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Summer/Été 2022 — No. 90



Frontiers in Digitization

DX and Industry 4.0

LoRa for Microgrids

IEEE Canada

The Institute of Electrical and Electronic Engineers Inc.



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35th IEEE Canadian Conference on Electrical and Computer Engineering

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- **Ethics and Policy**
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Robert (Rob) Anderson
P.Eng., SMIEEE

2022–2023 IEEE Canada President and Region 7 Director
Président de l'IEEE Canada 2022–2023 et directeur de la région 7

As we move into summer, I want to send a warm hello to all of the IEEE Canada members and volunteers. In this report, I will focus on the major activities that are upcoming for IEEE Canada events. The impacts of the COVID-19 pandemic have changed our daily lives, as we get glimpses of what the "new" normal will look like.

The impacts of the COVID-19 pandemic have changed our daily lives, as we get glimpses of what the "new" normal will look like.

One of the biggest and most significant changes is how businesses operated on a day-to-day basis and how meetings

(Continued on p. 2)

Alors que nous nous approchons de l'été, je voudrais envoyer un bonjour chaleureux à tous les membres et bénévoles de l'IEEE Canada. Dans ce rapport, je me concentrerai sur les principales activités à venir pour les événements de l'IEEE Canada. Les impacts de la pandémie de COVID-19

Les impacts de la pandémie de COVID-19 ont changé notre vie quotidienne, car nous avons un aperçu de ce à quoi ressemblera la «nouvelle» normalité.

ont changé notre vie quotidienne, car nous avons un aperçu de ce à quoi ressemblera la «nouvelle» normalité.

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(President's Message cont'd from p. 1)

and events were all held virtually. Lots of us learned to work from home. Starting in March of this year, my company implemented a return to the office by asking 25% to return to their office desks. April saw a 50% capacity limit, and so on, until 100% is reached at the end of June. They also provided a work-from-home option for many roles where it is possible, so I am not sure we will ever see 100% of the staff back in the office. I have talked with many colleagues across a variety of industries. They have also been given the work-from-home option.

IEEE Canada was able to remain fully operational during the pandemic despite the challenges, and we continued to deliver most services to our members. Membership in IEEE dropped during COVID-19 since many of our member companies reduced their work forces. The good news is that, as our colleagues return to work, they are returning to IEEE.

IEEE Canada was able to remain fully operational during the pandemic despite the challenges, and we continued to deliver most services to our members.

The IEEE Canada Board returned to face-to-face meetings starting in June 2022. This was the first gathering of the IEEE Canada Board since February 2020. Our volunteer and member safety continues to be a priority for us, so we will be following all local health guidelines while meeting in person. All IEEE Canada committee and affinity group meetings will continue to be held online, as this provides operational efficiencies. There are certain advantages to online meetings: no travel arrangements, no impact from the weather, and no venue logistics.

Local Section activities, which include Section executive meetings, technical seminars, workshops, conferences, symposiums, and forums, are slowly returning to face-to-face settings. The decision as to virtual versus in-person gathering will vary by Section: it is up to the Section executives and depends on local health guidelines. I recommend that you pay close attention to the invitations you receive. They could be online only, face to face only, or a hybrid meeting. If you are uncomfortable in any way about gathering in groups or want to attend and wear a mask, I fully support your decision.

One of IEEE Canada's flagship conferences is returning to an in-person format. The Canadian Conference on Electrical and Computer Engineering (CCECE) 2022 will take place in Halifax at the end of September 2022. This conference will also include the IEEE Canada Awards Gala. The call for papers for the conference has already closed.

The other two flagship conferences, the Electric Power and Energy Conference (EPEC) and 2022 IEEE Canada International Humanitarian Technology Conference (IHTC), will be held virtually in November and December 2022, respectively. Watch this publication and your inbox for electronic notifications/advertisements for these events.

(Continued on p. 3)

(Message du Président suite de p. 1)

L'un des changements les plus importants et les plus significatifs est la façon dont les entreprises fonctionnaient au jour le jour et la façon dont les réunions et les événements se déroulaient manière virtuelle. Beaucoup d'entre nous ont appris à travailler à domicile. À partir de mars de cette année, mon entreprise a mis en place un retour au bureau en demandant à 25 % de retourner à leur bureau. Avril a vu une limite de capacité de 50 %, et ainsi de suite, jusqu'à ce que 100 % soit atteint fin juin. Ils ont également fourni une option de travail à domicile pour de nombreux rôles là où c'est possible, donc je ne suis pas sûr que nous reverrons un jour 100% du personnel au bureau. J'ai parlé avec de nombreux collègues dans une variété d'industries. Ils ont également eu la possibilité de travailler à domicile.

IEEE Canada a pu rester pleinement opérationnel pendant la pandémie malgré les défis, et nous avons continué à fournir la plupart des services à nos membres. L'adhésion à l'IEEE a chuté pendant le COVID-19, car bon nombre de nos entreprises membres ont réduit leurs effectifs. La bonne nouvelle est que, alors que nos collègues retournent au travail, ils retournent à l'IEEE.

IEEE Canada a pu rester pleinement opérationnel pendant la pandémie malgré les défis, et nous avons continué à fournir la plupart des services à nos membres.

Le conseil d'administration de l'IEEE Canada a repris ses réunions en personne à partir de juin 2022. Il s'agissait du premier rassemblement du conseil d'administration de l'IEEE Canada depuis février 2020. La sécurité de nos bénévoles et de nos membres continue d'être une priorité pour nous, nous suivrons donc tous directives sanitaires locales lors d'une rencontre en personne. Toutes les réunions des comités et des groupes d'affinité de l'IEEE Canada continueront de se tenir en ligne, car cela permet une efficacité opérationnelle. Les réunions en ligne présentent certains avantages : pas d'organisation de voyage, pas d'impact de la météo et pas de logistique sur le lieu.

Les activités de la section locale, qui comprennent les réunions de l'exécutif de la section, les séminaires techniques, les ateliers, les conférences, les symposiums et les forums, reviennent lentement aux rencontres en personne.

La décision quant au rassemblement virtuel ou en personne variera selon la section : elle appartient aux dirigeants de la section et dépend des directives sanitaires locales. Je vous recommande de porter une attention particulière aux invitations que vous recevez. Ils pourraient être en ligne uniquement, en face à face uniquement ou dans le cadre d'une réunion hybride. Si vous n'êtes pas à l'aise de quelque manière que ce soit à l'idée de vous rassembler en groupe ou si vous souhaitez y assister et porter un masque, je soutiens pleinement votre décision.

L'une des conférences phares de l'IEEE Canada revient à un format en personne. La Conférence canadienne de génie électrique et informatique (CCECE) 2022 aura lieu à Halifax à la fin du mois de septembre 2022. Cette conférence comprendra également le Gala des prix IEEE Canada. L'appel à communications pour la conférence est déjà clos.

(Suite p. 3)

(President's Message cont'd from p. 2)

IEEE Canada will also be celebrating one of Canada's biggest engineering achievements. This summer, on Canada Day (July 1), we will be dedicating an IEEE Milestone to the Trans-Canada Microwave System. This system enabled direct-dial long distance across the country and allowed Canadians to watch live sporting events from coast to coast. This will be the largest single Milestone dedication in IEEE history, as Sections from across the country will be dedicating plaques in cities where the microwave towers were located. Watch for upcoming details on this as well.

If you have any comments, questions, or concerns about IEEE Canada, please feel free to reach out to me via email at president@ieee.ca. Have a safe and relaxing SUMMER. ■

Robert (Rob) Anderson, P.Eng., SMIEEE
2022–2023 IEEE Canada President
2022–2023 Region 7 Director

(Message du Président suite de p. 2)

Les deux autres conférences phares, la Conférence sur l'énergie électrique et l'énergie (EPEC) et la Conférence internationale sur les technologies humanitaires (IHTC) de l'IEEE Canada 2022, se tiendront virtuellement en novembre et décembre 2022, respectivement. Surveillez cette publication et votre boîte de réception pour les notifications/annonces électroniques de ces événements.

IEEE Canada célébrera également l'une des plus grandes réalisations d'ingénierie du Canada. Cet été, le jour de la fête du Canada (1er juillet), nous consacrerons une étape importante de l'IEEE au système à micro-ondes transcanadien. Ce système permettait d'appeler les appels interurbains directs partout au pays et permettait aux Canadiens de regarder des événements sportifs en direct d'un océan à l'autre. Il s'agira de la plus grande dédicace d'un jalon dans l'histoire de l'IEEE, car des sections de tout le pays dédicaceront des plaques dans les villes où se trouvaient les tours à micro-ondes. Surveillez également les détails à venir à ce sujet.

Si vous avez des commentaires, des questions ou des préoccupations au sujet de l'IEEE Canada, n'hésitez pas à me contacter par courriel à president@ieee.ca . Passez un ÉTÉ sûr et relaxant. ■

Robert (Rob) Anderson, ing., SMIEEE
Président de l'IEEE Canada 2022–2023
Directeur de la région 7 de l'IEEE 2022–2023

IEEE Canadian Review
La revue canadienne de l'IEEE

IEEE Canadian Review is published three times per year: Spring, Summer, and Fall.

Its **principal objectives** are:
To inform Canadian members of IEEE on issues related to the impacts of technology and its role in supporting economic development and societal benefits within Canada. To foster growth in the size and quality of Canada's pool of technology professionals to serve our increasingly knowledge-based economy.

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Jahangir Khan, Ph.D., P.Eng., SMIEEE
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Dear IEEE Canada members and readers everywhere,

Just when the world had a taste of normalcy, the war in Ukraine has opened a concerning chapter in our history. Apart from the direct human suffering, death, and destruction, the impact of the war has reached well beyond Europe's borders. The turmoil in the commodities market has pushed oil and food prices to historic levels, making some countries bankrupt. The pandemic -induced economic pendulum has been swinging desolately back and forth among deflation; inflation; and, possibly, stagflation.

(Continued on p. 5)

Chers membres et lecteurs de l'IEEE Canada et partout dans le monde,

Juste au moment où le monde avait un avant-goût de la normalité, la guerre en Ukraine a ouvert un chapitre inquiétant de notre histoire. Outre les souffrances humaines directes, la mort et la destruction, l'impact de la guerre a atteint bien au-delà des frontières de l'Europe. Les turbulences sur le marché des matières premières ont poussé les prix du pétrole et des denrées alimentaires à des niveaux historiques, entraînant la faillite de certains pays.

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(A Few Words From the Editor-in-Chief cont'd from p. 4)

While all of this sounds like another episode of doom and gloom, our personal and professional lives need to carry on. IEEE Canada, like IEEE in general, is not insular. Even with some hesitancy to travel and attend in-person events, we are seeing a healthy return to hybrid attendance. It appears that this model of work and professional activity is here to stay, and most are embracing it.

It appears that this model of work and professional activity is here to stay, and most are embracing it.

Recent tornadoes in Ontario, back-to-back heat waves and flooding in British Columbia, and extreme weather events in all of Canada and the United States make us think of the need for resilient critical infrastructure. This includes electrical power, communications, and health-care systems. This edition of *IEEE Canadian Review* touches on some of the fundamental issues, including digital transformation. Future issues will comprehensively look into the resiliency of critical systems.

The upcoming years will be of high significance as *IEEE Canadian Review* transitions into a more streamlined and sustainable publication. We will be restructuring the editorial team, upgrading the website, and aligning closely with IEEE's mainstream publication processes. Please continue to send your thoughts and comments—or, even better, render your knowledge and expertise through article and commentaries.

Enjoy the Summer edition of *IEEE Canadian Review*. Please share your thoughts and suggestions as you read. I can be reached at mjakhan@ieee.org. ■

(Quelques mots du rédacteur en chef suite de p. 4)

Le pendule économique induit par la pandémie oscille désespérément entre la déflation ; inflation; et, éventuellement, la stagflation.

Bien que tout cela ressemble à un autre épisode de malheur et de tristesse, nos vies personnelles et professionnelles doivent continuer. L'IEEE Canada, comme l'IEEE en général, n'est pas isolée. Même avec une certaine hésitation à voyager et à assister à des événements en personne, nous constatons un retour sain à la fréquentation hybride. Il semble que ce modèle de travail et d'activité professionnelle soit là pour rester, et la plupart l'adoptent.

Il semble que ce modèle de travail et d'activité professionnelle soit là pour rester, et la plupart l'adoptent.

Les tornades récentes en Ontario, les vagues de chaleur et les inondations consécutives en Colombie-Britannique et les événements météorologiques extrêmes dans tout le Canada et aux États-Unis nous font penser au besoin d'infrastructures essentielles résiliantes. Cela comprend l'alimentation électrique, les communications et les systèmes de soins de santé. Cette édition de IEEE Canadian Review aborde certaines des questions fondamentales, y compris la transformation numérique. Les prochains numéros examineront en détail la résilience des systèmes critiques.

Les années à venir seront d'une grande importance alors que la Revue canadienne de l'IEEE se transforme en une publication plus rationalisée et durable. Nous allons restructurer l'équipe éditoriale, mettre à niveau le site Web et nous aligner étroitement sur les processus de publication traditionnels de l'IEEE. Veuillez continuer à envoyer vos réflexions et vos commentaires ou, mieux encore, faites part de vos connaissances et de votre expertise par le biais d'articles et de commentaires.

Profitez de l'édition d'été de IEEE Canadian Review. S'il vous plaît partager vos pensées et suggestions pendant que vous lisez. Je peux être contacté à mjakhan@ieee.org ■

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Digital Transformation (DX)—Destination Society 5.0

by Rami Mrad and Nezih Mrad



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Digital transformation (DX) is dubbed as the *fifth Industrial Revolution* (Society 5.0) and is increasingly relying on advances of Industry 4.0 technologies. Like other industrial revolutions that are triggered by either major natural or human disasters, including major health outbreaks and wars, DX has taken hold during the COVID-19 pandemic, where a significant push toward the fifth Industrial Revolution (Society 5.0) took place. The incorporation of Society 5.0 transformations may be a game changer and will bring positive outcomes to society development and transformation into a more sustainable, safer, and inclusive balanced global future.

DX Outlook

In 2020, Mordor Intelligence reported that the global DX market was valued at about US$1 trillion and is expected to triple and reach a value of US$2.8 trillion by 2026, at a compound annual growth rate of 17.42% during the forecast period of 2021–2026 [1]. The growth is expected to be highest in Asian nations and Australia and the lowest in the Middle East, Africa, and South America, as depicted in the heat map of Figure 1. Other forecasts during the same period predict that the global DX market is to grow from about US$0.5 trillion to US$1 trillion by 2025 [2], reflecting the potential and unpredictable nature of the transformation. Furthermore, in 2020, the International Monetary Fund reported that 65% of the world's gross domestic product is predicted to be digitized by 2022 [3].

The highlighted significant economic potential, as reported by International Data Corporation (IDC) [4], comes with a significant investment of money, time, and effort. In fact, IDC predicts that worldwide spending on the technologies and services that enable the DX of business practices, products, and organizations is forecasted to reach US$2.3 trillion in 2023.

DX-Enabling Technologies

The commonly used technologies driving DX are those that enabled the Industry 4.0 revolution and include artificial intelligence (AI), big data, the Internet of Everything (IoE), digital platforms, augmented and virtual reality (AR/VR), and 3D printing. The top eight commonly adopted DX technologies, according to PTC [5], are those reflected in Figure 2 and include mobile, IoE, digital twin, robotics/automation, cloud, AI/machine learning (ML), deep learning (DL), and AR/VR. Big data, data analytics, mobile technology, application programming interfaces, and embeddable technologies have also been identified as being the top technologies implemented. In Figure 2, the average adoption rate of each technology is provided as a percentage; the highest maturity is seen in mobile and cloud and the least maturity in additive manufacturing and robotics.

In addition to the Industry 4.0 DX-enabling technologies and commonly used and adopted Industry 5.0 technologies, emerging technologies, highlighted in Figure 3, will increasingly shape the future of DX and digital adoption. These technologies,

which include data fabric; big data; data analytics; cloud-native platforms; everything-as-a-service and no-code, zero-trust networks/connectivity; cybersecurity mesh; data privacy and ownership; privacy-enhancing computation; quantum; edge computing; blockchain; distributed enterprise; mobile platforms; 6G; next-generation internet; hyperautomation; robotics; AI; ML; DL; generative AI; and AR/VR/computer vision, will enable organizational transformation, accelerate digital capabilities, and drive economic growth and competitiveness.

These emerging and disruptive technologies hold the promise to deliver outcomes that include zero-trust (engineering trust), hardened cost-efficient scaling of the information technology (IT) foundation; tailored/sculptured/scaled change to deliver adaptive automated business activities and optimized AI; and the enabling of faster, smarter, well-informed decision support and accelerated growth by unleashing IT force multipliers.

DX and Industry Adopters

DX can be defined as the reimagination of organizational processes using digital tools and technology to meet changing institutional and operational requirements. Alternatively, DX is the creation or adoption of a digital environment for improved organizational processes, culture, and user and customer experiences. DX is not only about digitizing analog signals and data, digitalization that brings value to the business, and automating a process—but it is also about culture change and embracing the Industry 4.0 digital revolution.



Figure 1: The DX market growth map by region for the period 2021–2026. (Source: [1]; used with permission.)

DX can be defined as the reimagination of organizational processes using digital tools and technology to meet changing institutional and operational requirements.

DX is a transformational journey for an organization with an embedded agile and adaptive strategy, as the core of its business practices, that ensure it remains competitive, relevant, and adaptive to business transformation and evolution as well as resilient in the face of economic volatility and the emergence of innovative and disruptive technologies. Industrial enterprises, led by

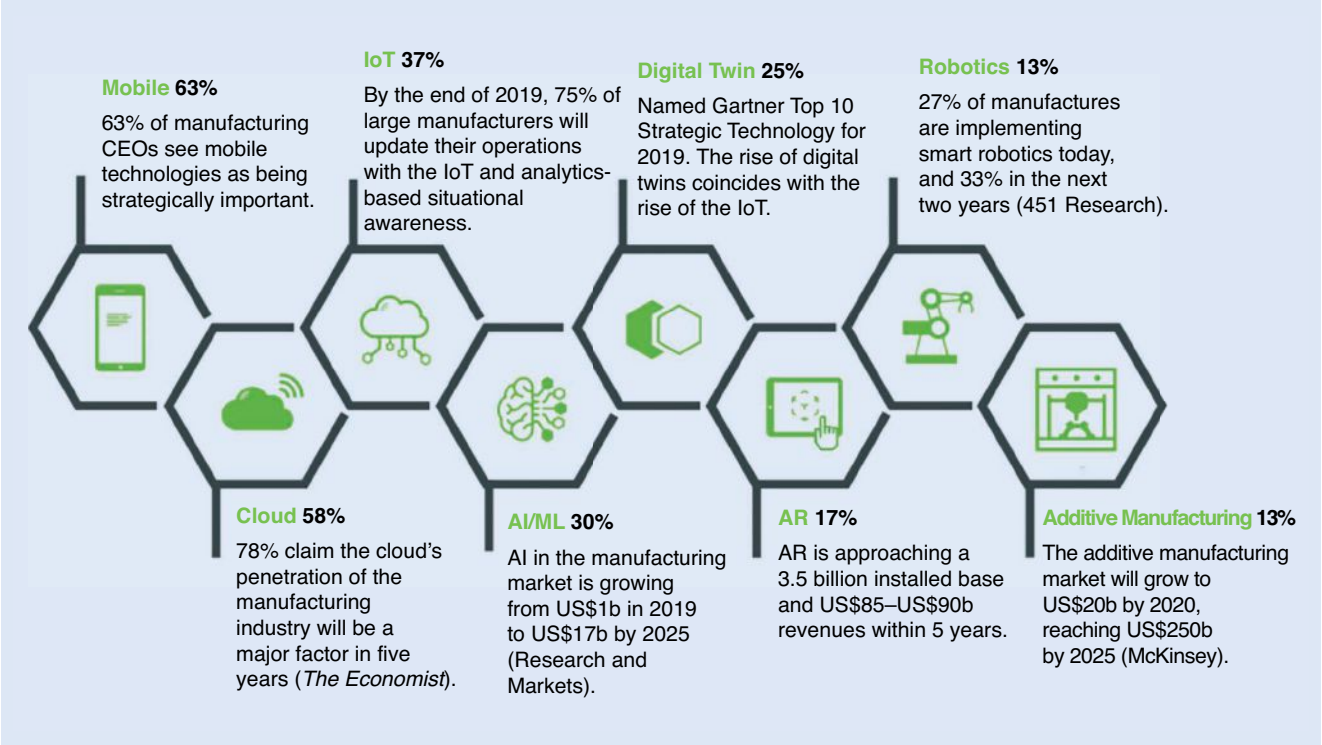


Figure 2: The technologies driving the DX market. AR: augmented reality; b: billion; IoT: Internet of Things; ML: machine learning. (Source: [5]; used with permission.)

Some of the risks associated with the production of a successful DX reside in the organization's ability to adapt to culture change and fear of change.

manufacturing, transportation, hospitality/tourism, health care, financial services, education, energy, media, and government services, are among those that benefited the most from DX during its development.

DX Business Strategy

Frequently, organizational transformation and efficiency are sought in a DX, overlooking key transformations in processes, business models, transformation domains, and people/culture while focusing on short-term gains. To achieve the sought-after benefits of increased operational efficiency, meeting changing customer expectations, and improving new product quality and business opportunities while increasing market share as well as to enable an organization to be successful in its DX, it must adopt an inclusive strategy. The strategy should focus on the three key pillars of leadership/investment, culture/people, and technology/innovation as its foundation.

The strategy's essential fundamental blocks to drive digital success in the enterprise are presented in Figure 4. In this model, DX is considered as a continuum by which it adapts to emerging transformations and executes a continuous improvement process where lessons learned drive innovation. Leadership and champions empowered with resources and vision serve as enablers and promoters for mobilizing partners, stakeholders, and clients around developing governance and policies to support the DX journey—the governance layer. Business processes, data warehouses, information, novel technologies, architectures, and standards are identified, acquired, refined, and/or developed to further enable governance execution of the transformation—the technology/processes layer. Both governance and technology converge to develop integrated solutions that are implemented by operators/users realizing the DX—the implementation layer. Outcomes of the transformation are assessed against organization objectives, and a continuous process improvement is adopted to fine-tune, evolve, and adapt the strategy/model in response to the transformation effectiveness in adapting to the organization objective and to changes in the transformation ecosystem.

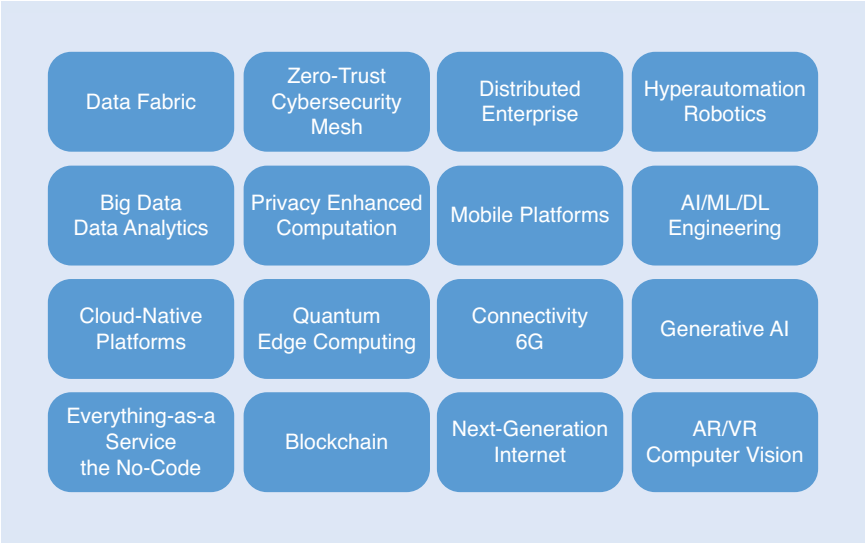


Figure 3: Strategic emerging technologies—trends for 2022 [7].

DX Challenges

The potential opportunities that the DX will unleash are limited only by our ability to innovate, available resources, available

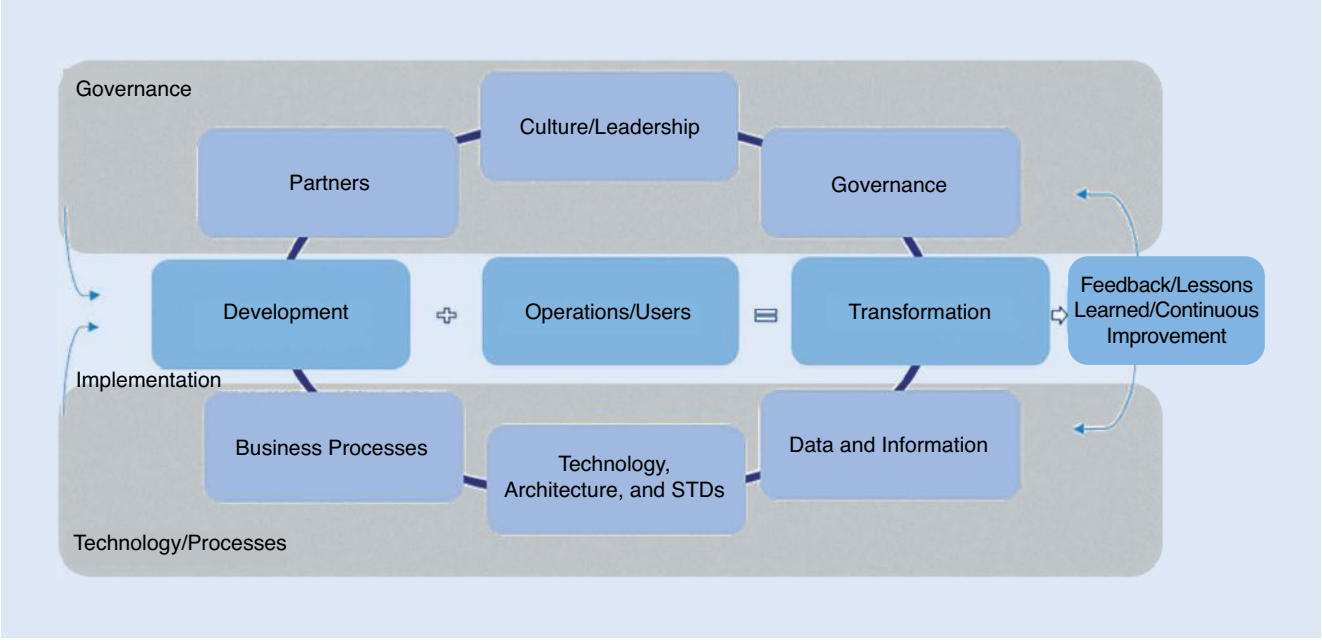


Figure 4: A DX business model.

talent and skills, technology readiness, and policy and standards. These opportunities will enable improved operational efficiencies; faster and robust product designs and product development/delivery to market; increased revenues and a reduction of overhead costs; more personalized services; improved customer experience; efficient response to market fluctuations in high-impact, low-probability events; operational superiority; and increased global penetration and dominance.

Some of the risks associated with the production of a successful DX reside in the organization's ability to adapt to culture change and fear of change. For instance, McKinsey and Company reported that companies with fewer than 100 employees are nearly three times more likely to say that their DX was a success than companies with more than 50,000 employees [7]. The latter might be due to the fact that larger organizations' CEOs, boards of directors, senior executives, and department heads are more inclined to hold back or not align and fully support transformation initiatives than middle managers and employees. Furthermore, there are risks that emanate from sponsors' and/or leaders' lack of experience and understanding of transformation management principles and best practices and that there are organizational obstacles, such as culture, structure, capabilities, and policies, that are not being sufficiently addressed to derive the full value of the transformation.

Lastly and most importantly, business leaders must be agile, adaptive, and agents of change to enable organization transformation harnessing the benefits derived from the Society 5.0 revolution.

A limited strength, weakness, opportunity, and threats (SWOT) analysis was conducted and is summarized in Figure 5.

Conclusion

To unleash the power of DX and mature Society 5.0, a DX business strategy should be part of the organization's vision and should contain the three pillars of leadership/culture change, technology, and people. The new corporate role that includes DX in its business requires digital skills that either do not exist or are deficient, requiring training or reskilling. Investing in technology innovation and digital solutions is equally important to harness the success of the transformation and its value added to the business. Lastly and most importantly, business leaders must be agile, adaptive, and agents of change to enable organization transformation harnessing the benefits derived from the Society 5.0 revolution. In doing so, the strategy should address the issues of security, privacy, ethics, and transparency. ■



Figure 5: A DX SWOT analysis.

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LoRa for Remote Microgrid Communication

Cherechi Ndukwe

A *microgrid* is defined as a viable and scalable integration of various distributed energy resources to ensure a reliable and secure energy supply to the remote communities and utility grids [1]. To guarantee economical and reliable operation of the microgrid, smart system monitoring, control, and energy management is required. Equipping a remote microgrid with smarter sensors for monitoring, along with a reliable and secured communication system, is very critical toward achieving a resilient smart grid [3].

With the shift in paradigm from centralized regulated present-day power systems to deregulated evolving electricity systems, there is also a dynamic change in energy demand and an increased integration of various distributed energy resources into one large microgrid. This therefore emphasizes the importance of a modern monitoring, control, and energy management system to ensure economical and reliable operation [1]–[6]. On the consumer side, a reliable monitoring and control system will enable consumers to make smart decisions on energy usage and integration of various renewable energy sources, which are distributed in nature. With solar, wind, and small hydro getting integrated into the modern-day electrical network at a considerable rate, robust monitoring and control are important.

Communication technologies currently employed for microgrids monitoring can be categorized into wired and wireless:

- wired communication for data transfer within microgrids, including ModBus, ProfiBus, power line communication, and the Ethernet
- wireless communication technologies, such as Zig-Bee, Wi-Fi, WiMax, and cellular.

Until recent times, the aforementioned communication systems have been employed for data transfer within the microgrid. With development of the Internet of Things (IoT), various areas of electrical systems, including meters, generators, and so on, are shifting toward the employment of various low-power wide-area network (LPWAN) technologies such Sigfox, Dash7, and Ingenu [7]. These recent IoT-based systems have brought enormous scalability and reliability in small electrical systems. However, they also face some communication challenges, such as data transfer distance, data rate, and data bandwidth (BW) [7]. These drawbacks have some effect on their ability to be solely employed for data transfer and control purposes in microgrids located in remote areas with no existing communication infrastructure. Specifically, to achieve an autonomous monitoring and control of these remotely located microgrids with the new LPWANs, which are IoT based, requires a communication infrastructure that addresses the drawbacks of other LPWAN technologies.

LoRa, also known as 'long-range', is an emerging communication technology, having applications in the IoT with various

advantages over other LPWAN technologies. LoRa provides benefits such as security, long range of data transfer, interference immunity, and very low cost of operation. LoRa is discussed in detail in this article as well as how it can be applied for efficient monitoring of remote microgrids.

LoRaWAN and LoRa Technology

The LoRaWAN protocol is an LPWAN designed for wireless connection of equipment to the internet [8] to achieve bidirectional communication between nodes and servers. A typical LoRaWAN architecture consists of various end nodes connected to sensors, one or more gateways, and a minimum of one network server, as shown in Figure 1. LoRaWAN is deployed in a star of stars topology, where various nodes are connected to the gateway via LoRa radio-frequency links, and the gateway is connected to the network servers by Internet Protocol (IP) networks or on a single machine in cases where internet is not required [9].

The communication between nodes and the gateway is achieved by the physical layer LoRa communication system. The gateway functions more like a router that relays the data received from various nodes to the Server (see Figure 1). A comparison of the LoRaWAN protocol to the Open System Interconnection (OSI) reference as shown in Figure 2 can serve as a better explanation of the LoRaWAN protocol.

LoRaWANs are differentiated from the classical TCP/IP communication through gateways and end nodes [9]. The network server operates over the Transport Layer and controls the Media Access Control layer functions of the network [9]. LoRa, a physical layer technology, operates on the "Physical" layer "(L1)" in Figure 2, with its main function as the "Application" layer "(L7)" data transmission to the medium [9]. The OSI model's "Data link" layer "(L2)" matches the LoRaWAN protocol, which defines secure medium access and end-node management strategies [9]. The end nodes also have a function of energy conservation, which is at the "Application" layer "(L7)" in the OSI model. Therefore, the end nodes conduct functions at L1, L2, and L7 of the OSI model [9]. For more details on LoRaWAN, the reader is referred to [8].

LoRa is the physical layer, or the wireless modulation used in creating a long-range communication link [8]. Most of the known wireless communication technologies use frequency-shift keying (FSK) modulation at the physical layer [8] to achieve low power communication. LoRa, on the other hand, makes use of the chirp spread spectrum (CSS) modulation technique, which can achieve both low power and LoRa communication. The chirp spread spectrum for message modulation works with chirps whose frequencies increase or decrease linearly over a certain amount of time [10]. LoRa operates in the free-spectrum Industrial, Scientific and Medical (ISM) band, for example, at the 868- and 915-MHz bands for Europe and the United States, respectively [11]. It has a low data rate of up to 50 kbps [11] and BW capabilities of 125, 250, and 500 KHz [12]. Conventionally, it uses a sweep tone, which increases (up-chirp) or decreases (down-chirp) in frequency over time for message encoding,

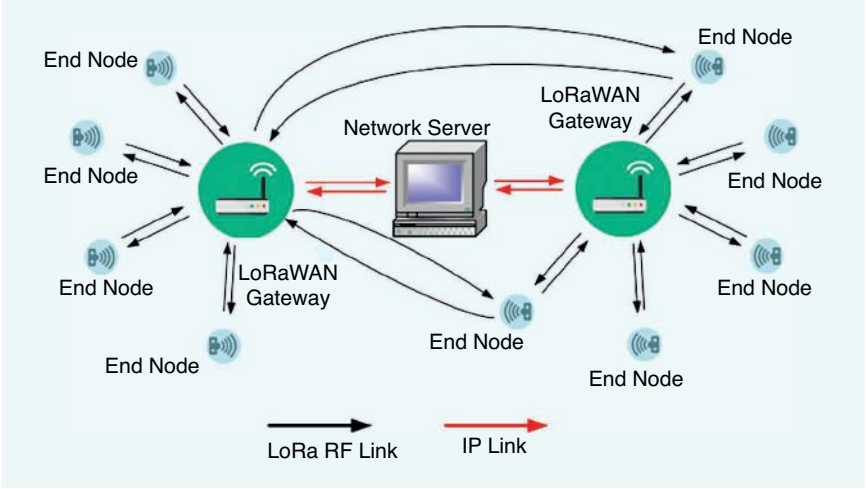


Figure 1: An illustration of a typical LoRaWAN architecture. IP: Internet Protocol; RF: radio frequency.

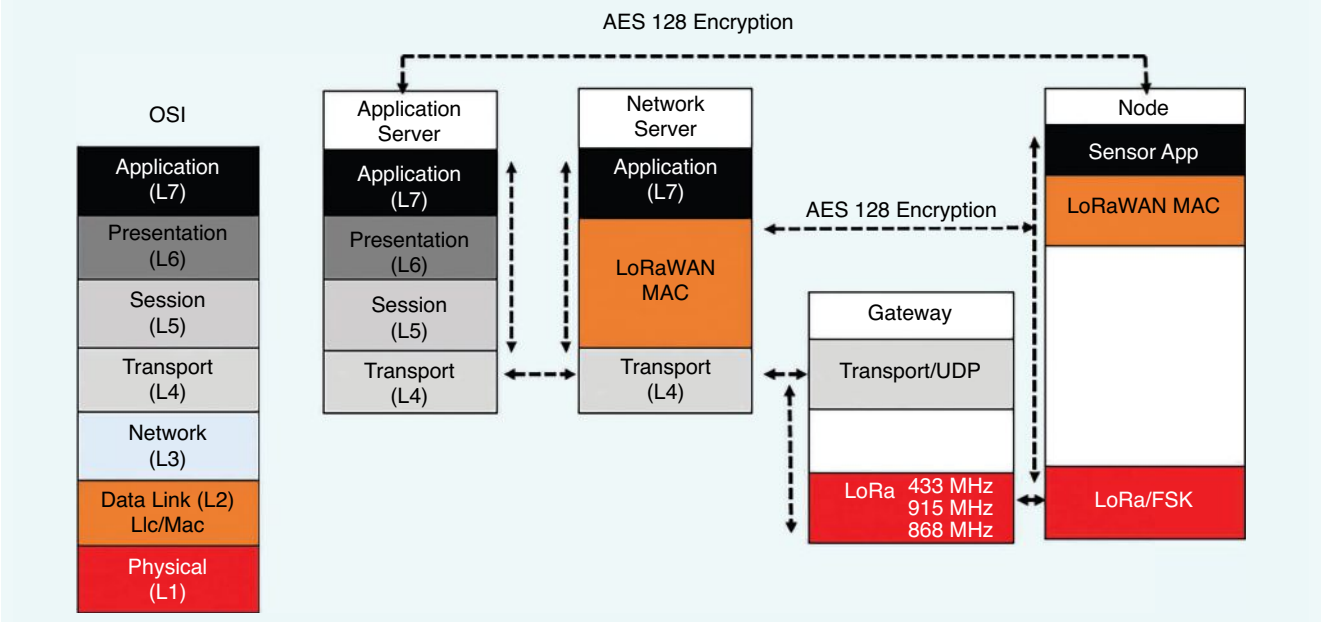


Figure 2: A comparison of a LoRaWAN to the OSI model. FSK: frequency-shift keying; AES: Advanced Encryption Standard; UDP: User Datagram Protocol.

instead of the pseudorandom binary sequence used by the well-known direct-sequence spread spectrum (DSSS) [13]. The modulation technique employed in LoRa spreads the message (signal) over a wide BW, which makes it less affected by noise and interference [13]. Other low-power communication systems do not have this feature by default. A LoRa transceiver can decode transmissions 20 dB below the noise floor, making very long-distance communication at low power consumption possible.

The following four important parameters control LoRa communication and must be well adjustable to achieve peak communication:

1) *Transmission Power*: The transmission power is typically between 2 and 14 dBm, although it can be adjusted to between –4 and 20 dBm. This parameter has a direct impact on the system's energy consumption and the range of signal coverage [13].
2) *Spreading Factor (SF)*: The SF is concerned with how many bits are encoded in each symbol, which can be set from 6 to 12. The ranges of signal and signal-to-noise ratio are both increased by an amplified SF. However, it has a reducing effect on the transmission rate when the energy consumption is increased.
3) *Bandwidth (BW)*: LoRa operates on 125-, 250-, and 500-kHz BW.
4) *Coding Rate (CR)*: The CR is the amount of forward error correction (FEC) applied to the message for protection against interference [13].

LoRa Application for Remote Microgrids

LoRa is a fast-rising wireless communication technology. Its advantages over existing wireless technologies make it a suitable choice for communication applications in remote microgrids. Table 1 lists a comparison of LoRa technology with other technologies already employed for microgrid monitoring. LoRa can be the most attractive technology for microgrid communication applications, particularly in remote areas. For a complete LoRa communication system design, three components (node, gateway, and server) are important, which are briefly explained in the following sections.

LoRa Node

LoRa nodes are basically Semtech SX1276 transceivers that operate at the ISM frequency bands (868, 915, 433 MHz) of various regions of the globe. The nodes can send and receive data over the frequencies with capabilities to directly connect with sensors through microcontrollers, which makes them very reliable for communication. LoRa nodes can connect to a large number of sensors, which are employed to measure various physical data such as voltage, current, temperature, and pressure. The LoRa node is limited by the fact that it can only communicate with a node that is set to the same frequency. In microgrids, the LoRa node will basically fit into the end nodes such that the remote terminal units are connected to various distributed generation units for data acquisition through sensors and microcontrollers. The acquired data are then sent out at a fixed frequency. A LoRa node has the capability to operate with open source microcontrollers such as the Arduino Uno, Arduino Mega, or ESP 32 and other industrial-grade controllers to process the acquired data. There are three classes of LoRa nodes (Class A, B, and C) based on their ability to enable bidirectional communication. In particular, Class C allows for seamless bidirectional communication [8].

LoRa Gateway

A LoRa gateway normally comprises a concentrator board with the capability to receive and forward LoRa packets (data received from the nodes) to the server. It also allows reverse communication from the server to the nodes for control purposes. A LoRa gateway is described as a bridge between the sensors and the server, which can be replicated as the master terminal unit (MTU) hosting the human–machine interface (HMI) in normal supervisory control and data acquisition (SCADA) systems. There are two types of LoRa gateways: single and multichannel. The multichannel gateway has the ability to receive data at different frequencies simultaneously, and is normally applied mostly to systems that require high number of nodes operating at different frequencies. In microgrids, the LoRa gateway can be located at the MTU, where it can obtain the data transmitted by various nodes connected to different distributed generation units. Although the gateway has no data processing capabilities, it can collect all the data received from the nodes and then relay them to the server for processing.

LoRa Server

A server is a designed application that comprises a database and a user interface (HMI) where the acquired data can be stored, processed, and displayed to the personnel. In microgrids, the server serves SCADA application MTU, which hosts the HMI for data reception, processing, and supervisory control transmission back to the end nodes.

Advantages of a LoRa Application in Remote Microgrids

A LoRa application in remote microgrids has the following advantages:

- *Low cost*: LoRa operates in the ISM spectrum, and as a result does not require various licensing fees and continuous subscriptions. Furthermore, LoRa allows for open source development, which involves various low-cost communication modules from numerous vendors being employed with minimal cost and connected together to achieve a cheap and functional microgrid-monitoring system at different complexity levels.
- *LoRa communication*: LoRa achieves a normal data-transmission range of 15 km in remote communities with reduced obstructions. This is normally a typical environment for deployment of remote microgrids. Although at the moment LoRa cannot achieve data

Table 1: A comparison of LoRa and other wireless communication techniques for use in microgrids.

Specification	LoRa	ZigBee	WiMax	Bluetooth	Cellular	Wi-Fi
Low cost of system components	●	●	—	●	—	—
High interference immunity	●	—	—	—	—	—
Long-distance coverage	●	—	—	—	—	—
Low power consumption	●	●	—	●	—	—
Multipoint connection	●	●	●	—	●	●
High security	●	●	●	—	—	●
Sensor direct connectivity	●	●	—	●	—	—
Expansion capability	●	●	—	●	—	●

coverage distance compared with that of cellular and WiMax, it is more advantageous from other perspectives, such as low cost, low power consumption, and scalability, critical factors for remote microgrid applications. Research activities are ongoing to determine approaches through which the range of data transfer can be extended in LoRa.

- *Low power consumption*: A study was carried out in real time where actual power requirements of the routers were used. The power-requirement values were obtained from the data sheets of the devices for each communication system [14]–[16]. The results of study are listed in Table 2 and were obtained for data transfer between two devices of each wireless communication system. This approach reduced the complexity of the study as expanding the network would subsequently increase power consumption. LoRa communication systems still show one of the lowest power consumptions. This is because achieving a highly reliable remote microgrid is dependent on continuous monitoring and control.
- *Multisensor connection capabilities*: LoRa as a communication system allows the connection of a high number of sensors, which is a highly desirable feature for IoT application in remote microgrids monitoring. This enables the simultaneous monitoring of various parameters from a high number of distributed energy generation systems dispersed in various remote locations.

Table 2: A power-requirement comparison for various wireless communication systems.

Communication System	Power Consumption (W)
Zigbee	3.7
Wi-Fi	4.9
WiMax	72
Cellular	28.8
LoRa	4.2

Conclusion

This article presented the employment of LoRa communication technology for possible applications in remote microgrids. With the continuous penetration of renewable energy sources such as wind and solar, which are typically located in remote areas, suitable monitoring systems are required to achieve optimum performance of systems. Recently, many smaller companies have shown interest in investing in these areas who may not be able to afford the various proprietary communication systems employed in large systems by big companies due to high cost. Investigations are currently searching for less expensive options to achieve the same level of system monitoring. The IoT paradigm is helping develop systems that are carrying out this function in an efficient, cost-effective manner. LoRa, as presented in this article, can be a possible replacement for the various turnkey systems in the effective monitoring of remote microgrids with the required system connections and upgrades. LoRa technology has various advantages, which makes it a very good candidate for this function. ■

Acknowledgment

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Cherechi Ndukwe received his B.Eng. degree in electrical and electronic engineering from Federal University of Technology Owerri, Nigeria, in 2011, where he became a graduate assistant after his compulsory national youth service in 2013. He received his M.Sc. degree in electronic and electrical engineering from the University of Leeds, U.K., in 2015. He is currently pursuing his Ph.D. degree in electrical engineering at the Memorial University of Newfoundland, St. John's, Newfoundland, Canada. His research interests include communication applications to power systems, renewable energy systems, and semiconductor devices.

We Just Couldn't Resist ...

David Green
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Amanda was a senior electrical engineer working at the local power utility. Her coworkers thought very highly of her. She was a top-notch troubleshooter. Usually, any power interruptions lasted less than an hour because of her acumen and familiarity with the system. The people who reported to her admired her calm and patient demeanour. She also put in long hours to make sure everything was running smoothly.



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One Monday, her car started acting up on the way to work. She noticed excessive noise when changing from second to third gear. She didn't really have any time to look at it herself, so she brought it to a mechanic shop that had just opened up near her house. The young mechanic had a look and confidently proclaimed, "I've seen this sort of thing before for this make and model of car. It'll be fixed by the end of the day."

Amanda went to pick up the car at the end of the day and noticed that there was a different noise being made, this time when changing to the reverse gear. The repairs were under warranty, so she brought it back the next day. The mechanic had another look. He came back and, with some embarrassment, admitted, "Geez, seems like I must have used the wrong parts. I'll order the correct ones in and have it fixed by Wednesday." Amanda didn't think it was a big deal and went on her way to work via bus.

Wednesday came, and again Amanda went to pick up the car. On the way office the next day, she noticed that there was a different noise being made, this time when changing between first and second gear. She brought it back at the end of the day. The mechanic had yet another look and, completely red-faced, confessed, "I'm begging your pardon—it seems I remounted the gearbox housing incorrectly. I'm a bit behind, but I promise it will be ready for Friday afternoon." Amanda left the car yet again and took the bus to work the next day.

Finally, Amanda picked up the car on Friday afternoon. It ran smoothly with no problems all weekend.

On the following Monday morning, one of her coworkers asked why she had taken the bus to work several times last week. Amanda told her the whole story. The coworker replied, "This mechanic doesn't sound very reliable. Three tries to fix what should be a very simple gearbox problem. You've been without your car for a week. You must have the patience of a saint!"

Amanda replied, "Ah, go easy on the guy. He's just starting out. Plus, you work at a power utility: you should know very well that transmission is done in three phases." ■



Theme: *Towards Smarter and Greener Integrated Energy Systems*
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IEEE Canadian Foundation Scholarships—Recipients Reflect

IEEE Canadian Foundation Scholarships are the Foundation's lead program to support Student Members of IEEE across Canada. These donor-supported scholarships have provided 248 scholarships totalling $746,454 since they were established in 1985. Canadian IEEE Student Branch counsellors can nominate an exceptional student registered in electrical, electronics, or computer engineering or a technology programme for his or her final year of undergraduate studies.

Within the limitations imposed by course work, the scholarship holder is expected to work closely with the IEEE Student Branch executive and be active in the IEEE McNaughton Learning Resource Centre. Additionally, you, your family, your colleagues, your employer, or your business may wish now or in future plans to endow a named scholarship to recognize and honour a person, encourage character traits that are important to you, or encourage specific learning and skills growth. The 2022 IEEE Canadian Foundation Scholarship recipients and past recipients from 20 years ago, now well established in their careers, reflect here on the personal and professional benefits and impact of receiving this scholarship.



The IEEE Canadian Foundation Scholarship has been a confidence booster to most students by recognizing their commitment to the organization and their respective Student Branches throughout their academic studies. As an active member of my university, I have seen students actively commit to organizing incredible yet beneficial workshops and events for fellow students, especially during the pandemic. Being recognized within the IEEE community for their service has had a great impact that helped them grow academically and professionally to become the next generation of leaders within the IEEE and engineering communities.

—Hamas Waqar, 2022 Recipient
Student Member, Carlton University



The IEEE Canadian Foundation Scholarship has been a boost to my morale in my academic, professional, and personal life. The scholarship has reduced the burden of tuition fees, allowing me to put more headspace into future academics and utilize what the scholarship is subsidizing. Being involved in the IEEE Student Branch, I've put in great effort to create an environment for students to develop academic and professional skills. Recognition of these efforts from the ICF assures me and my peers that IEEE is invested in the personal and professional well-being of not only professional engineers but also engineering students.

—Keaton Mollberg, 2022 Recipient
Student Member, University of Saskatchewan



Receiving the IEEE Canadian Foundation Scholarship while attending McMaster University was a highlight of my volunteer experience with IEEE. It gave me a sense of accomplishment and helped significantly with my final year tuition fees. It was my work with the Student Branch that enabled and encouraged my involvement with the Hamilton Section for several years that followed. Almost 20 years later, I value the role IEEE plays in the semiconductor industry that I have spent the majority of my career working, learning, and growing in.

—Lisa Tse, 2002 Recipient
Member, Hamilton Section
SOC Program Manager at AMD



It has been nearly 20 years since I was awarded the IEEE Canadian Foundation Scholarship, as a young and enthusiastic computer engineering student attending Memorial University. I recall feeling a strong sense of accomplishment but also an appreciation for the support the Foundation provides its members. This motivated me to become more engaged with IEEE, and I fondly remember my time spent organizing events with the Student Branch and local Chapter. Today, I am a professor of engineering and still an active member of IEEE, yet now I have gained a new appreciation for the organization and its work in supporting numerous academic conferences and journals in my field.

—Sheldon Andrews, 2002 Recipient
Member, Ottawa Section
Associate Professor at École de technologie supérieure

Radio Science in Canada



by David G. Michelson

The International Union of Radio Science (abbreviated URSI, after its French name, Union Radio-Scientifique Internationale) has a long history of cooperating with IEEE to advance international cooperation in the study of electromagnetic fields and waves. This month's column focuses on the CNC-URSI Roundtable on Electromagnetics Education in the 21st Century, to be held online in Fall 2022; the URSI Electromagnetic Theory Symposium, to be held in Vancouver in May 2023; and the URSI General Assembly and Scientific Symposium, to be held in Sapporo, Japan, in August 2023.

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CNC-URSI ROUNDTABLE ON ELECTROMAGNETICS EDUCATION IN THE 21ST CENTURY—FALL 2022

Ørsted's discovery of the relationship between electric current and the magnetic field in 1820 launched the field of electromagnetics. Two hundred years later, our world depends on a plethora of electrical, electromechanical, and electronic devices and systems that are used to exert force, interact with matter, and transfer both power and information across a distance.

Innovation in fields as diverse as electrical power and energy, digital systems, wireless communications, microelectronics, and biomedical engineering depends on successful exploitation of electromagnetic principles. For this reason, electromagnetic field and wave concepts continue to form a key component of undergraduate electrical engineering curricula.

The Canadian Engineering Accreditation Board mandates that courses in undergraduate engineering programs undergo continual improvement in order to ensure that they remain relevant to the evolving needs of Canada's engineering profession. This fall, the Canadian National Committee of URSI will host an online roundtable discussion on the challenges and opportunities associated with continual improvement of electromagnetics education in Canada.

Previous Discussions

A recent search of IEEE *Xplore* using the term *electromagnetics education* revealed that in the 30 years between 1992 and mid-2022, an astonishing 1,207 documents were published on this topic, including 796 conference papers, 331 journal articles, 70 magazine articles, 10 early access articles, and several regular columns and special issues. Electromagnetics education is clearly an area of considerable interest.

It's no surprise that almost all of these publications begin by acknowledging the foundational nature of electromagnetics courses and the need to continually improve them. Many publications comment on the numerous challenges that students face when encountering electromagnetic field and wave concepts for the first time with particular emphasis on the abstract and mathematical nature of the course material.

Conducting a Course

Conducting an electromagnetics course involves four main steps: 1) specifying student outcomes, 2) developing teaching and learning materials, 3) delivering the course, and 4) assessing student outcomes. In military and industrial settings, these steps are usually performed by separate teams. In universities, they are frequently performed by a single individual. All four steps have potential to be improved.

Very few publications concerning electromagnetics education have considered improvements to either the specification or assessment of student outcomes. Most of them focus on various means for improving student engagement and course delivery and the teaching and learning materials that must be developed to support such improvements.

Recurring topics in these publications include 1) new ways to introduce or explain key concepts, 2) the inclusion of computational electromagnetics in introductory courses, 3) increased focus on applications to demonstrate relevance and build motivation, and 4) use of computer simulations, lab assignments, and course projects to build intuition and understanding.

The Scholarship of Teaching and Learning

For many years, engineering education practice was driven almost exclusively by a combination of institutional edict and instructor experience. During the 1990s, the notion that the effectiveness of teaching and learning methods could be usefully assessed through scholarly research and inquiry and shared with the community gave rise to the Scholarship of Teaching and Learning (SoTL) movement [1].

Although SoTL has gathered a large following within the academic community in recent years, adoption of SoTL by the engineering disciplines and, in particular, electromagnetics educators, is still in its early stages. Development of a strategy for promoting SoTL within the electromagnetics education community will be one useful outcome of the roundtable.

URSI ELECTROMAGNETIC THEORY SYMPOSIUM 2023—VANCOUVER, CANADA

The first URSI Electromagnetic Theory Symposium (EMTS) was organized and hosted by Prof. George Sinclair of the University of Toronto in 1953. Seventy years later, in May 2023, EMTS will return to Canada. Under the leadership of Prof. David Michelson, Prof. Lot Shafai, and Prof. John Volakis, EMTS 2023 will bring a few hundred electromagnetics researchers to the University of British Columbia in Vancouver to share recent results concerning topics within the fields of interest of URSI Commission B—Fields and Waves.



The topics of interest for EMTS include electromagnetic theory, analysis, computation, experiments, validation, and applications. The areas of emphasis include time- and frequency-domain phenomena, scattering and diffraction, general propagation including waves in specialised media, guided waves, antennas and radiation, and inverse scattering and imaging.

The paper submission deadline is 15 December 2022. Acceptance letters will be sent no later than 10 January 2023. The symposium will be held from 22–26 May 2023. The planning for EMTS 2023 has already begun. Those interested in joining the group of volunteers that is organizing and running the symposium should contact Prof. David Michelson at president@ursi.ca.

URSI GENERAL ASSEMBLY AND SCIENTIFIC SYMPOSIUM 2023—SAPPORO, JAPAN

The XXXVth URSI General Assembly and Scientific Symposium (GASS) will be held from 19–26 August 2023 in Sapporo, Japan, under the leadership of the Japanese National Committee of URSI. At URSI GASS 2023, the URSI Council, Board of Officers, and Scientific Commissions will each meet to set goals and objectives for the next triennium. The meeting will also give a few thousand electromagnetics researchers from around the world an opportunity to share recent results concerning topics within the fields of interest of all 10 URSI Commissions.

The fields of interest for URSI GASS include electromagnetic metrology, fields and waves, radiocommunication systems and signal processing, electronics and photonics, electromagnetic environment and interference, wave propagation and remote sensing, ionospheric radio and propagation, waves in plasmas, radio astronomy, and electromagnetics in biology and medicine.

The paper submission deadline will be in January 2023. For more information, contact the URSI Secretariat at info@ursi.org. ■

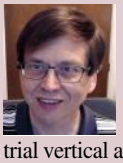
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The National Research Council of Canada is the adhering body for Canadian membership in URSI and appoints the members of the Canadian National Committee of URSI.

For more information about URSI International, please visit http://www.ursi.org/. For more information about URSI Canada, please visit http://www.ursi.ca/

About the Author



David G. Michelson is president of the Canadian National Committee of the International Union of Radio Science (2018–2024). He has led the Radio Science Lab at the University of British Columbia, Department of Electrical and Computer Engineering, University of British Columbia (UBC), since 2003. His current research focuses on short-range/low-power wireless networks for industrial vertical and transportation applications, millimetre-wave channels and systems, and satellite networks for communications and remote sensing. In 2011, he received a Faculty Certificate on Teaching and Learning in Higher Education from UBC. From 2012–2013, he served as director of education and training for the IEEE Communications Society. Prof. Michelson currently serves as a member of the Board of Governors of the IEEE Vehicular Technology Society, as a member of the Steering Committee of the National Institute of Standards and Technology-sponsored NextG Channel Model Alliance, as director of the AURORA Smart Transportation Testbed, and as principal investigator of the Campus as a Wireless Living Lab project at UBC.

IMPORTANT UPDATES

IEEE Canadian Review (*ICR*) is now a "default-digital" publication.

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An Interesting Number

by Jon Rokne

Ramanujan's Remark

In a book about Paul Erdös, *The Man Who Loved Only Numbers* by Paul Hoffman [1], there is an anecdote attributed to Ramanujan by Hardy: "I had ridden in taxi-cab No. 1729, and remarked that to me the number seemed a rather dull one, and that I hoped it was not an unfavourable omen. 'No,' he reflected, 'it is a very interesting number; it is the smallest number expressible as the sum of two cubes in two different ways.'" That is, $1,729 = 1^3 + 12^3 = 9^3 + 10^3$.

Having reached the tender age of 81, I asked myself the same question for the number 81. The following is a partial answer.



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The Number 81

I was 81 years old a few days ago, and, because of this, I wondered if the number 81 was interesting. In order to determine this, I had to consider two aspects of numbers.

The first aspect is the actual counting aspect. That is, what does a number represent? The answer is that it is an abstraction of a set of items with some common properties. We say that there are four nuts, and it is immediately understood that the items are nuts and that there are four of them. Properties that rely on the counting aspect of a number are denoted as being *intrinsic properties* of a number in this discussion.

The second aspect is the representation of a number. For small numbers, there are special symbols, such as 1, 2, 3, and so on. When we run out of these special symbols, we group them together and use a positional system where the location of a digit implies that it has been multiplied with a power of a so-called base. The usual base is 10, and this means that, as an example, the number 123 represents $3 + 2 \times 10 + 1 \times 10^2$. Properties that depend on the representation of a number are denoted as representational properties.

Shallit [2] similarly considers the difference in terms of number theory and formal languages: "Number theory deals with the properties of integers, and formal languages deals with the properties of strings. At the intersection lies (a) the study of integers based on their *representation* in some manner—for example, representation in base k; and (b) the study of the property of strings of digits based on the integers they represent."

The first interesting property of the number 81 is that the sum of the digit is $8 + 1 = 9$, and $9 \times 9 = 81$. That is, the sum of the digits squared is the number itself.

The question is, now, how special is this property? It is a representational property since it is dependent on the representation in base 10, and, hence, one might ask the following: given any base b representation of integer numbers, does there exist a two-digit example for which $(d_b^1 d_b^2)_b = (d_b^1 + d_b^2)_b^2$? It turns out to be true for integer bases $b > 2$. To show this, let $d_b^1 = b - 2, d_b^2 = 1$, and $d_b^3 = d_b^1 + d_b^2$. Then,

$$(d_b^1 d_b^2)_b = (b-2)b + 1 = b^2 - 2b + 1 = (b-1)^2 = (d_b^3)_b^2, \quad (1)$$

where the left side (before the equal sign) and the right side (after the last equal sign) are represented in base b, whereas the calculations between the equal signs are done in base 10.

As an example, with $b = 7$, it follows that, with $d_7^1 = 5$ and $d_7^2 = 1$, we get $(51)_7 = (5 \times 7 + 1)_{10} = 36_{10} = (6 \times 6)_{10} = ((6_7)^2)_{10} = (51)_7$, calculated in the same manner as in (1).

The next question is this: what if the digits of 81 are multiplied together and squared instead of added together and squared as shown? Obviously, the result is 8, which, squared, is 64—and a nice symmetry is obtained between $64 = 4^3$ and $81 = 3^4$.

A third property is that it is one of three numbers—81; 1,458; and 1,729—whose reverse sum of digits squared is the number itself. This is trivially true for 81. For 1,458, we have $1 + 4 + 5 + 8 = 18$, from which $18 \times 81 = 1,458$. For 1,729, we have $1 + 7 + 2 + 9 = 19$, from which $19 \times 91 = 1,729$ (from [3]). This is a representational property of 1,729. Curiously, there is also an intrinsic property of this number, namely, the aspect of 1,729 noted earlier that Ramanujan found interesting [1].

When checking if the square of the reverse sum of the digits of a number is equal to the number, it is clear that this is trivially satisfied by 81. The other numbers for which this is true are $5,184 = 72^2, 6,561 = 81^2$, and

$8,281 = 91^2$. It is notable that the second result is the square of 81, and the last result contains the digits 81 as part of the number.

Another interesting representational property is that $1/81 = 0.012345679$, where the sequence 012345679, which contains all of the decimal digits except for 8, is recurring. The reason for this can be explained as follows. Let $1/81 = 0.1111111/9$, where the numerator is an infinite sequence of 1s. Then consider the equation $(j \times 10_1)/9 = j + (j+1)/9$, which recursively produces the single digit j in the division process for $j = 0,\ldots,7$ when performing the division .01111111/9. For example, for $j = 6$, we get $(6 \times 10 + 1)/9 = 6 + (6+1)/9$ or $61/9 = 6 + 7/9$, which shows that, from the digit 6 in the division process, we get the digit 7. The only exception is $j = 8$, when $(j \times 10 + 1)/9 = j + 1 + 0/9$, or, in other words, $81/9 = 9 + 0/9$, again emphasizing the special representational nature of 81. When $j = 9$, the process is started over again.

It also turns out that, if $k/81$ is computed for $k = 1,\ldots,80$, then the results are recurring sequences that contain the digits 0 to 9 with one digit missing, providing k is not divisible by 3. For example, for $k = 20$, the result is $20/81 = 0.246913580$ recurring. Note that all of the digits except 7 are in the recurring sequence. If k is divisible by 3, then the recurring sequences are shorter.

Then, we note that $3^2 = 2^3 + 1^3$; that is, the sum of the digits of 81 can be written as the sum of two integers to the power 3.

As noted earlier, $81 = 3^4$ (i.e., 3 to the power 4), which is moderately interesting. The immediate question that follows is, "What about 4^3?" It turns out that this is 64. Then, we can ask what can be done with $3^4 - 4^3$. This is 17, which can be written as $2^3 + 3^2$. So, in the end,

$$3^4 = 4^3 + 2^3 + 3^2. \qquad (2)$$

This equation shows that 81 is 3^4, a symmetry in four dimensions, which is composed of two symmetries in three dimensions, namely, 4^3 and 2^3, which are added to one symmetry in two dimensions, namely, 3^2.

Having previously completed the ages represented by the symmetries 3^2, 2^3, and 4^3, this discussion shows that I have now ascended to a symmetry in four dimensions. Although I did briefly ascend to a symmetry in four dimensions at the age of 2^4, that is, 16, it was brief visit since I was a very unfocused teenager.

It is relatively lonely up here in the fourth dimension ascended to by 81. However, one advantage is preferred access to COVID-19 vaccines.

Having noted these facts, I checked with Dr. Google if there were any interesting articles about the number 81. It turns out that Wikipedia [3] has a long list of further facts about the number 81, including many—but not all—of these observations.

It is also interesting that many of these observations are intrinsic properties independent of the base. One could almost say they are baseless. ■

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About the Author



Jon Rokne is a professor and former head of the Computer Science Department at the University of Calgary. Educated in Norway and Canada, he obtained a Ph.D. in mathematics from the University of Calgary. He chaired the Computer Science Department at the University of Calgary from 1989 to 1996. He has published extensively in mathematics and computer science, including coauthorship of the *Encyclopedia of Social Network Analysis and Mining*. He is also a co-organizer of the IEEE/Association for Computing Machinery ASONAM Conference series. He has been extensively involved with IEEE activities, including having been the IEEE Publications Services and Products Board vice president in 2009–2010, holding membership on a number of boards and committees, and developing several new IEEE transactions and magazines.



Shadows of the Past

by David G. Michelson

Our sense of who we are, our values and beliefs, and our ambitions for the future are guided, in large part, by the stories and anecdotes concerning the past that we share with each other. In this light, history may be viewed as a formal process by which we preserve, organize, and interpret the stories that both matter to and define us.

While historical fact is immutable, historical evidence is inherently fragile and often irreplaceable. Accordingly, efforts to preserve and interpret the past are among the most valuable of legacies. In this column, we consider the challenges and opportunities that face historians of modern technology.



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Plutarch, in the opening sentences of his *Life of Demosthenes*, reminds us that many of the challenges that historians face today are longstanding:

> "Whosoever shall design to write a history, consisting of materials which must be gathered from observation, and the reading of authors not easy to be had nor writ in his own native language, but many of them foreign and dispersed in other hands: for him it is in the first place and above all things most necessary to reside in some city of good note and fame, addicted to the liberal arts, and populous, where he may have plenty of all sorts of books, and, upon inquiry, may hear and inform himself of such particulars as, having escaped the pens of writers, are yet faithfully preserved in the memories of men; lest otherwise he publish a work deficient in many things, and those such as are necessary to its perfection." [1]

Historical study is dependent on evidence that is inherently fragile and often irreplaceable. A number of related practices, including historic preservation, museum curatorship, archival science, records management, and oral history, have evolved to preserve such evidence for both academic study and the public good. As events recede ever further into the past, the effort required to locate and preserve these shadows of the past increases dramatically. Accordingly, efforts to preserve the past should ideally begin in the present.

Although historical evidence is necessary for historical study, it is not in itself sufficient. Both historical context and historical imagination are required to usefully reconstruct or interpret historical events. Much of our current thinking regarding such matters comes from the work of R.G. Collingwood, a British philosopher and historian who was active in the first half of the 20th century [2]. Collingwood was especially concerned with the similarities and differences between the work of the natural scientist and the work of the historian and how historians could and should use historical evidence to interpret or reconstruct the past.

Collingwood believed that history, as an organized body of knowledge, is a science. However, he argued that history differs from natural science in that natural scientists can generally observe the target of their study directly and repeatedly, while historians are generally limited to studying whatever evidence remains after the event took place. If there are gaps in the evidence, the historian generally has no alternative but to either find additional evidence or use his or her best judgment to fill in or reconstruct the missing details.

Collingwood also argued that historical events have both an "external" or observable component and "internal" or experiential component. The observable component, concerned with what transpired, is often resolved based on multiple observations from multiple perspectives and is only fully knowable after the event. By contrast, the experiential component is concerned with how the event was perceived or experienced by individual participants. Collingwood's belief that both perspectives are essential for reconstructing and interpreting historical events provides vital clues regarding the nature, and especially the diversity, of the historical evidence that we should seek to preserve.

Primary or original source materials are generated as the historical event unfolds, or afterwards by those who experienced the event. They may take the form of plans and drawings, orders and schedules, diaries and firsthand accounts, recordings (including photographs and video and audio recordings), internal reports (including technical reports, conference presentations, and journal papers), external reports (including news accounts), artifacts (including devices and engineering prototypes), and landmarks (including structures and buildings). Secondary source materials are interpretations of primary source materials produced by those who didn't directly experience or witness the event.

The amount of primary source material that is generated depends greatly on the nature of the event and the organization involved. In many cases, the historical significance of an event may not be recognized until long after the event has taken place. Once the primary source material is generated, it must be preserved and made accessible for future use. This doesn't happen automatically, and a great deal of historical evidence is lost as individuals and organizations discard records and evidence that are no longer required for their original purpose.

Historical evidence tends to fall into four categories, which we may denote as Types 1, 2, 3, and 4. Type 1 evidence is the living memory of those who experienced the event and who can both share information and respond to requests for clarification or additional information. Type 2 evidence includes records, reports, and media of various types including oral and firsthand histories. It is the most easily stored, shared, and interpreted of the three types. Type 3 evidence includes artifacts, prototypes, and other hardware. Type 4 evidence includes structures and landmarks associated with the event. Type 3 and 4 evidence helps provide

both context and continuity but may be difficult to interpret in the absence of Type 1 or 2 evidence.

All historical evidence degrades with time, albeit at different rates and for different reasons. Type 1 evidence, living memory, is among the most valuable, but memory fades with time, and the human lifespan is finite. Moreover, recollections may become biased or inaccurate for many reasons. Type 2 evidence, records and reports, may be lost as documents and records deteriorate, can no longer be read (possibly due to technical obsolescence), or are no longer required for their original purpose and discarded. Type 3 evidence, artifacts, may be lost as equipment deteriorates or is no longer required for its original purpose and discarded. Type 4 evidence, structures and landmarks, may be lost as properties deteriorate, are upgraded, redeveloped, or are no longer required for their original purpose and demolished.

As a historical event recedes ever further into the past, we may identify four different "pasts." In the *recent past*, which may either be exceedingly brief or last for up to several years after an event, the people, places, artifacts, and records associated with the event are still intact and the context for the event easily discerned. In the *living past*, which may either be exceedingly brief or last for up to few decades, relevant landmarks, artifacts, and records may be lost over time, but witnesses are still able to offer firsthand accounts and answer questions. In the *historical past*, no one with living memory of the event remains, but a fairly diverse set of records, artifacts, and landmarks is still available (although many have been lost). In the *distant past*, records, artifacts, and landmarks become increasingly rare, context becomes less clear, and the task of interpretation and reconstruction becomes very difficult.

Until the latter part of the 20th century, the study of contemporary science and technology, i.e., events and achievements that occurred during the previous 50 years (or during the *recent* and *living pasts*), was mostly limited to personal biographies, project histories (sometimes referred to as management histories), science and technology journalism, and survey papers. At an International Workshop on the Historiography of Contemporary Science, Technology and Medicine that was held from 16 to 17 September 1994 at Goteborg University, Sweden, historians grappled with the challenges associated with historical study of contemporary science and technology [3]. They concluded that

> "Historians of science (including related areas of history of technology and history of medicine) are confronted with a paradox: more than 90 percent of all science in history has been produced during the last half century but so far only a small fraction of historical scholarship deals with this period. One reason for this glaring discrepancy may be that historians who approach the recent and contemporary technoscientific scene are confronted with new and unfamiliar methodological and theoretical problems. How shall we handle the huge amounts of published and unpublished sources? Is it possible to write a synthetic history of recent science? What level of scientific training is necessary to understand recent and contemporary science? Does the lack of historical distance prevent good scholarship?

Canadian Journal of Electrical and Computer Engineering–an IEEE Journal

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> Can (and will) historians of recent science share the turf with other professional groups, such as active scientists, scholars of science and technology studies, and science journalists? How shall we deal with scientists' and technocrats' constant interference with our work? Whose history are we writing? Whose science?" [3]

What is frequently overlooked (and underappreciated) is the vital role that individual scientists and engineers play in preserving historical evidence relevant to the history of science and technology. It's obvious that such individuals are a valuable repository of Type 1 evidence—living memory. However, although the most visible repositories of Type 2 and 3 evidence are corporate archives, public archives, and public museums, where they are highly accessible to professional historians, an astounding amount of such evidence is in the hands of private individuals, private collectors, and private museums.

In conjunction with recognition of completion of the Trans-Canada Microwave System in 1958 as an IEEE Milestone, IEEE Canada is launching the Trans-Canada Microwave System History Project, an effort to augment what already exists in corporate and public archives and public museums with 1) oral histories and firsthand accounts from those who were involved with the system during its more than four decades of operation and 2) photographs and related media and relevant records and documents concerning the systems that are currently in private hands. Social media will play a vital role in this effort. Although this project should have been launched long before now, it's not too late. For more information, please see http://www.ieee.ca/en/history/. ■

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About the Author



David G. Michelson is the IEEE Canada historian and chair of the IEEE Canada History Committee. An active contributor to the history of technology for two decades, he has been a member or associate member of the IEEE History Committee since 2012 and is responsible for one quarter of the 18 IEEE Milestones that recognize Canadian technology achievements. He is also a member of the Society for the History of Technology (and its Special Interest Group on Telecommunications History) and a member of the History and Archives committee of the Engineering Institute of Canada. His research interests in this area include the historiography of contemporary science and technology, the development and impact of Canadian science and technology since the Second World War, and the development and impact of both wireless technology and space technology since the Second World War. He can be contacted at dmichelson@ieee.org or historian@ieee.ca.

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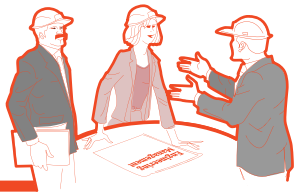
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Biz Tech Report



by Terrance Malkinson

The Canada Council for the Arts has named the 2022 winners of the Killam Prize (https://www.canadacouncil.ca), which is awarded annually to scholars who have distinguished themselves in their fields:

- In the humanities, Dalhousie University's Françoise Baylis's research focuses on how decisions that we make today on DNA technology will secure a better world for all of us in the future.
- In engineering, Dalhousie University's Jeff Dahn is recognized as a pioneer in the lithium-ion battery technology used in power tools, electric vehicles, and many other applications.
- In the social sciences, York University's Carl James won the prize for his work on how to create a more equitable society.
- In the natural sciences, the University of Toronto's Geoffrey Ozin has made intellectual quantum leaps in nanoscience that have surprised, excited, and inspired researchers, industrialists, entrepreneurs, and policy makers around the world.
- In the health sciences, McMaster University's Salim Yusuf was commended for his work on the prevention and treatment of cardiovascular disease, benefitting tens of millions of people worldwide.

Canadians received four of this year's seven Gairdner Awards (https://gairdner.org), which recognize the world's most significant scientific discoveries impacting human health:

- The University of British Columbia's biochemistry professor Pieter Cullis developed nucleoside-modified mRNA and lipid nanoparticle drug delivery, which are the foundational technologies for the COVID-19 mRNA vaccines.
- John Dick, a senior scientist at Toronto's Princess Margaret Cancer Centre, discovered and characterized leukemic stem cells, providing insights into the understanding, diagnosis, and treatment of acute myeloid leukemia.
- Zulfiqar Bhutta, a senior scientist at Toronto's Hospital for Sick Children, developed evidence-based interventions to support child and maternal health in marginalized populations.
- The Canada Gairdner Wightman Award went to McMaster University's Deborah Cook for her multidisciplinary research on evidence-based critical care medicine, informing best practices around the world.

Gairdner International Award winners included Stuart Orkin, Drew Weissman, and Katalin Kariko. A total of 96 Gairdner winners have gone on to receive Nobel Prizes.

Lumafield (https://www.lumafield.com) was founded in 2019 by a team of engineers with experience in design and manufacturing in response to the need to scan inside and outside an object, closing the loop between design and manufacturing. Lumafield, headquartered in Cambridge, Massachusetts, designed a new type of computed tomography scanner using a series of X-ray images to create a detailed, multicolored 3D reconstruction of a scanned object. The results allow designers and engineers to visualize and measure aspects of products that had previously been invisible. Posted on their website are a number of fascinating 3D scans of commonly used items.

A century after it sank off the coast of Antarctica in 1915, polar explorer Ernest Shackleton's ship, HMS *Endurance*, has been located resting 3,008 m deep in the Weddell Sea, south of the Falkland Islands (https://endurance22.org). The ship got stuck in the sea ice, and its 28 sailors abandoned ship. The team's survival without any loss of life was seen as a triumph of their tenacity and the leadership skills of Shackleton. The search team used specially made underwater autonomous search vessels to locate the wreck, which was upright, intact, and well preserved. *Endurance* will not be moved. It will remain where it is and be studied, mapped, and photographed.

Windsor Ontario will soon be home to Canada's first electric vehicle battery plant (https://www.cbc.ca/news/canada/windsor/automotive-announcement-windsor-1.6393463). South Korean battery manufacturer LG Energy Solution and European automaker Stellantis will bring this first lithium-ion electric vehicle battery plant to Canada. The $4.9 billion plant is expected to create 2,500 jobs and an anticipated 10,000 spin-off jobs. It's set to be operational in 2024. Charging stations, supply chain partners, research and development, and postsecondary education are just a handful of areas that could see Canadian job growth.

Scientists are very satisfied with the first test images of distant stars and galaxies from the James Webb Space Telescope (https://www.space.com/james-webb-space-telescope-first-photos-unveiled). NASA's test image was aimed at a star 100 times fainter than the human eye can see and 2,000 light-years away. The galaxies shown are several billion years old. When fully operational, Webb will see back in time—a couple hundred million years after the "Big Bang." The first science images are scheduled for June or early July. Canada has contributed to the development of the telescope and will take a leading research role in its observations.

The NASA Exoplanet Archive (https://exoplanetarchive.ipac.caltech.edu) has now grown to more than 5,000 confirmed planets beyond our solar system. Exoplanets were only first discovered in the 1990s. The diversity of exoplanets represents populations of planets unlike anything found in our solar system. So far, 30% are gas giants, 31% are super-Earths, and 35% are Neptune-like. Only 4% are terrestrial, or rocky planets, like Earth or Mars. The James Webb Space

Telescope, launched in December, will be able to peer through the atmospheres of exoplanets. There are likely hundreds of billions of exoplanets across the Milky Way galaxy.

It's been nearly 50 years since humans last set foot on the moon. The goal of NASA's new Artemis program (https://www.nasa.gov/artemis program) is to send astronauts to the lunar surface by 2025. The new rocket will be the most powerful in the world. It is 98 m tall, weighs 5.75 million lb, has 8.8 million lb of thrust, and will be capable of lofting about 24 t to the moon. Canada is a contributor to the mission. Some of the experiments on the effects of space radiation beyond low-Earth orbit were developed by Dr. Troy Harkness at the University of Saskatchewan (https://research.usask.ca/our-impact/highlights-of-our-research.php).

During his extraordinary career as an athlete, a health and physical fitness expert, and a media personality, Lloyd Percival's creativity and vision were ahead of his time and influenced athletics in Canada and worldwide (https://www.cbc.ca/radiointeractives/features/lloyd-percival-sports-prophet?cmp=newsletter_Ideas_5859_424375). Recently, Gary Mossman reviewed Percival's contributions in his book *Lloyd Percival: Coach and Visionary*, second edition (2022). He trained athletes in a multitude of sports, including dozens of Canadian Olympians. Shortly after his death in 1974, Percival was honoured with induction into the Canadian Sports Hall of Fame. Many countries are investing in top coaches and high-performance training. With his visionary eye, Percival suggested changes that Canada needed to implement in its athletic training capacity to be competitive internationally.

The Intergovernmental Panel on Climate Change has released its "Sixth Assessment Report: Impacts, Adaptation, and Vulnerability" (https://www.ipcc.ch/report/ar6/wg2/). This is the result of two years of work from 330 scientists around the world. Among other things, it looks at what rising levels of greenhouse gases mean for Canada. By 2080, the report predicts that cumulative forestry losses from fire, pests, and other climate change factors could add up to $459 billion. Climate change has nearly wiped out kelp beds off the Nova Scotia coast, an important habitat for fish. The ocean acidification caused by carbon dioxide will harm squid, cod, and halibut. The lack of moisture will negatively affect agriculture. Melting permafrost and ice thaw will damage infrastructure and transportation networks in the north. Extreme weather events worsened by climate change will disrupt international supply chains, markets, finance, and trade, reducing the availability of goods in Canada and increasing their price as well as damaging markets for Canadian exports (https://www.cnn.com/2022/02/28/world/un-ipcc-climate-report-adaptation-impacts/index.html).

With his visionary eye, Percival suggested changes that Canada needed to implement in its athletic training capacity to be competitive internationally.

Moderna (https://www.modernatx.com) has confirmed that it has chosen the greater Montreal area as the location for its new biomanufacturing plant (https://www.cbc.ca/news/canada/montreal/moderna-montreal-facility-mrna-1.6435636). This will be the company's first plant outside of the United States and is a long-term strategic partnership with the government of Canada. The $180 million facility is expected to produce 100 million doses of mRNA vaccines per year. Construction is expected to be completed by 2024. The facility will also include a research centre that will work in collaboration with researchers from McGill University. The facility will also have the capacity to produce mRNA vaccines against other respiratory viruses, including the seasonal flu, and have the capacity to adapt and adjust manufacturing to address novel or emerging viruses. This Moderna manufacturing plant will help Canada prepare for future pandemics by reinforcing domestic supply chains and vaccine autonomy. Canada's biomanufacturing industry has declined substantially in the last 40 years (https://www.cbc.ca/news/politics/domestic-vaccine-manufacturing-canada-1.6004427), and, when COVID-19 vaccines were needed, no facility in Canada was able to manufacture them. ■

About the Author



Terrance Malkinson is the author of more than 590 peer- and editorial-reviewed publications and is now retired. His diverse career path includes 26 years in medical research as a founding member of the Faculty of Medicine at the University of Calgary as well as a three-year appointment as a business manager with General Electric Company followed by a one-year applied research appointment with SAIT Polytechnic. He is an alumnus of continuing professional education programs with Outward Bound International, the Banff Centre for Management, the Massachusetts Institute of Technology, and the University of Colorado. During his long career, he has advanced both basic and applied medical, health and wellness, scientific, and engineering knowledge. He has trained and mentored undergraduate, graduate, and postdoctoral students as well as staff in the business sector and government. He is a 45-year Life Senior Member of IEEE. He has served in many professional, public and private governance, and publication roles. He is the recipient of several peer-selected awards, including induction into the Order of the University of Calgary, IEEE achievement medals, and APEX awards for publication excellence. In retirement, he vigorously continues basic and applied research with an extensive portfolio of projects. Other passions include communicating emerging technologies to the public, investigative journalism, philanthropy, and mentorship. His current research interest in emerging technologies and health and wellness extends to being an accomplished multisport triathlete, including, among other events, the completion of 11 full-distance Ironman Triathlons.

IEEE Canada IHTC 2022 – International Humanitarian Tech. Conference

Virtual, 2 – 4 December 2022





Photo: OLE Nepal, Om Yadav

Poster Contest

Design projects seeking to solve Humanitarian issues using Technology done from July '15 to June '17 are welcomed. Judging to be based on innovation, feasibility, relevance to real-world problems and cost-effectivness.

The theme of IEEE Canada IHTC 2022 is "Engineering and Technology for Greater Good" with emphasis on policies, practices, and technologies aimed at building resilient communities. IEEE Canada IHTC 2022 is a unique conference that will focus on humanitarian applications of technologies, aligning with Sustainable Development Goals of the United Nation: Mainly, sustainable development of communities, health, disaster mitigation and management; and engineering education with an emphasis on humanitarian issues. The conference will feature outstanding keynote speakers, workshops, a student paper/design competition, and peer-reviewed papers.

CALL FOR PAPERS

The technical program committee invites you to submit a 200-300 word abstract of a paper in any of the following track areas.

1. Poverty alleviation, achieving food security and improved nutrition
2. Promote sustainable agriculture.
3. Effective management of refugees, (re)settlements and integration
4. Ensuring healthy lives and promote well-being for all at all ages
5. Quality education and promote lifelong learning opportunities for all
6. Sustainable management of water and sanitation for all
7. Affordable, reliable, sustainable and modern energy for all
8. Making cities and human settlements safe, resilient and sustainable
9. Disaster mitigation, management, relief, and recovery
10. Combating climate change and its impacts
11. Social impacts of technology
12. Data and personal security humanitarian technology
13. Humanitarian and educational technologies
14. Community engagement

IMPORTANT DATES

Paper submission deadline	**Sep 04, 2022**
Acceptance notification	**Oct 23, 2022**
Submission of camera-ready papers Registration Deadline	**Nov 15, 2022**

SPEAKERS, WORKSHOPS, PANELS

Proposals are invited for half-day tutorials, workshop on new and emerging topics within the scope of the conference.

Please describe the content, importance and timeliness, the speaker(s), brief CVs, and where appropriate, topics each will cover. For further info, contact: anis.b.a@ieee.org

Submission due September 04, 2022

SUBMISSIONS

Papers to be uploaded at: https://edas.info/N29896

Please use PDF format for both papers/paper abstracts, as well as proposals for tutorials, workshops and panels. Detailed information on paper format and submission procedure can be found on the conference website.

WHO SHOULD ATTEND?

The target audience for the conference includes researchers, practitioners and students in the fields of sustainability, human development, education, disaster relief, STEM fields and management sciences as well as interested professionals and anyone wanting to contribute their talents on the humanitarian and sustainable development fields.

Exhibition: Showcase your products and services to Canadian and international audiences. If you require more details please email:

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For detailed up-to-date information, visit the Conference web site:

IEEE Canada

https://ihtc2022.ieee.ca/paper-submission/

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