is today: A vibrant globally diverse organization that engages students and professionals, celebrates excellence in scholarship and service, transforms individuals, and brings IEEE's mission to life in communities worldwide."

For more information on IEEE-Eta Kappa Nu, please email Nancy Ostin, Director, at [n.ostin@ieee.org](mailto:n.ostin@ieee.org) 

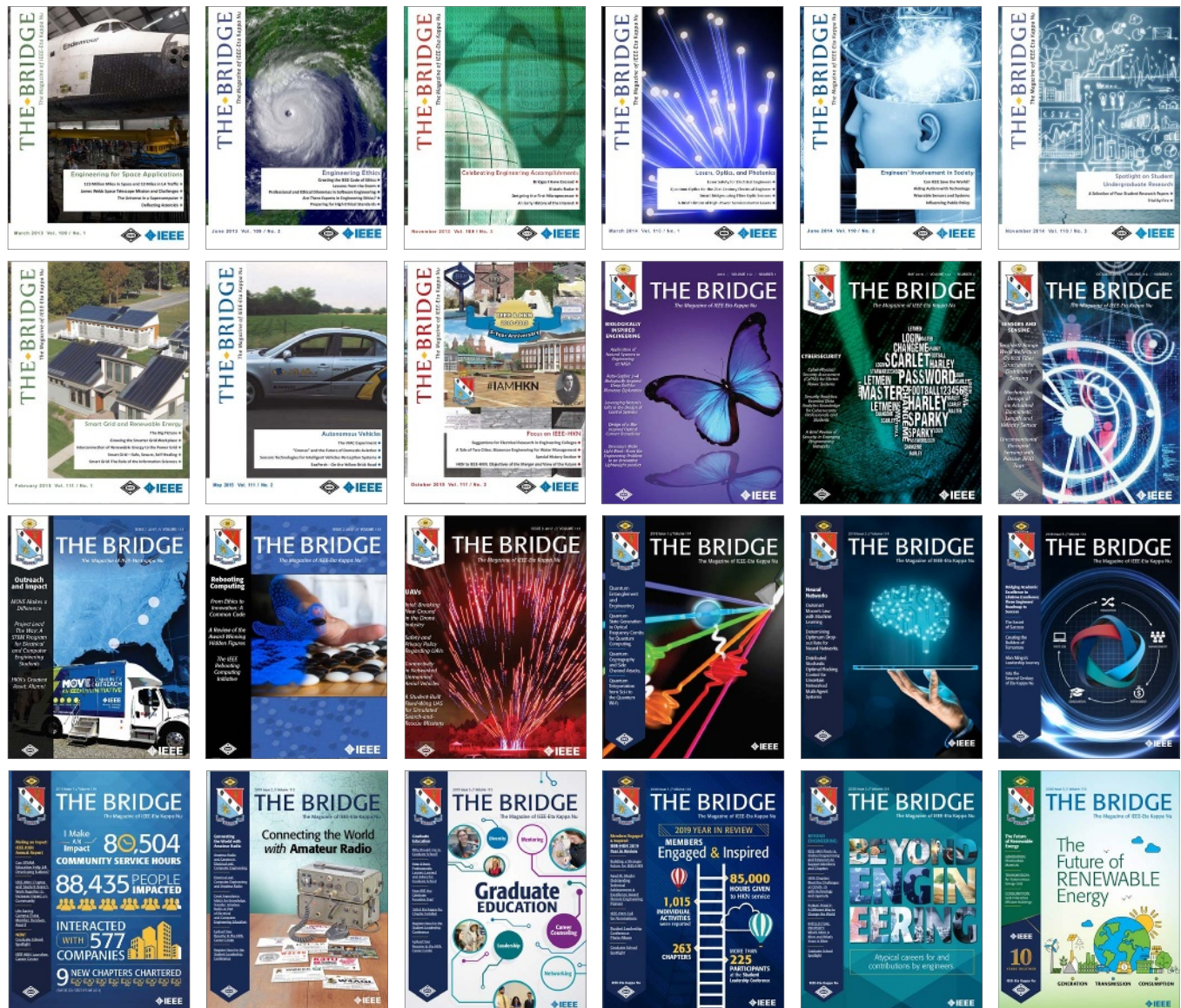
## THE BRIDGE Magazine of Eta Kappa Nu: Part I

Steve E. Watkins

Eta Kappa Nu (HKN) recognized the need for a publication to communicate with members and alumni and to archive activities since its founding. The first publication was an annual booklet called *The Electric Field* which evolved into *The Yearbook* and finally took the name of HKN's Wheatstone bridge emblem as *THE BRIDGE*. The volume count of the magazine dates back to the publication year of 1905; this current issue reflects this long history as volume

116. The schedule has varied between one issue to four issues per year. Editor duties have been handled on occasion by a volunteer editor or association officer and at other times by the executive secretary/director. Currently, a volunteer editor-in-chief and editorial board manage the magazine with the support of paid staff. Content contributors have included founders, officers, members, alumni, and other prominent professionals. HKN founder, Maurice L. Carr (1877-

### Magazine issues from 2013 to 2020





1942), was an active author, writing 32 articles during his lifetime. Other frequent authors were Alton B. Zerby, 1914-15 President and 1934-58 Executive Secretary, and Larry Dwon, 1958-59 President.

As a magazine of the honor society for IEEE, the current charter for the editorial board identifies *THE BRIDGE* mission as “an archival, flagship publication for IEEE-Eta Kappa Nu that highlights content with organizational, professional, technical, and career relevance to student and professional members.” Furthermore, the scope states that “the magazine shall support the scholarship, leadership, and service values of IEEE-Eta Kappa Nu and shall highlight technical achievement in, and history of the profession.”

The figure to the left shows the magazine covers from 2013 to the present. These covers reflect the theme or chosen content from each issue. Typical content consists of features on a technical or professional theme, IEEE-HKN corporate activity and news, chapter contributions, member profiles, and advertisements. The chapter contributions related to special activities or local impact have been a long-established emphasis; chapters were encouraged to have a Bridge Correspondent for many years. Such contributions often highlight best practices among chapters.

One of the earliest changes after HKN became IEEE-HKN was the move to electronic-only publication of *THE BRIDGE* magazine. A volunteer editorial board took the lead in 2013 as a standing committee. Members were Steve E. Watkins (EIC), Catherine Slater,

**The magazine shall support the scholarship, leadership, and service values of IEEE-Eta Kappa Nu and shall highlight technical achievement in, and history of the profession.**


EDITORIAL BOARD CHARTER



Awards since 2014

excellence for seven consecutive years from 2014 to present. The magazine continues to emphasize HKN ideals of *scholarship, character, and attitude* while being HKNs archival record.

Part II will provide an index of articles for recent issues.

More information on the history of Eta Kappa Nu and of *THE BRIDGE* Magazine can be found at the Engineering and Technology History [Wiki page](#). This page has a link to the *History of Eta Kappa Nu* (1975) by Larry Dwon in which *THE BRIDGE* is the subject of Chapter I. The page also contains an archive of many issues from the 1980s, 1990s, 2000s, and 2010s. One issue from this archive, the millennium issue (Volume 96, No. 3, 2000), includes selected articles of past issues between 1909 to the 1990s. Recent electronic issues are available on the [IEEE-HKN website](#). 



**Steve E. Watkins** was the 2018 President of IEEE-Eta Kappa Nu and is Co-Editor-in-Chief for *THE BRIDGE*. He was inducted by the Gamma Theta Chapter at Missouri University of Science and Technology. He is a professor and Chair of Electrical and Computer Engineering at Missouri S&T. He has been a Faculty Advisor for the Gamma Theta Chapter since 1992.

HKN History Note: Alton B. Zerby and Paul K. Hudson, both Executive Secretaries, managed *THE BRIDGE* magazine as editors for over 20 years each.





### Lauren McDaniel

Theta Lambda Chapter  
University of South Alabama  
Bachelor's, Electrical and  
Computer Engineering

Lauren McDaniel is from Mobile, Alabama and is a recent graduate of the University of South Alabama, where she double-majored in Electrical and Computer Engineering. She is the recipient of the 2019-2020 Department of Computer Engineering Student of the Year. At South, she served as 2019-2020 President of the IEEE-HKN Theta Lambda Chapter, as well as the Treasurer of the IEEE Student Branch. In addition to her involvement with IEEE, she participated in many other organizations including: Mortar Board, College of Engineering Ambassadors, and the Freshman Leadership Scholars. Since graduating this past May, she has moved from the Mobile area to begin her career in the engineering field, where she hopes to continue to learn, while also using all of the knowledge that she gained from earning her undergraduate degree.

#### **What has it meant to you to be inducted IEEE-HKN?**

Being inducted and being able to serve as the president of my HKN chapter gave me the greatest sense of community and involvement with my fellow classmates that I had experienced in all of the 4 years that I attended the University of South Alabama. I was able to enter the organization, as well as the position with a goal to grow our organization and involve the students within it both locally and beyond, but this goal, in turn, allowed me to personally feel the greatest sense of community with my fellow classmates, and even students nationwide.

#### **Do you have a best HKN story to share?**

My favorite HKN memory was attending the Student Leadership Conference in Boston, Massachusetts in the Fall of 2019. I would recommend this conference to all HKN

student members, because meeting students from various universities all throughout the country, and network and connect with them was one of my favorite experiences of my college years.

#### **Why did you choose to study the engineering field?**

Other than general interest in STEM, I like a good challenge! Going into college, the engineering field terrified me, but that's precisely what I loved about it. I chose to pursue engineering because I knew that I would never stop learning because this field never stops advancing.

#### **What do you love about engineering?**

Like I previously said, engineering never fails to challenge me, and I always end up learning something new, no matter how small.

#### **What is your dream job?**

I believe it goes without saying that my dream job is one within the Electrical and Computer Engineering field. But my dream job is also one that never grows to be monotonous, and always continues to advance with the rate of growth of modern technology, and always keeps its employees learning. I wouldn't mind it being located in a really big and awesome city as well!

#### **Whom do you admire (professionally and/or personally) and why?**

I admire my dad. Along with showing me my entire life what it means to be both strong and self-sufficient, he has done nothing but encourage me from the beginning my engineering journey all the way to beginning of my career. He's my biggest fan, and I wouldn't be an engineer without him!


#### **What is the next BIG advance in engineering?**

I think the next big advance in engineering would be the normalization of space travel, and just extending the human presence in space in general.

#### **What is the most important thing you've learned in school?**

The most important thing I learned is how to learn and be receptive to new knowledge, and adapt what you know to new things that you're learning. Mostly everything you learn in school is connected in some way, and if you can make those connections, you're pretty much unstoppable.

#### **What advice would you give to other students entering college and considering studying your major?**

If you're thinking about majoring in engineering, be very introspective and positive that you have a passion for it. It will take a lot of time and effort, and you have to absolutely love what you're doing to want to put in the effort that a degree in engineering demands. Study hard! When you get into your upper-level courses, you're going to wish you could go back and take your lower-level courses so don't take them for granted while you're in them. 



## Dr. Sarah Rajala

Beta Gamma Chapter  
IEEE Life Fellow  
Michigan Technological University

### Laying the Groundwork of a Successful Career


Dr. Sarah Rajala, inducted in 1972 into the Beta Gamma Chapter at the Michigan Technological University, has watched IEEE-Eta Kappa Nu grow over the years and has played an active role in the sustainability of the organization. Even after retiring from 40 years in academia, either teaching electrical and computer engineering or serving as the Dean of those departments, Dr. Rajala has never stopped being interested in the professional development and education of young people. One way she continues to support students is through her financial contributions to IEEE-HKN.

Dr. Rajala serves as a Delegate on the IEEE Foundation Board of Directors, where she has felt a strong commitment to IEEE and HKN since becoming a member almost 50 years ago. Through her financial contributions as a board member of the IEEE Foundation, she always commits part of her giving toward HKN. She recalls: "One of the things that was always important to me throughout my time as an undergraduate as well as in my career, was my participation in Eta Kappa Nu, so I wanted to provide some of the funding I gave to the IEEE Foundation to

dedicate it to Eta Kappa Nu." From experience in her own life, she knows a strong education is the stepping stone to professional excellence, and HKN walks alongside students to equip them to be engineers who are not just successful, but also intentional in giving back and responsible for their decisions. To be a part of preparing the next generation of engineers is something that compels Dr. Rajala to keep giving.

Looking back at her own professional development, Dr. Rajala describes her experience in Eta Kappa Nu as, "Empowering." She continues: "As an organization, they play an important role in recognizing the students in electrical and computer engineering and broad disciplines supported by IEEE. I think that's important because it really helps reinforce students' capabilities, and gives them an opportunity to be connected with local chapters, where they are often engaged in service-oriented activities." IEEE-HKN gives students the opportunity to engage with peers locally in their Chapters, but also know they are connected to a global network of students and professionals who want to use their expertise as a means to benefit others.

With 40 years of working in academia after being an undergrad, masters, and doctorate student herself, Dr. Rajala can look back from where she came and give a unique perspective to those following in her footsteps. She says: "I've had a very long and successful career in engineering as an academic. I had opportunities to serve in various leadership positions both in professional societies as well as at my university, and I really have to thank Eta Kappa Nu for laying the groundwork for me back as an undergraduate. I never realized it at that time, and often students don't when they're going through the process, but it provided me opportunities and recognized I had some abilities in the context of technically doing well in the program, as well as leadership opportunities. That is groundwork I can look back now and see, though I certainly didn't see it at the time."

To help equip and support the students of IEEE-HKN throughout their academic journey, please follow this [link](#). 

# Mu Theta Chapter President Participates on Panel Discussion on 'Role of Women in Engineering'

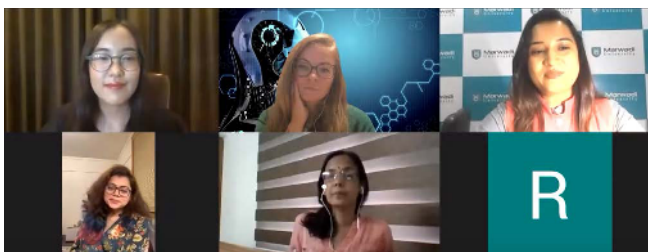
*Thittaporn Ganokratanaa, Mu Theta Chapter President*

WIE IEEE Gujarat Section in association with Marwadi University organized a panel discussion on "The Role of Women in Engineering" on the occasion of International Women in Engineering Day, 23 June 2020. The panel provided a truly an inspirational discussion and great support that encourages girls and women to believe in themselves and do what they love.

More than 100 people attended the session, which explored what a woman engineer as an individual can do. It allowed the audience to raise questions and encourage deep thoughts about women engineers of the 21st century. The topics included the importance of diversity at work, gender gap, leadership lessons learned, and work-life balance in the pandemic situation. Eminent speakers from all over the globe were invited.

Thittaporn Ganokratanaa, the president of the IEEE-HKN Mu Theta Chapter at Chulalongkorn University, Thailand, served as one of the panelists. She discussed women empowerment and gave advice to young women trying to break into engineering and technology fields and how to overcome problems of gender inequality in the workplace or in internships. She also addressed how WIE has helped her to pursue her passion for studying engineering.

[A recording of the panel can be found here.](#) 



Thittaporn Ganokratanaa, President of the Mu Theta Chapter (upper left corner), discussed women empowerment.

# A Look Inside Beta Chapter's Lounge

*Nicholas Haythorn, Beta Chapter President*

Eta Kappa Nu's Beta Chapter was chartered at Purdue University in 1906. Unfortunately, the first few years were rough due to a university wide ban on fraternal organizations. In 1913, the university lifted the ban on organizations and the Beta Chapter was able to reestablish its presence on campus. The chapter has been active since, making it one of the oldest continually active organizations on Purdue's campus.

The HKN Lounge at Purdue was established in 1968, having recently celebrated its 50th anniversary. Historical knowledge among current Beta Chapter students indicates that the lounge has operated every semester since then. Beta Chapter students operate the HKN Lounge during both semesters of the academic year, except for the first week of the semester (to prepare) and the last week of the semester (for finals). "The Lounge" as it is affectionately referred to, is open to all Purdue students, faculty, and staff from 7:30 a.m. until 5 p.m. five days a week. It is divided into two rooms. The Outer Lounge is a cozy space with tables, chairs, and couches for patrons to enjoy. The lounge is usually full of students enjoying snacks, studying, playing Super Smash Brothers on the Lounge's




The Outer Lounge offers a cozy space for studying and playing games.






Traditionally the Beta Lounge has served as a gathering spot for members and faculty, as shown in this photo taken before the COVID-19 pandemic.

Nintendo Wii, and even occasionally napping. The Inner Lounge is a miniature café, selling donuts, bagels, coffee, snacks, sodas, and other treats to the Purdue University population. In its 50 years of operation the lounge has become a Purdue University institution, having 4.8 stars on Google.

A day at the Lounge is divided into 10, one-hour Person on Duty (POD) shifts, each of which is staffed by at least two active Beta Chapter members. Because the Lounge is in the basement of Purdue's Electrical Engineering building and staffed by student volunteers, it can provide snacks and drinks at incredibly discounted rates. Breakfast at HKN, consisting of a bagel with cream cheese, and a cup of freshly brewed coffee costs just US\$2.00. A student looking for a can of soda can find it for US 60 cents, far less than any vending machine. If one was looking for a sweet treat, he or she could find any major candy bar for sale at US 90 cents, or a donut for a US\$1.00. The Beta Chapter does make a small profit from the Lounge. Funds from the lounge are used to keep it in operating condition and fund the Beta Chapter's weekly member events. In the fall semester of 2019, the lounge served 7,151 coffees, and 4,332 bagels, donuts, and muffins. The Lounge is primarily managed by three of Beta Chapters officers. Beta chapter is hoping to save up enough funds to get the lounge renovated in the next few years, enabling its continued ability to serve Purdue University and the greater West Lafayette area. 

## Welcome to the Gamma Theta Lab

The first thing one sees as he or she approaches the IEEE-HKN Student Project Lab at Missouri S&T is a display of HKN memorabilia, an events calendar and of course, the current year Outstanding Chapter Award. The Gamma Theta Chapter is one of IEEE-HKN's most active, consistently receiving the IEEE-HKN Outstanding Chapter Award for its remarkable line-up of community service, alumni outreach, tutoring, technical and social events and its commitment to the highest standards for inducting new members and other Chapter operations. The lab is where IEEE-HKN members gather to lay their plans for the year; meet with potential members and their Faculty Advisors; provide resources for student success; and socialize. 



The IEEE-HKN Student Project Lab at Missouri S&T is the perfect spot for Gamma Theta Chapter members to meet to plan upcoming events, and to display the Chapter's numerous Outstanding Chapter Award plaques.

# A Goal for Safe and Reliable Off-Grid Communities

*John Nelson, IEEE Smart Village–Next Generation (ISVx) Chair*

IEEE Smart Village (ISV) has a mission to integrate sustainable electricity, education, and entrepreneurial solutions to empower off-grid communities.

ISV is not a charity that provides money and walks away. Rather than giving a fish to a hungry person, ISV provides the fishing pole so that the person can feed not only himself or herself, but can use the fishing pole to feed the entire community, and make a profit doing so. Unlike fishing though, there are dangers and hazards involved with providing electricity, especially to those who have never been exposed to the hazards of electricity.



Dangerous Arc Flash Incident


Electricity provides many benefits for empowering people and improving the standard of living. However, electricity is colorless, odorless and tasteless. It can also be dangerous in that it can shock, injure, burn and even kill a person. That is why ISV recently introduced a new Electrical Safety, Reliability and Standards Committee, which oversees issues surrounding the introduction of electricity, especially to an off-grid community.

During the August 2020 IEEE Power Africa Virtual Conference, one of the sessions included a 90-minute panel discussion with audience participation. Representatives from North America, India, Kenya, Democratic Republic of Congo and Angola were the panelists. The first 60 minutes included a moderated panel discussion among the expert panelists. The question-and-answer period was lively, especially by those involved with micro-grids who were voicing concerns.



Arc Flash Testing for IEEE Std 1584

Electrical safety, according to the panelists, must be interwoven into a safety culture involving government standards, codes, regulations and enforcement. It must include a top-down approach, in which businesses must take electric safety seriously. It also requires education and training of electrical workers as well as the general public. For instance, a downed conductor may show no indications of being energized. But like that passive cobra, it can reach out and strike an unsuspecting person. It has been reported that fatalities from improperly maintained overhead power lines are a very serious issue: More than 22 people are electrocuted daily in India from overhead power lines.

Electrical Standards, again according to the panelists, are either inconsistent or non-existent in many developing countries where ISV and others are installing micro-grids. 

# IEEE Power & Energy Society

*Daniel C. Toland, CAE*

The [IEEE Power & Energy Society \(PES\)](#) has experienced growth of membership, business activities, and member services over the last few years. At the end of 2019, the membership increased to just over 40,000 members, and the Society maintains the position as the second largest IEEE Society. PES members see the value of their PES membership and recognize that it is an exceptional, cost effective way to acquire the latest information about all aspects of the electric power and energy industry.


In joining PES, you will have access to the IEEE PES Resource Center, the most extensive library in the world devoted exclusively to the power and energy industry. There are over 2,000 items in the Resource Center's vast array of industry-oriented content, which is available to assist in your research, presentations, or academic programs, and benefit your professional development!

Young engineers may want to consider getting involved in one of the 17 PES technical committees or four PES coordinating committees. These committees play an integral role in the development of IEEE Standards and have a major impact within the industry.

PES technical committees are responsible for the technical activities in each of their sub-disciplines within the broad power and energy discipline. Activities include: the development of standards, technical reports, technical sessions for various IEEE PES technical meetings – paper sessions, poster sessions, panel sessions, and super sessions – and identify, explore, and provide solutions to emerging topics of interest within their sub-disciplines. A detailed description of the various technical committees and their activities can be viewed by navigating to each technical committee's website from the [PES Technical Council website](#). You can also learn about all PES Technical Committees in their [updated brochure](#).

If you are interested in renewable energy, you may want to learn more about the [PES Renewable Systems Integration Coordinating Committee \(RSICC\)](#). This committee serves as a focal point within PES for the identification of challenges associated with the integration of renewable energy resources (such as wind, solar, hydro, and bioenergy), related energy carriers (such as storage, fuels, and heat), and related electrification applications (transportation, buildings and industry).

The RSICC serves as the point of coordination for other organizations dealing with similar challenges and establishes liaisons to coordinate and help identify the appropriate technical resources within the PES and other IEEE societies to address the issues. The RSICC seeks opportunities to conduct jointly sponsored activities to promote the sharing of knowledge and experience among diverse organizations working on similar issues through the conduct of studies, symposia, workshops, panel discussions, and tutorials.

If you aren't sure if a PES Technical Committee is right for you, you can also get involved with [PES Young Professional](#) activities. Members of this group assist each other in evaluating their career goals, polishing their professional image, and creating the building blocks of a lifelong and diverse professional network. 

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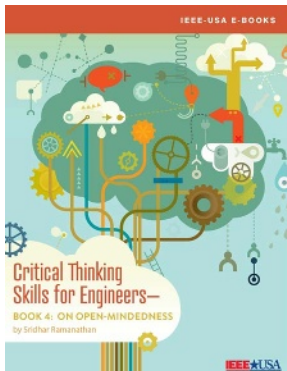
**Dan Toland** is the Director of Society Operations for the IEEE Power & Energy Society. He is responsible for managing and supervising the PES business segments involving conferences, education, membership, chapters, sales and marketing.



# New IEEE-USA E-Books Encourage Engineers to be Open-Minded, Analyze Information Sans Judgement; Provide Strategies for Expanding Creativity

Georgia C. Stelluto

In an article in Psychology Today, on Open-Mindedness and Skepticism in Critical Thinking, Dr. Christopher Dwyer offers readers a thorough definition of open-mindedness: "Open-mindedness refers to an inclination to be cognitively flexible and avoid rigidity in thinking," Dwyer wrote. Further, open-mindedness includes tolerating divergent or conflicting views; and treating all viewpoints alike, prior to subsequent analyses and evaluation, he said. It also involves detaching from one's own beliefs—to consider, seriously, points of view other than one's own—without bias, or self-interest.



In his new e-book, [Critical Thinking Skills for Engineers—Book 4: On Open-Mindedness](#), author Sridhar Ramanathan maintains that the world would be a much different place without the foresight and open-mindedness of visionary, and creative and curious thinkers and

investors. These people saw the huge potential for Amazon, Tesla and Netflix—among many others. He also builds a persuasive argument for why engineers, and other technical professionals, should enhance their critical thinking skills—by putting aside preconceived notions and assumptions—and simply analyzing the information at hand.

Six different components comprise the heart of Ramanathan's newest book in the [Critical Thinking](#) series. These are the qualities that nurture open-mindedness: overcoming cultural bias, objectivity, humility, inclusivity, observation and reflection.

"In short," Ramanathan writes, "open-mindedness is about being willing to change your mind, in light of new evidence. The key word here is "evidence," meaning based on data; rather than one's attitudes, opinions, beliefs, assumptions, interpretations, or judgments.

IEEE Members: You can download [Critical Thinking Skills for Engineers—Book 4: On Open-Mindedness](#) for free. Nonmembers pay \$4.99.

Go to:

<https://ieeusa.org/shop/careers/career-resources/critical-thinking-skills-for-engineers-book-4-on-open-mindedness/>; log in to your IEEE Web Account; add the book to your cart—and checkout!

Learn to Think Creatively—It's a Skill!

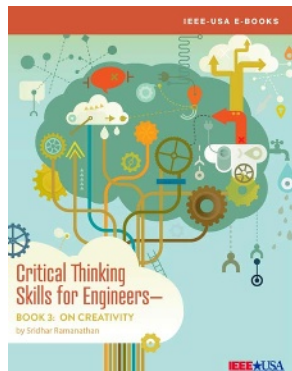
People in the profession often consider creativity the core of engineering. It is from creativity that engineers devise unique solutions to society's challenges. In his third e-book of IEEE-USA's [Critical Thinking Skills for Engineers](#) series, author Sridhar Ramanathan builds further upon critical thinking, by exploring creative approaches for both individuals and groups. Don't just take his word for it: The World Economic Forum moved Creativity up from No. 10 to No. 3 in its ranking of important attributes required for jobs of the future. LinkedIn's Learning Study ranked Creativity No. 1 in its poll of critical job skills.

Ramanathan believes that without self-awareness and some preliminary effort, thinking creatively can be an obstacle for engineers. "Creativity demands that we suspend disbelief, put aside practicality, let go of judgments coming from yourself and others, and overcome the fear of being wrong and appearing stupid," he says. "Engineers are trained to be problem solvers and rational thinkers, and they rarely feel comfortable taking such risks—especially in front of peers."

Published in 2019, Books 1 and 2 in Ramanathan's Critical Thinking e-book series focus on analytical skills (Book 1) and communication (Book 2). Here in Book 3, the author provides many ideas to stimulate fresh thinking. In it, he discusses nine different approaches to fueling creativity — ranging from divergent and convergent thinking to cognitive flexibility and visualization.

IEEE Members: You can download [Critical Thinking Skills for Engineers—Book 3: On Creativity](https://ieeusa.org/shop/careers/career-resources/critical-thinking-for-engineers-book-3-on-creativity/) for free. Nonmembers pay \$4.99.

Go to: <https://ieeusa.org/shop/careers/career-resources/critical-thinking-for-engineers-book-3-on-creativity/>;



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Ramanathan is planning one more volume in this e-series on critical thinking for engineers. The next one will be about problem

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**Georgia C. Stelluto** is IEEE-USA's Publishing Manager; Manager/Editor of IEEE-USA E-BOOKS; InFocus Department Editor for IEEE-USA InSight; and Co-Editor of the IEEE-USA Conference Brief.



## In Memory: Irving Engelson, HKN Board Member 1988-1990




As reported in The Institute

- Served as Former managing director of IEEE Corporate and Technical Activities
- Life Fellow
- Died 21 April at the age of 90

Irving Engelson was an active volunteer. He became a member of the IEEE Systems, Man, and Cybernetics Society almost 40 years ago. He served as chairman of the society's Strategic Planning Task Force, was a member of the board of governors, and was vice president of the long-range planning committee. He served on the Eta Kappa Nu (HKN) Board of Governors from 1988-1990, before the honor society's merger with IEEE.

He also was an IEEE employee. He was managing director of the Corporate Activities and Technical Activities groups. He also served on the IEEE Board of Directors, both as division and region director. He was elected IEEE parliamentarian, and he is the only person to have held the position of IEEE presidential advisor.

Before working for IEEE, Engelson held senior executive positions at RCA in Camden, N.J. He also was an electrical engineering professor at the University of Nebraska, in Lincoln and the New Jersey Institute of Technology, in Newark. He was a National Science Foundation faculty research Fellow at the Princeton Neuropsychiatric Institute, in New Jersey.

Engelson received a bachelor's degree in electrical engineering from the Polytechnic Institute of Brooklyn, now the NYU Tandon School of Engineering. He earned a master's degree in EE from Rutgers University in New Brunswick, N.J., and a Ph.D. in EE from Worcester Polytechnic Institute, in Massachusetts. 

# IEEE Eta Kappa Nu Launches IEEE-HKN Career Center



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