IEEE Canadian Review
La revue canadienne de l'IEEE
Spring 2020 – No. 83

Connecting the Dots

In Focus With Ibrahim Gedeon

HF Radar Ocean Remote Sensing on the Atlantic's Edge

Nobel Prize Inspired by Radar Technology

IEEE Canada
The Institute of Electrical and Electronic Engineers Inc.

COVID–19 Update for IEEE Canada Operations and Events – A Message from the IEEE Canada President

The health and safety of IEEE Members and our communities is our first priority. IEEE Canada has been monitoring the COVID-19 pandemic through official channels like Public Health Agency of Canada, the World Health Organization, and the Centers for Disease Control and Prevention (United States).

In light of recent changes in public policy and the bans on public gatherings, IEEE Canada recommends that all in-person IEEE meetings, working groups, and conferences sponsored by Region 7/IEEE Canada and/or the Sections, Chapters, Affinity Groups, and Student Branches within IEEE Canada that have been planned to be held before 1 May 2020 be cancelled, postponed, or replaced by virtual meetings.

If you have an ieee.org email account, you have access to the Google GSuite, which includes Google Hangouts. Hangouts support up to 100 users for a remote meeting, and this capacity is anticipated to increase to 250 shortly.

Also, more and more IEEE Organizational Units are using remote web conferencing in lieu of in-person meetings. As an alternative, IEEE MGA offers WebEx meetings for Sections. Please find additional information at: https://site.ieee.org/vtools/remote-conferencing/.

Stephen Welby, IEEE executive director and COO, has communicated that

> *All IEEE operations are continuing. At most of our global offices, IEEE staff will now support IEEE's mission while teleworking from their homes to minimize risk.*
>
> *Most upcoming IEEE conferences and meetings have been postponed or replaced with virtual meetings. IEEE publications continue to accept, review, and publish submissions. IEEE standards development also continues, using online collaboration to replace in-person working groups.*

IEEE Canada will continue to monitor the COVID-19 outbreak and will provide updates or new recommendations as new information becomes available.

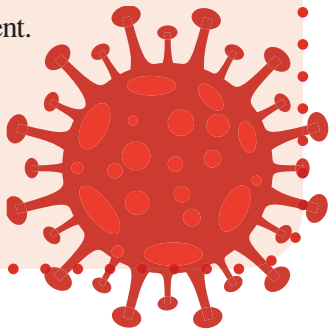
At this critical juncture, prevention and preparedness remain key. To reduce the spread

- Wash your hands frequently with soap
- Cough or sneeze into your elbow or a tissue
- Clean high-touch surfaces and objects often
- Avoid touching your eyes, nose and mouth with unwashed hands.

In addition, everybody is reminded that *social distancing* is of paramount importance**.**

Our hearts, thoughts and prayers go out to those impacted by this unprecedented event.

Jason Gu, Ph.D., P.Eng., FEIC, FCAE
IEEE Canada President, 2020–2021
IEEE Region 7 Director, 2020–2021



President's Message/Message du Président

Jason Gu
Ph.D., FEIC, FCAE

2020–2021 IEEE Canada President and Region 7 Director
Président de l'IEEE Canada et directeur de la région 7, 2020–2021

As the newly appointed Region 7 director and IEEE Canada president, I am excited to work with all the volunteers and members of our Region. It will be my honor to represent Region 7 on the IEEE Board of Directors for the next two years.

Acknowledging Past Contributions

My sincere gratitude to Maike Luiken of the London Section for completing her term as IEEE Canada president with such commitment and devotion. Through her superb leadership, Maike's team of volunteers contributed immensely to IEEE Canada. It is no surprise that Maike has recently been elected as the IEEE vice-president-elect, MGA/IEEE Member and Geographical Activities Board chair-elect. Congratulations on behalf of IEEE Canada! We look forward to working with Maike on the IEEE Board of Directors and also as IEEE Canada past-president.

I would like to take this opportunity to thank Witold Kinsner of the Winnipeg Section for his tireless and resolute leadership during the last six years, most recently as past-president of IEEE Canada. I had the privilege of receiving

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En tant que nouveau directeur de la région 7 et président de l'IEEE Canada, je suis ravi de travailler avec tous les bénévoles et les membres de notre région. Ce sera pour moi un honneur de représenter la région 7 au conseil d'administration de l'IEEE pour les deux prochaines années.

Reconnaître les contributions passées

Je remercie sincèrement Maike Luiken de la section de Londres d'avoir terminé son mandat de présidente d'IEEE Canada avec tant d'engagement et de dévouement. Grâce à son excellent leadership, l'équipe de bénévoles de Maike a énormément contribué à l'IEEE Canada. Il n'est pas surprenant que Maike ait récemment été élue membre de l'IEEE et présidente élue du conseil d'administration des activités géographiques. Félicitations au nom de l'IEEE Canada! Nous sommes impatients de travailler avec Maike au conseil d'administration de l'IEEE et aussi en tant qu'ancienne présidente.

J'aimerais profiter de l'occasion pour remercier Witold Kinsner, de la section de Winnipeg, pour son leadership inlassable et résolu au cours des six dernières années, plus récemment en tant qu'ancien président de l'IEEE Canada. J'ai eu le privilège

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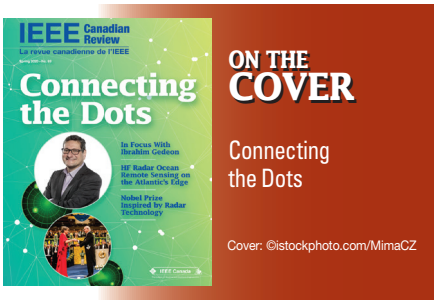

President's Message/Message du Président

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guidance and encouragement from Witold, and I wish him the best in all his new endeavours.

I would like to welcome Robert Anderson of the Southern Alberta Section as our new president-elect. Greetings to all the new and reappointed volunteers of IEEE Canada. I am truly fortunate to work with such a motivated and dedicated group of volunteers. I thank all of you for your time, effort, and enthusiasm.

Looking Ahead

As I start my term, I would like to share my focus for 2020–2021. Working together, I would like our Region to target the following areas:

- membership development
- relationships with the industry, government, and other professional societies
- challenges in small Sections
- collaboration and communication between Sections
- volunteer recruitment and continuity
- transparency in nominations, elections, finances, and awards and recognitions.

I will be sharing my thoughts in detail in future columns and will be working with the IEEE Canada team to achieve these term goals.

I would like to draw your attention to the following two signature events that are scheduled in the coming months:

1) The 2020 IEEE Canada Conference on Electrical and Computer Engineering will take place in London, Ontario. The conference date has been postponed to early September 2020 due to the growing concerns about the spread of COVID-19. Please visit the conference website (https://ccece2020.ieee.ca/) for more details. I look forward to meeting all of you there. Together, we will celebrate the achievements of our award recipients at the IEEE Canada Gala Awards Dinner.
2) The triennial IEEE Section Congress 2020 will take place in Ottawa, Ontario, 21–23 August. More than 336 IEEE Sections from all over the world will congregate. With a total expected attendance of more than 1,000 members, we are delighted to be the host country. IEEE Canada has set up a Congress Committee that will be actively involved in the organization of the event. At the venue, IEEE Canada will showcase its significant achievements over the past 25 years. IEEE Canada will also have its Regional Board Meeting during the Section Congress. In addition to the regular training sessions for the Section delegates, an important voting session will be held to seek recommendations from all the IEEE Regions.

As we welcome spring through this edition of *IEEE Canadian Review*, I wish a new beginning to all the readers, and I thank you for your continued support. Your comments and suggestions for any aspect of IEEE Canada's operation are welcome. Please contact me at jason.gu@ieee.org. I look forward to hearing from you. Be safe and healthy, and have a joyful and prosperous year ahead. ■

Jason Gu, Ph.D., FEIC, FCAE
2020–2021 IEEE Canada President
2020–2021 IEEE Region 7 Director

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de recevoir des conseils et des encouragements de Witold, et je lui souhaite le meilleur dans toutes ses nouvelles entreprises.

J'aimerais souhaiter la bienvenue à Robert Anderson, de la Section du sud de l'Alberta, à titre de nouveau président élu. Salutations à tous les nouveaux bénévoles et nommés de nouveau de l'IEEE Canada. J'ai vraiment la chance de travailler avec un groupe aussi motivé et dévoué de bénévoles. Je vous remercie tous pour votre temps, vos efforts et votre enthousiasme.

Regard vers l'avenir

Au début de mon mandat, j'aimerais partager mon objectif pour 2020–2021. En travaillant ensemble, j'aimerais que notre Région cible les domaines suivants:

- développement des membres
- relations avec l'industrie, le gouvernement et d'autres sociétés professionnelles
- défis dans les petites sections
- collaboration et communication entre sections
- recrutement et continuité bénévoles
- transparence dans les nominations, les élections, les finances, et les récompenses et les reconnaissances.

Je partagerai mes réflexions en détail dans les prochaines colonnes et je travaillerai avec l'équipe de l'IEEE Canada pour atteindre ces objectifs à terme.

Je voudrais attirer votre attention sur les deux événements phares suivants qui sont prévus dans les prochains mois:

1) La Conférence de l'IEEE Canada 2020 sur le génie électrique et informatique aura lieu à London, en Ontario. La date de la conférence a été reportée au début du mois de septembre 2020 en raison des préoccupations croissantes concernant la propagation de COVID-19. Veuillez visiter le site Web de la conférence (https://ccece2020.ieee.ca/) pour plus de détails. J'ai hâte de vous rencontrer tous là-bas. Ensemble, nous célébrerons les réalisations de nos lauréats lors du dîner de gala de l'IEEE Canada.
2) Le Congrès triennal de la section de l'IEEE 2020 aura lieu à Ottawa, en Ontario, du 21 au 23 août. Plus de 336 sections de l'IEEE du monde entier se rassemblent. Avec une fréquentation totale prévue de plus de 1 000 membres, nous sommes ravis d'être le pays hôte. L'IEEE Canada a mis sur place un comité du Congrès qui participera activement à l'organisation de l'événement. Sur le site, l'IEEE Canada présentera ses réalisations importantes au cours des 25 dernières années. L'IEEE Canada tiendra également sa réunion régionale du conseil d'administration lors du congrès de la section. En plus des séances de formation régulières des délégués de la Section, une importante session de vote sera organisée pour demander des recommandations de toutes les régions de l'IEEE.

Alors que nous accueillons le printemps dans cette édition de la Revue canadienne de l'IEEE, je souhaite un nouveau départ à tous les lecteurs, et je vous remercie de votre soutien continu. Vos commentaires et suggestions pour tout aspect de l'exploitation de l'IEEE Canada sont les bienvenus. S'il vous plaît contactez-moi à jason.gu@ieee.org. J'ai hâte de vous entendre. Soyez sain et sauf, et passez une année joyeuse et prospère. ■

Jason Gu, Ph.D., FEIC, FCAE
Président de l'IEEE Canada 2020–2021
Directeur de la Région 7 de l'IEEE 2020–2021

A Few Words From the Editor-in-Chief / Quelques mots du rédacteur en chef

Jahangir Khan
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As the unprecedented scale, magnitude, and toll of the COVID-19 pandemic start to sink in, we are all struggling to process the suddenness and its surreal ferocity. Basic privileges and conveniences can no longer be taken for granted, "social distancing" is the new norm, and the economy is in peril. At the time of writing this editorial, a dark ominous cloud is still lingering on the horizon. This truly is a challenge to human civilization, and how we handle it will define our generation.

As I look in the rearview mirror and reflect on a few other significant events that have caught us by surprise in the last few months, I see a pattern of global connectivity and interdependence. Although the Brexit fiasco in the United Kingdom and the impeachment drama in the United States may be behind us, only time will tell what the political and economic implications will be—not to mention the impacts of COVID-19 pandemic.

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Alors que l'ampleur et le bilan sans précédent de la pandémie du COVID-19 commencent à s'enfoncer, nous luttons tous pour traiter la soudaineté et sa férocité surréaliste. Les privilèges et les commodités de base ne peuvent plus être pris pour acquis, la «distanciation sociale» est la nouvelle norme, et l'économie est en péril. Au moment d'écrire ces lignes, un nuage sombre et inquiétant s'attarde encore à l'horizon. C'est vraiment un défi pour la civilisation humaine, et la façon dont nous la gérons cette pandémie définira notre génération.

En regardant dans le rétroviseur et en réfléchissant à quelques autres événements importants qui nous ont pris par surprise au cours des derniers mois, je vois un modèle de connectivité et d'interdépendance mondiales. Bien que le fiasco du Brexit au Royaume-Uni et le drame de la destitution aux États-Unis soient peut-être derrière nous, seul le temps nous dira quelles seront les implications politiques et économiques — sans parler des effets persistants de la pandémie de COVID-19.

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A Few Words From the Editor-in-Chief / Quelques mots du rédacteur en chef

(A Few Words From the Editor-in-Chief cont'd from p. 3)

On the other hand, what started as a military escalation in the Middle East quickly hit home when hundreds of innocent civilians perished in the Iran air disaster. Our hearts continue to bleed as we mourn the loss of at least five active IEEE Canada members, who were among the passengers. Early in the new year, news of a novel coronavirus started to break. What arguably started in a fish market in Wuhan, China, had become a global concern overnight, reaching Canada within a few days.

Amidst the sadness of loss and worries of the COVID-19 pandemic, we need to search our souls as a professional community. We must stay strong and support each other. We must maintain professionalism and share the facts, not misinformation. We must find humanitarian solutions beyond the boundaries of country, race, religion, and gender. After all, our organization is dedicated to advancing technology for the benefit of humanity.

Social media and the Internet played a key role when news of the Iran air crash and the coronavirus outbreak started to sink in. We have seen an outpouring of grief and support for the victims of the Iran air disaster. During the coronavirus outbreak, we have seen unprecedented support for the deceased medical doctor in Wuhan who made the first attempt to alert the world. Communication is key in such trying times, and global connectivity is more important than ever.

This issue of *IEEE Canadian Review* (*ICR*) covers a number of feature articles that encompass the broad theme of connectivity and communication: from classical terrestrial radar and space radio to state-of-the-art 5G and Internet of Things technology. The interview with Ibrahim Gedeon, chief technology officer, TELUS, is a very special and timely piece in this issue.

The Fall 2019/Winter 2020 issue (no. 82) was an amazing journey of revival.

I welcome a few new *ICR* authors who spent countless hours during the Christmas holiday and in the new year preparing their articles. Special thanks to our regular contributing editors Dave Michelson, Terrance Malkinson, and Dario Schor—you truly are the lifeline of this magazine. Currently, we are in the process of restructuring and rejuvenating the editorial team. There will be more to come on this initiative in future issues of *ICR*.

Amid the doom and gloom of the last couple months, we have good reason to celebrate. Thanks to all the support, we have restarted the publication of *ICR*. The Fall 2019/Winter 2020 issue (no. 82) was an amazing journey of revival. Many thanks to Maike, Wahab, Ekram, Jason, Rob, Christopher, Dennis, Jeffrey, and the rest of the IEEE Canada team.

In November 2019, we created a temporary opt-in platform for the readers who wish to receive print copies. This was a fairly complicated process, but we tried to keep it as simple as possible. Our intention is to set up an easier and permanent opt-in platform, preferably embedded in the IEEE membership renewal portal. I thank you for your patience and understanding.

Our website needs substantial upgrades, and our advertisement stream needs an uplift. We have an immense opportunity to

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(Quelques mots du rédacteur en chef suite de p. 3)

D'un autre côté, ce qui a commencé comme une escalade militaire au Moyen-Orient a rapidement frappé la maison lorsque des centaines de civils innocents ont péri dans la catastrophe aérienne en Iran. Nos cœurs continuent de saigner alors que nous pleurons la perte d'au moins cinq membres actifs de l'IEEE Canada, qui faisaient partie des passagers. Au début de la nouvelle année, la nouvelle d'un nouveau coronavirus a commencé à éclater. Ce qui a sans doute commencé dans un marché aux poissons à Wuhan, en Chine, était devenu une préoccupation mondiale du jour au lendemain, atteignant le Canada en quelques jours.

Au milieu de la tristesse de la perte et des inquiétudes de la pandémie de COVID-19, mondiale, nous devons fouiller nos âmes en tant que communauté professionnelle. Nous devons rester forts et nous soutenir mutuellement. Nous devons maintenir le professionnalisme et partager les faits, et non pas la désinformation. Nous devons trouver des solutions humanitaires au-delà des frontières du pays, de la race, de la religion et du sexe. Après tout, notre organisation se consacre à l'avancement de la technologie au profit de l'humanité.

Les médias sociaux et Internet ont joué un rôle clé lorsque les nouvelles du crash aérien en Iran et de l'épidémie de coronavirus ont commencé à affluer. Nous avons assisté à une vague de chagrin et de soutien aux victimes de la catastrophe aérienne en Iran. Pendant l'épidémie de coronavirus, nous avons vu un soutien sans précédent au médecin décédé de Wuhan, qui a fait la première tentative d'alerter le monde. La communication est essentielle en ces temps difficiles, et la connectivité mondiale est plus importante que jamais.

Ce numéro de la *Revue canadienne de l'IEEE* (*RCI*) couvre un certain nombre d'articles de fond qui couvrent le vaste thème de la connectivité et de la communication: du radar terrestre classique et de la radio spatiale aux technologies de pointe 5G et Internet des Objets. L'entrevue avec Ibrahim Gédéon, directeur de la technologie chez TELUS, est un article très spécial et opportun dans ce numéro.

Je souhaite la bienvenue à quelques nouveaux auteurs de la *RCI* qui ont passé d'innombrables heures pendant les vacances de Noël et la nouvelle année à préparer leurs articles. Un merci spécial à nos rédacteurs en chef réguliers Dave Michelson, Terrance Malkinson et Dario Schor — vous êtes vraiment la bouée de sauvetage de ce magazine. Actuellement, nous sommes en train de restructurer et de rajeunir l'équipe éditoriale. Il y aura plus à venir sur cette initiative dans les prochains numéros de l'*RCI*.

Au milieu du destin et de la morosité des deux derniers mois, nous avons de bonnes raisons de célébrer. Grâce à tout le support, nous avons relancé la publication de la *RCI*. Le numéro d'automne 2019 / hiver 2020 (no. 82) a été un incroyable voyage de renouveau. Un grand merci à Maike, Wahab, Ekram, Jason, Rob, Christopher, Dennis, Jeffrey et au reste de l'équipe de l'IEEE Canada.

En novembre 2019, nous avons créé une plateforme de choix de participation temporaire pour les lecteurs qui souhaitent recevoir des exemplaires imprimés. C'était un processus assez compliqué, mais nous avons essayé de le garder aussi simple que possible. Notre intention est de mettre en place une plateforme de choix de participation plus simple et permanente, de préférence intégrée dans le portail de renouvellement d'adhésion à l'IEEE. Je vous remercie de votre patience et de votre compréhension.

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Radio Science in Canada

by David Michelson

Last year, the International Union of Radio Science (abbreviated URSI, after its French name, Union Radio-Scientifique Internationale*) celebrated its centennial. The past 100 years have borne witness to the tremendous impact that the application of electromagnetic fields and waves have had on society, industry, and the economy. From wireless communications to microwave ovens to fibre optics to radar to remote sensing to radio astronomy, it is difficult to imagine today's world without the benefits of electromagnetic technology.*

URSI has a long history of cooperating with the IEEE to advance international cooperation in the study of electromagnetics. One of the best-known examples is, of course, the IEEE Antennas and Propagation Society (AP-S) Symposium on Antennas and Propagation and the Radio Science Meeting that is organized each summer by the AP-S and the U.S. National Committee (USNC) for URSI. In July 2020, the Canadian National Committee (CNC) of URSI, also known as URSI Canada, *will join the effort as we cohost the meeting in Montréal.*

In our first two "Radio Science in Canada" columns, we provided a general introduction to URSI as a global organization including its structure, publications, and conferences; the history of URSI in Canada; and the major URSI awards through which many Canadian contributions to radio science have been recognized over the years. We also presented a focus on URSI Commission J, Radio Astronomy, and Commission K, Electromagnetics in Biology and Medicine in Canada. In this column, we present highlights from the current version of URSI Canada's Strategic Plan for 2020–2022, share some of the resources available to those interested in the history of radio science in Canada, and present a focus on URSI Commission A, Electromagnetic Metrology in Canada.

Dave G. Michelson;
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Highlights From URSI Canada's Strategic Plan: 2020–2022

The mission of CNC-URSI is

- to promote, within Canada, international programs in radio science and Canadian participation in international activities sponsored by URSI so as to ensure maximal benefits to Canada
- to promote within URSI international activities that are relevant or of special interest to Canada and to coordinate all aspects of Canadian participation in the discussion and dissemination of the results of such activities
- to formulate Canadian positions with respect to URSI activities and advise the URSI Council on Canadian participation and on the activities of URSI and CNC-URSI
- to act as a channel of communication between URSI, the National Research Council, Canadian scientific societies, Canadian scientists, and Canadian industry.

During 2020–2022, CNC-URSI will take the following steps to pursue its mission:

- cohost the 2020 IEEE AP-S/URSI Symposium in Montréal, 5–10 July 2020
- participate in the 23rd General Assembly and Scientific Symposium of URSI in Rome, 29 August–5 September 2020
- work with IEEE Canada to develop and promote the biennial ANTEM conference, next scheduled to be held in 2021
- incorporate as a federal nonprofit corporation
- establish a standing committee to promote greater awareness of the history of radio science in Canada
- establish a standing committee to encourage international conferences with relevant radio science content to come to Canada
- establish a standing committee to promote the participation of Canadian radio science researchers in international programs
- establish a standing committee to encourage Canadian radio science researchers to participate in international programs to develop humanitarian technologies
- establish a standing committee on radio science education.

The History of Radio Science in Canada

The URSI centenary provides an opportunity to reflect on the history of radio science in Canada. Museums are important repositories of documents and artifacts relevant to this history. Some such museums have been established by the government or industry, while others were started by private collectors interested in sharing their collections and love of this history with the public.

The URSI centenary provides an opportunity to reflect on the history of radio science in Canada.

The number of museums with relevant collections in Canada is surprisingly large. CNC-URSI is creating a directory of these museums for the benefit of radio science researchers, engineering professionals, and the public. The possibility of CNC-URSI endorsing museums that meet a certain set of requirements and allowing them to display signage to that effect is also being considered.

Here, we review a sampling of some of the museums and historic sites across Canada that preserve both sites and artifacts associated with several key milestones in Canadian radio science. A more complete listing will be posted to the

This regular feature in *IEEE Canadian Review* provides IEEE Canada Members with an opportunity to learn more about URSI, its organization and activities, and how they can both contribute to and benefit from URSI's mission.

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URSI Canada website, http://www.ursi.ca/, in mid-2020.

SPARC Museum, Vancouver, British Columbia

The SPARC museum's extensive collection is divided into 10 themes: amateur, Bamfield, broadcast, broadcast studio (Figure 1), marine, military, museum library, shortwave and commercial, spark era, and television.

The amateur radio section features large tube equipment, mostly from the 1930s through 1950s, vintage Collins A-line and E.F. Johnson radio equipment from the 1940s, and Collins S-Line equipment from the 1960s. The military section features transceivers manufactured in Canada for use in tanks on the Russian front in World War II, racks of Canadian Navy

FOCUS ON

URSI Commission A—Electromagnetics Metrology: Electromagnetic Measurements and Standards

Dr. Marina Gertsvolf
Canadian representative to Commission A and member, Canadian National Committee

Commission A Canadian National Committee Representative

Dr. Marina Gertsvolf is a research officer and a team leader at the Frequency and Time Group, National Research Council (NRC) Canada, Metrology Research Centre. Marina's research interests are in the field of frequency and time dissemination and measurements, automated time scales, and frequency standards development. She is also a vice chair of the Frequency and Time Working Group of the Sistema Interamericano de Metrologia and a chair of the Working Group on the International Atomic Time of the Consultative Committee on Time and Frequency of the International Bureau of Weights and Measures.

Commission A Mission Statement

Commission A promotes research and development of the field of measurement standards and physical constants, calibration and measurement methodologies, and improved quantification of accuracy, traceability, and uncertainty. Areas of emphasis include

- development and refinement of new measurement techniques and calibration standards, including techniques for antennas
- development of primary standards, including those based on quantum phenomena, and the realization and dissemination of time and frequency standards
- characterization of the electromagnetic properties of materials, physical constants, and the properties of engineered materials including nanotechnology
- methodology of space metrology and electromagnetic dosimetry as well as measurements for health diagnostics applications, and biotechnology, including biosensing
- measurement in advanced communication systems and other applications.

The commission fosters accurate and consistent measurements needed to support the research, development, and exploitation of electromagnetic technologies across the spectrum and for all commissions.

Commission A Activities

In Canada, activity in measurement science is concentrated at the NRC Metrology Research Centre, where the International System of units (SI) is realized and where the research and development of next-generation standards and highest-accuracy measurement techniques are underway. Electromagnetic metrology underpins many areas of measurements and the realization of several SI units. These include

- the definition of the SI second, where the microwave frequency of 9,219,631,770 Hz is realized by caesium atoms in the primary frequency standard at the NRC
- the unit of length, the metre, which is defined in terms of an optical wavelength (or frequency) of electromagnetic radiation
- the unit of temperature, the kelvin, which, in its realization with acoustic thermometry, relies on accurate frequency reference of radio-frequency electromagnetic waves
- the newly fixed value of the Planck constant
- the realization of the unit of mass, the kilogram, with the Kibble balance, which, again, relies on accurate frequency calibration of a laser light.

In June 2017, the NRC reported yet another lowest-uncertainty evaluation of the frequency measurement achieved with a single trapped strontium ion electric quadrupole transition frequency. The evaluation uncertainty of this system was 1.5 parts in 10^{17}, and the measurement uncertainty was 1.7 parts in 10^{15}, the best values for Canada reported to date.

This measurement is especially important for the development of electromagnetic-frequency metrology in Canada because it supports the next big transformation of SI units, the transition of the definition of the unit of the second from a microwave domain (gigahertz transition frequency in an atom of caesium) to an optical one (terahertz transition frequency of an atom or ion).

The future optical definition of the second will allow frequency measurements to be performed with the same accuracy as their evaluation, whereas, currently, they are limited by the lowest uncertainty of the frequency realization with a caesium fountain, at the level of 2 parts in 10^{16}.

Commission A has played an important role at past URSI general assemblies, scientific symposia, and satellite conferences, with a consistent roster of presentations on research in measurement science.

radio equipment, and transmitters and receiver/direction-finding equipment from bombers. The museum pursues an active restoration program.

The museum is located on the Riverview Hospital grounds in Coquitlam, British Columbia, Canada, about 15 minutes east of Vancouver. Further details concerning the location, admission fee policy, and hours of operation can be found on the museum's website at https://sparcradio.ca.

Hammond Museum of Radio, Guelph, Ontario

The Hammond Museum of Radio got its start when museum founder Fred Hammond, VE3HC, began collecting early radio and wireless artifacts at the age of 16 years. The museum moved to its current location in 1999.

The museum is now home to hundreds of receivers and transmitters (Figure 2) dating from the spark era up to and including National's first solid-state HRO500. It hosts one of the largest collections of Collins radio equipment anywhere, including a rare but fully operational Collins 30K. Kept in pristine condition, the station frequently takes to the air with the same bold signal it produced the day it left the Collins factory.

The museum is located 40 minutes west of Toronto in Guelph, Ontario. Further details concerning the location, admission fee policy, and hours of operation can be found on the museum's website at http://www.hammondmuseumofradio.org.

Canadian Forces Museum of Aerospace Defence, North Bay, Ontario

The Canadian Forces Museum of Aerospace Defence traces the evolution of aerospace defence through four eras: World War I, World War II, the Cold War, and the post-Cold War.

A significant portion of the museum's collections are devoted to the development of the Pinetree Line, Mid-Canada Line, and Distant Early Warning Line air-defence radars during the 1950s,

The history of Canadian military signals dates from 1903, when the militia-based Canadian Signal Corps was established.

the three-storey underground complex that was built 60 storeys beneath the surface at 22 Wing/Canadian Forces Base North Bay to house Canada's air defence headquarters, electronic warfare, and the growing importance of space defence (Figure 3).

The museum is located at 22 Wing/Canadian Forces Base North Bay near Jack Garland Airport. Further details concerning the location, admission fee policy, and hours of operation can be found on the museum's website at https://www.aerospacedefence.ca.

Military Communications and Electronics Museum, Kingston, Ontario

One of Kingston's largest museums, the Military Communications and Electronics Museum features the troops, times, and technologies used in Canadian military communications and electronics (Figure 4).

The history of Canadian military signals dates from 1903, when the militia-based Canadian Signal Corps was established. The exhibits are arranged chronologically from that time, through World Wars I and II, the Korean War, and various NATO and United Nations peacekeeping missions. The museum also features a complete working amateur radio

Photo: SPARC Museum

Figure 1: A broadcast studio at the SPARC Museum.


Photo: Hammond Museum

Figure 2: A vintage radio exhibit at the Hammond Museum of Radio.

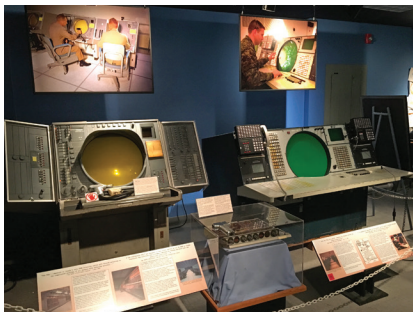
Photo: CFMAD Museum

Figure 3: A radar exhibit at the Canadian Forces Museum of Aerospace Defence.

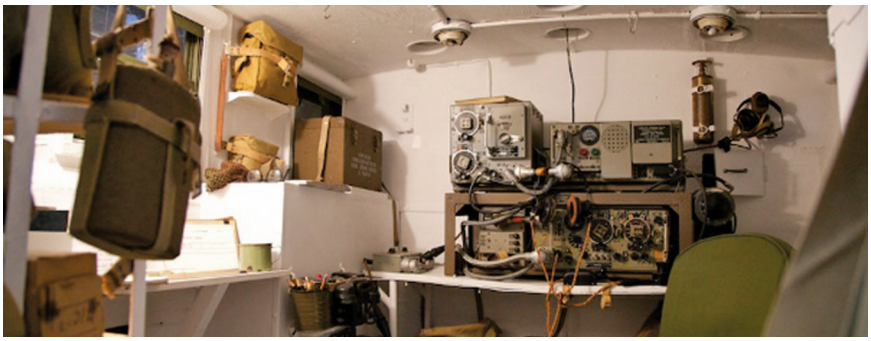
Photo: MCEM Museum

Figure 4: A wireless exhibit at the Military Communications and Electronics Museum.

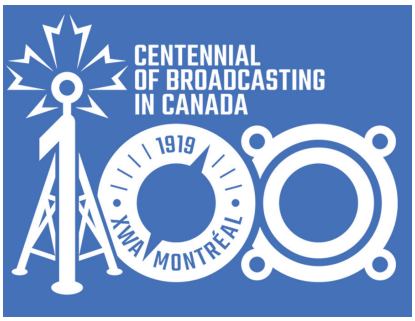

Figure 5: The logo of the centennial of broadcasting in Canada.

station as a gateway into the Canadian Forces Affiliate Radio System.

The museum is located at CFB Kingston, just off Ontario Highway 2. Further details concerning the location, admission fee policy, and hours of operation can be found on the museum's website at http://www.candemuseum.org.

Musée des ondes Emile Berliner, Montréal, Quebec

The collection of the Musée des ondes Emile Berliner has expanded greatly during the past 25 years and now consists of more than 30,000 audio reproduction and recording devices, radios, televisions, and architectural acoustic plans.

The year 2019–2020 is particularly noteworthy as it marks the 100th anniversary of broadcasting in Canada (Figure 5). In December 1919, radio station XWA was the first to conduct experimental broadcasting from its William Street studio in Montréal. The musée and the Société Québécoise de Collectionneurs de Radios Anciens have joined their efforts with those of other groups in the Montréal area to highlight this anniversary.

The musée is located in the old RCA building in St. Henri (Montréal, Quebec). Further details concerning the location, admission fee policy, and hours of operation can be found on the museum's website at https://moeb.ca.

Admiralty House Communications Museum, St. John's, Newfoundland

H.M. Wireless Station Mount Pearl was constructed by the Marconi Telegraph Company in 1915 as a wireless station for the Royal Navy. One of 13 identical stations that were built across the globe in that era, it is the last one still standing.

Photo: Admiralty House

Figure 6: The main building of the Admiralty House Communications Museum.

The year 2019–2020 is particularly noteworthy as it marks the 100th anniversary of broadcasting in Canada.

The Museum's collection is presented in both general history exhibits and two wireless exhibits (Figure 6). The first wireless exhibit is dedicated to H.M. Wireless Station Mount Pearl and its role in intercepting German naval transmissions, tracking icebergs, and listening for ships in distress. The second is called Telegraph Alley and features the development of modern wireless communications and the contributions of Samuel Morse, Guglielmo Marconi, Reginald Fessenden, and others.

Admiralty House is located in Mount Pearl just outside St. John's, Newfoundland. Further details concerning location, admission fee policy, and hours of operation can be found on the museum's website at http://admiraltymuseum.ca.

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

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

Prof. David Michelson (davem@ece.ubc.ca) is the chair of the Canadian National Committee of the International Union of Radio Science (2018–2020). He has led the Radio Science Lab at the 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 smart utility, smart transportation, and natural-resource applications; millimetre-wave channels and systems; and satellite networks for communications and remote sensing. Prof. Michelson serves as a member of the board of governors of the IEEE Vehicular Technology Society, as a member of the steering committee of the NIST-sponsored 5G mm-Wave Channel Model Alliance, and as codirector of the AURORA Connected Vehicle Technology Testbed at UBC.

An Interview With

Ibrahim Gedeon, Chief Technology Officer, TELUS

Ibrahim Gedeon, chief technology officer, TELUS, discusses his organization's vision in leading the ever-changing landscape of Canadian telecommunications. With the reckoning of 5G in Canada, *IEEE Canadian Review (ICR)* finds this interview very timely, unique, and thought provoking.

ICR: As one of the most prominent leaders in the global telecommunication industry, what is your broad assessment of the current trends, challenges, and opportunities in the Canadian telecom sector?

IJG: I am a firm believer that, since the invention of the digital switch, the industry has had continuous amazing innovations, the latest of which is 5G. Today, we would be remiss if we did not mention 5G as the largest disruptor. However, it is 5G as a new technology, enabling quality of service (through slicing), low latency (through mobile/multiaccess edge computing), and ultra-broadband, or else 5G is the next "G," simply faster. Leveraging 5G requires massive investment in backhaul and multiple-input, multiple-output. In addition, we have numerous adjacent trends, such as the cloud and blockchain, both coming with new opportunities. We are on the verge of the consumerization of networks and services, and that is uber exciting.

ICR: Looking back two decades at the Canadian Conference on Electrical and Computer Engineering (CCECE 2000), you talked about the "dawn of the optical network." In what ways were your expectations of the technology and the market fulfilled? In what ways did its unfolding fall short?

IJG: One cannot have 5G without major investments in fiber to provide the level of data capacity and performance needed for next-generation networks. For example, a typical Canadian city like Vancouver contains hundreds of cell sites. Since 2000, TELUS has

invested more than $40 billion across our leading wireless and wireline broadband network technologies, including our generational investment in PureFibre, to help connect Canadians across our country's vast and diverse landscape. In total, we have invested $175 billion in operations and technology to position TELUS as a network leader. Efforts like open radio access network leveraging, switched optical networks, and software-defined networking (SDN) may have fallen short. I believe we are not maximizing the benefits of true networking, and optical networks are a core element of them.

ICR: In the early 2000s, the telecom industry expected enormous growth in network traffic that didn't quite materialize. With the advances in sensors, applications that will flourish in 5G, and the incipient adoption of 5G, that growth seems poised to happen now. Are we in a better position to predict just how much growth there will be?

IJG: Thanks to the maturation of standardization, automation, analytics, and reporting, market penetration has increased significantly. To give you a sense of its growth, it is estimated there will be 75 billion Internet of Things (IoT) devices connected in North America by 2025. The adoption of 5G is essential to accommodating the volume of data and providing a secure and reliable customer experience. Globally, the 3.5-GHz spectrum band is the one of choice for 5G devices and applications. In Canada, that is expected to be auctioned later this year. We will start to fully realize the 5G benefits in 2021 and more so in 2022. I am an engineer who observes the trends. I cannot really predict the actual numbers. The reality is Canada will be 5G enabled once we, as a nation, can use the spread of available spectrum for 5G.

ICR: What are the challenges around investing in 4G while paving the way for 5G? How is the industry making the transition from one to the other?

IJG: Geography, along with access and costs associated with network infrastructure and spectrum, are among the top challenges around investing in a network that can support 5G connectivity. Provided the infrastructure is available, a number of 4G vendors support dual-mode 4G and 5G, which makes it easy to transition. Over the last number of years, TELUS has invested a significant amount of capital in fiber, connecting homes and businesses directly to our PureFibre network, while at the same time connecting our wireless sites, including small cell technologies to fiber. This investment will position us for a successful transition to 5G. When combined with our PureFibre deployments, TELUS will invest approximately $40 billion in state-of-the-art network infrastructure, including 5G technology and operations over the next three years. The outcome from the Canadian 5G spectrum auctions (namely, 3.5 GHz) in 2020 will influence how Canadian operators transition to 5G.

ICR: How would you describe network virtualization, and why is it important to the industry?

IJG: Network function virtualization (NFV) is a disruptive innovation. This takes physical pieces of custom network equipment and then replaces

them with off-the-shelf servers that run software to automate and streamline the operations. To this end, it is important for our industry to change the cost structures to become more efficient in how we spend capital funds. The traditional cost structures won't scale, and both telcos and vendors need to reinvent how we're operating to get the most out of our investments. NFV has been a critical move to decentralize the networks, and it enables massive resiliency through SDN. The current standards are at NFV 1.0, which move bespoke networks into the telco cloud as a first step. It is critical to continue down the path to enable NFV 2.0, which is based on true SDN, and enables N + 1 resiliency and survivability. This would provide cost structures that are affordable at the edge, akin to hyperscales such as Amazon and Google.

ICR: How will the TELUS Health Exchange and global mobile connectivity (GMC) be enabled by network virtualization?

IJG: Through the intuitive functionality and low latency of network virtualization, the TELUS Health Exchange and GMC is building an ecosystem to enable customer experience (fully connected, always available, and with high throughput). Partnering with start-ups and industries like banking, insurance, and health care to support innovation and development, TELUS is adopting network virtualization to improve lives through technology. For example, we have linked the Health Exchange with Babylon Health so that individuals can access and manage their health anywhere, anytime and speak to a medical practitioner right from their mobile device.

ICR: Is the process for approving network communication standards nimble enough? Is there a way to make the adoption of technology move more easily through these standards?

IJG: The convergences of wireless and wireline, network and IT, and the telco cloud and data centre cloud is indeed causing massive overlap and redundancy in the standards bodies. TELUS selectively supports specific verticals. "Secure by design" is our mantra, and that is an area where we are participating in with the ITU, the GSMA, the ATIS, and the NGMN. Other than IP through the MEF and IETF, standards are slow, unfortunately. However, I recall standardizing IMS versus a stand-alone core for 5G. This is an order-of-magnitude improvement, so we are moving in the right direction.

ICR: Are there any other key trends/future directions you're seeing in the telecom industry that we have not discussed?

IJG: Security and privacy and trust will be critical elements for every application and service. The notion that we build now and secure later is difficult to implement. Traditional service providers such as TELUS are overly cautious to ensure security and to maintain privacy. Another emerging trend in the telecom industry is smart cities, which we need to approach from an enablement platform point of view so that citizens and companies of all sizes can participate in the innovation. I also think of the IoT and agriculture and those are areas where Canada can take a global share of the technology. All these need to be supported by a world-class 5G and fiber infrastructure.

ICR: You have provided and continue to provide a lot of support to academia, especially with funding cutting-edge research projects that help faculty and students work within the industry. What is your advice on how this partnership between academia and industry can be advanced, leading to mutual benefits?

IJG: I believe R&D within the telecom industry has been redefined. However, the interfaces into academic institutions and the respective reward systems have not changed in 20 years. What is needed is a collaborative definition on needs and wants between both. I find success is not per institution but with specific individuals. TELUS, for example, in 2018 alone, invested $307 million in R&D to advance next-generation technologies as part of our journey to unleash the potential of 5G for Canadians.

ICR: You were the general chair of the IEEE International Conference on Communications (ICC) held in Ottawa in June 2012. Currently, you are the general chair of the same ICC to be held in Montreal in June 2021. What are your expectations, and how will you make this conference another success?

IJG: TELUS is excited to be the prime sponsor of ICC 2021. Having Canada as a meeting point for global researchers not only showcases Canada but also Canadian innovation. In 2012, we were the first paperless conference, and in 2021, we will have 5G enabling massive connectivity and video streaming.

ICR: You have been a very big supporter of the IEEE. You continue to serve the IEEE in many capacities: the Institute, Society, Region, Section, Chapter, and committee levels. What is your expectation of the IEEE?

IJG: The IEEE is part of who I am. I've become an avid supporter throughout my time with various companies. As the organization plans for the future, I would encourage IEEE executives to consider how industry has changed and where it is going. We all love open source and global collaboration, but that also means that local fundamental research is more directed and not general anymore. I believe taking an agile approach, listening and collaborating with the next generation of engineers to explore upcoming trends that will help the IEEE keep a relevant focus on how technology is shaping society.

Acknowledgments

- Original interviewers
  - Vawn Himmelsbach, freelance reporter, is a freelance writer and editor based in Toronto. She has covered technology and business for almost two decades for a number of major media outlets.
  - Bruce Van-Lane, past editor-in-chief, *ICR*, is the founder of Communication Matters, a public relations and publishing consultancy company. He was the editor-in-chief of *ICR* during 2015–2018.
- Follow-up interviewers
  - Dr. Wahab Almuhtadi, past chair, IEEE Canada Publications and Communications Group (2017–2019)
  - Dr. Jahangir Khan, editor-in-chief, *ICR* (2019–present).

ICR thanks Shoaib Khan, RideShark, for editorial support and Peter McHugh, TELUS, for facilitating the interview. ■

What's New in the Literature?

by Terrance Malkinson

Selected in 2017, Canada's two newest astronauts, Jenni Sidey-Gibbons from Calgary and Joshua Kutryk from Fort Saskatchewan, graduated on 10 January 2020 from NASA's astronaut basic training, making them eligible for space flight [www.cbc.ca/news/technology/csa-astronaut-graduation-1.5421957]. They spent two years in Houston, Texas, with 11 other astronaut candidates training in NASA's Artemis program [www.nasa.gov/what-is-artemis]. Candidates have been learning the many skills they will need to blast off and work in space, including operating robotics systems on the International Space Station and spacewalking. The class was taught by astronaut Jeremy Hansen, the first Canadian ever to teach it.

A Toronto-based investment firm has signed a $1 billion deal to return Canadian ownership of the space technology company behind the RADARSAT Earth-observation satellites and the Canadarm robotic mechanisms on the International Space Station. A consortium led by John Risley's Northern Private Capital with financial backing from equity investors that includes BlackBerry's former chairman Jim Balsillie, the Montreal investment company Senvest Capital will acquire all Canadian and U.K. operations of MacDonald, Dettwiler and Associates (MDA). The group says MDA's corporate headquarters will return to Canada, where it employs more than 1,900 people. The investment group sees significant growth potential for MDA under its new ownership. Over its 50-year history, MDA has grown from a B.C.-based start-up into a world-class space technology company and an anchor for Canada's space program. The organization is committed to providing a new robotic arm for the Lunar Gateway program. They are also producers of advanced surveillance, intelligence, defense, and maritime systems as well as being a supplier of satellite images for the Canadian government. This iconic advanced engineering Canadian company will once again be owned and controlled in Canada. Recently (26 December 2019), Canadian engineer and entrepreneur John S. MacDonald who, with fellow engineer Werner Dettwiler, founded MDA in 1969, passed away. His life story was published in the 17 January 2020 issue of *The Globe and Mail* [p. B20].

Over its 50-year history, MDA has grown from a B.C.-based start-up into a world-class space technology company and an anchor for Canada's space program.

A $5 million gift by the Bank of Montreal to the University of Toronto will help create the multidisciplinary BMO Laboratory for Creative Research in the Arts, Performance, Emerging Technologies and Artificial Intelligence. This multidisciplinary long-term thinking approach will allow graduate students, faculty, and artists to study how artificial intelligence can augment human creativity. Darryl White, BMO's chief executive, states, "We all know that AI ultimately will have some role to play in transforming, over the course of time, just about every industry we look at, and create, in our case, probably a different type of financial system."

In 1959, Ken Barnes was a senior draftsman for A.V. Roe (Avro) Canada, working on the Arrow, one of the most advanced fighter jets of its time. When the program was cancelled by then-Prime Minister John Diefenbaker, the government ordered the destruction of all documents related to the project. However, Barnes quietly gathered blueprints of the project and kept them in his home for decades. These original blueprints of the famously cancelled Canadian military project Avro Arrow are now on display at the University of Saskatchewan's Diefenbaker Canada Centre as part of its exhibition, Touch the Sky: The Story of Avro Canada. The cancellation of the Avro Arrow project continues to be extremely controversial, as it was seen as an opportunity for Canada to enter the high-tech world of aviation design. The unique aircraft Arrow was designed to intercept planes from the Soviet Union and shoot them down before they could bomb targets in North America. The plane was able to travel nearly twice the speed of sound and was the fastest jet in its class. After the project's closure, designers went on to work on some high-profile projects, including the Concorde jet, and Ken Barnes joined the design team of the Canadarm in the 1970s. The Touch the Sky: The Story of Avro Canada exhibit runs until April [www.diefenbaker.usask.ca/exhibits/Current-exhibits.php#].

The scientific discoveries emanating from exascale computers are predicted to change our daily lives in ways currently unimaginable. An exascale computer is a supercomputer capable of performing more than a billion-billion calculations per second (1 exaflops). This is more than 60 times faster than today's fastest supercomputers and, in other metrics, would take roughly 31.7 billion years to complete by hand. Exascale supercomputers will allow researchers to tackle problems that are currently impossible to solve. Outcomes will have impact and promise to fundamentally change society. With six extremely powerful GPUs per compute node, Argonne National Laboratory's Aurora, the first exascale supercomputer in North America, is scheduled to come online in 2021. Several other exascale computers in the United States, China, Europe, and Japan are also being built. The benefit of supercomputing research is trickle-down electronics. Benefits can be applied across the economy and throughout society to develop new products and solve problems. This

technology will give those countries possessing it a competitive advantage in the world marketplace.

Alberta's Royal Tyrrell Museum [www.tyrrellmuseum.com] has applied 3D printing technology to reconstruct fragile dinosaur specimens to advance knowledge and create compelling exhibits. Priceless specimens in paleontology are very delicate and can be easily damaged. 3D printing technology is helping museum staff learn without harming the delicate specimens. Expert staff build a photographic digital blueprint of the museum's specimens by taking multiple photographs from various angles and then triangulating them using computer programs. From this, a 3D model emerges. As one example, the technology has benefits for curator François Therrien's research on dinosaur brains. He is using reconstructed brain cavities to gain a better understanding of dinosaurs. Previously, reconstructing the brain structure or the brain shape of these long-extinct animals required a lot of manual work, including breaking the bones, pouring latex, peeling it out, and then casting the brain cavity. This can now be accomplished nondestructively, with cameras, scanners, computer analysis, and 3D printing.

A report by NASA [www.climate.nasa.gov] and the National Oceanic and Atmospheric Administration [www.noaa.gov] describes how the decade that just ended was the hottest ever measured and forecasts no end to the way man-made climate change will continue to increase, as evidenced by the decade's raging wildfires, melting ice, and extreme weather, which researchers have repeatedly and publicly associated with human activity. The decade averaged 14.7 °C worldwide, or 0.8 °C higher than the 20th century average and more than one-fifth of 1 °C warmer than the previous decade. 2019 was the second-hottest year in the 140 years of record keeping. NASA's data shows that overall, Earth is now roughly 1.2 °C hotter compared to the beginning of the industrial age. "We have strong human-induced global warming," said Friederike Otto, a climate scientist at the University of Oxford. Parts of Europe, Asia, Australia, Africa, and South America experienced record-high temperatures in 2019, as did Alaska, New Zealand, and New Mexico. Alaska was 3.4 °C warmer than average, at 0.11 °C. Sea ice, in both the Arctic and Antarctic, reached second-lowest levels in 40 years of monitoring. Others, such as Hans-Otto Portner, who heads the United Nations Intergovernmental Panel on Climate Change team, confirm the reality that global warming is already being seen in heat waves, ice sheet melt, more wildfires, stronger damaging storms, flood-inducing rain storms, and accelerating sea level rise.

An exascale computer is a supercomputer capable of performing more than a billion-billion calculations per second (1 exaflops).

Following the success of the 50.45-km Channel Tunnel [www.thoughtco.com/the-channel-tunnel-1779429], of an undersea tunnel linking southern England and northern France started in 1988 and completed in 1993, thoughts are now focusing on an undersea tunnel or bridge to connect Scotland and Northern Ireland. Leaders of both countries are supportive of the multibillion-dollar project that, if constructed as a bridge, would be one of the longest waterway crossings in the world, and many engineering challenges would need to be overcome.

The world is becoming increasingly interconnected and interdependent. Individuals and nations no longer exist in isolation. Events occurring in distant lands often have effects locally. The savvy engineer takes note of forecasts of the future and positions him or herself for career and personal success. A special issue of *The Economist,* "The World in 2020," [www.economist.com] provides the reader with 150 pages of global insights and forecasts for the year. Authoritative articles covering 2020 visions, business, finance, science and technology, and culture complement numerous other articles that discuss world, regional, and national developments. The cover story of the January 2020 issue of *Fortune* [181(1):41–64; www.fortune.com] provides the predictions of 20 "big thinkers" of world-changing, epic, disruptive, thrilling, terrifying, and fascinating ideas that will define the next decade. ■

About the Author

Terrance Malkinson, the author of over 500 peer- and editorial-reviewed publications, is now retired. However, in retirement, he vigorously continues an extensive portfolio of basic and applied research projects, innovation opportunities, journalism, philanthropy, athleticism, and mentorship. His diverse career path includes 26 years in medical research as a founding member of the Faculty of Medicine at the University of Calgary, a three-year appointment as a manager with the General Electric Company, followed by a one-year applied research appointment with SAIT Polytechnic.

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, long-term Member of the IEEE and, over the years, served in many IEEE governance and publication roles. He is a longtime contributor of feature articles to *IEEE Canadian Review.* His primary current research interest in health and wellness extends to being an accomplished multisports triathlete, including, among others, the completion of 11 long-distance Ironman Triathlons.

To date, there have been fewer than 600 humans who have crossed the Kármán line, defined by the Féderátion Aéronautique International as the boundary separating the atmosphere from space. The limited data set is not enough to confidently embark on a long-duration mission beyond low-Earth orbit. Thus, researchers have turned to analog environments to vet out procedures in a controlled environment. In this column, we take a quick look at some of the analog environments that will prepare humans to explore our cosmic neighborhood.

Ad adstra,
Dario Schor; schor@ieee.org

Analog missions are like controlled experiments that prepare humans for long duration space flight (LDSF). Crews made up of astronauts, researchers, and graduate students spend anywhere from a few days to over a year working inside a habitat, while receiving support from their mission control center (MCC). Just like in a real space mission, the crew members run experiments, perform maintenance activities, and even don spacesuits for extravehicular activities outside the habitat. Even though they know they are on Earth, they take their job very seriously and follow all the proper protocols as if they were exposed to the hazards of spaceflight. This allows researchers to test new technologies, evaluate protocols, and observe the behavioral impact from working in space.

Space agencies, research organizations, and universities manage analog facilities around the world. Although each site offers unique conditions well suited for specific kinds of research, they all simulate conditions of isolation and confinement—as that is one of the major areas of research for LDSF. In future missions, astronauts will have to spend extended periods cramped into a small spacecraft, find a way to get along with the rest of the crew, manage their limited resources, and potentially deal with communication delays when venturing beyond low-Earth-orbit. Hence, this is the reason why many astronauts shared videos online of their experience and lessons learned during the COVID-19 quarantine.

Deserts have been used since the Apollo program to train astronauts to identify and collect interesting geological samples.

Deserts have been used since the Apollo program to train astronauts to identify and collect interesting geological samples. Thus, it is no surprise that there are many analogs set up in deserts around the world. For instance, the NASA Desert Research and Technology Studies in Flagstaff, Arizona, (see Figure 1) is one of the oldest analog sites running missions since the beginning of the Cold War [1], [2]. Located near a meteor crater, it serves as a good analog for testing habitats, rovers, and spacesuits for multiple planetary destinations. In contrast, the Mars Society's Mars Desert Research Station (MDRS) near Hanksville, Utah, consists of a two-story habitat connected through tunnels to a greenhouse and an observatory [3]. This site is well known for its biological studies on extremophile organisms that live in the desert.

The NASA Extreme Environment Mission Operations underwater facility known as Aquarius (see Figures 2 and 3) is located at a depth of 20 m off the coast of Key Largo, Florida [2]. The habitat is 13.5-m long by 4-m diameter and uses an umbilical connected through a surface buoy to receive power and communications. Because it is permanently underwater, it emulates the reduced gravity conditions and hazards of an extreme environment from which one cannot emerge very rapidly without risking decompression sickness. Crews can spend up to three weeks in this environment, working on new procedures for extravehicular activities or telesurgery.

Another example of an analog in an extreme environment is the Hawaii Space Exploration Analog and Simulation, located 2,500 ft above sea level on the Mauna Lao volcano. The site had been used since 2013 to study human factors associated with future Mars missions. Unfortunately, the site has not run any missions since one of their analog astronauts suffered an electrical shock while performing some maintenance activities. Fortunately, since this was not a real Mars mission, the

Figure 1: The NASA Desert Research and Technology Studies habitat and rovers. (Source: NASA.)

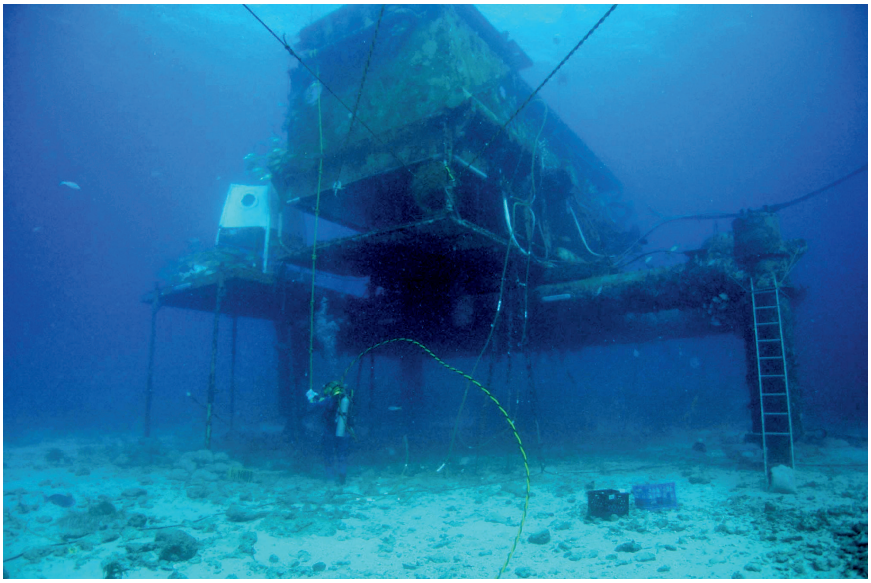

Figure 2: The Aquarius habitat. (Source: NASA.)

Figure 3: Canadian Astronaut David Saint-Jacques during the NASA Extreme Environment Mission Operations 15 in 2011. (Source: NASA.)

Photo: Mars Institute

Figure 4: The Haughton–Mars Project station located in Devon Island, Canada.

individual was admitted and treated at a nearby hospital.

Unlike its counterparts, the Human Exploration Research Analog (HERA) at the Johnson Space Center and the Institute for Bio-Medical Problems (IBMP) facility in Moscow are indoor habitats [2]. HERA is a three-story cylindrical facility with a diameter of 5.9 m that relies on artificial lighting to recreate daylight conditions for different planetary mission profiles. This facility has been used primarily to study communication latency, autonomous operations, and medical operations. Although HERA missions max out at 45 days, the IBMP is famous

The NASA Extreme Environment Mission Operations underwater facility known as Aquarius is located at a depth of 20 m off the coast of Key Largo, Florida.

for its very long simulations lasting up to 520 days (known as the Mars-500 analog). Intended for long analogs, the 500-m^3 facility has a large storage module for both refrigerated and nonperishable supplies, a medical module for routine tests, a habitat module with common and private quarters, and a Mars landing module simulator where crews perform extravehicular activities at the halfway point of the mission. The long simulations have enabled researchers to focus on the psychological effects of long-duration missions by studying communication patterns as well as results from periodic surveys on mood and performance.

Canada is home to the Haughton–Mars Project (HMP) (see Figure 4) located on Devon Island in the territory of Nunavut [2], [4]. Because of its remote location on an uninhabited island inside the Arctic circle, the site offers an isolated, confined, and extreme environment that resembles spaceflight. Unlike other analogs, the HMP does not have continuous communications with the MCC and instead relies on satellite communications with limited data rates. As a result, crews are granted higher levels of autonomy to schedule activities, including habitat maintenance, spacesuit tests, and geological experiments in the 20-km diameter Haughton crater.

The Inflatable Lunar–Mars Analog Habitat at the University of North Dakota has been running multiple two-to-four-week missions per year since 2015 to give students a chance to learn how to build, maintain, and conduct experiments. Comparable in volume to the International Space Station (ISS), the habitat consists of living, extravehicular activity, plant production, human performance, and geology modules. These allow research projects in a variety of topics from microbiology, communications, psychology, and testing new technologies for extravehicular activities. Student volunteers gain experience by serving as crew members, mission control operators, and researchers.

The aforementioned analogs do not expose crews to unique microgravity conditions or the hazards of spaceflight. Consequently, NASA introduced the use of the International Space Station as a high-fidelity analog for LDSFs [1], [5]. Known as the ISS Testbed for Analog Research, the initiative gives researchers access to limited astronaut time to perform human experiments, evaluate procedures, and test new tools. The challenge is finding a compromise with the institutional review boards to perform experiments that do not pose risks for the crew or negatively affect other ongoing research projects on the station.

Just like actors rehearse and athletes practice for countless hours, analog missions allow us to identify and mitigate risks in preparation for future LDSFs. If you are a student or young professional interested in participating, visit the websites for the MDRS or the various university analog missions to contribute to and experience what it would be like to work in space. ■

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A Few Words From the Editor-in-Chief / Quelques mots du rédacteur en chef

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

index select *ICR* articles in IEEE *Xplore*. We will be working on these areas in the coming months. In the future, we aim to publish thematic issues covering such broad areas as power systems, data governance, and many other topics.

We are all particularly excited about the 2020 Sections Congress in Ottawa, Ontario. A number of signature events are also on the horizon: the Canadian Conference on Electrical and Computer Engineering (CCECE) in London, Ontario; the IEEE Vision, Innovation, and Challenges (VIC) Summit in Vancouver, British Columbia; the Photonics North Conference in Niagara Falls, Ontario; and the Electric Power and Energy Conference (EPEC) in Edmonton, Alberta, to name a few.

COVID-19 update: Please visit the conference websites for the latest updates.

Please continue to share your stories, photos, comments and, of course, concerns. I can be reached at mjakhan@ieee.org or icr@ieee.ca. ■

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

Notre site Web a besoin de mises à niveau substantielles et notre flux de publicités a besoin d'être amélioré. Nous avons une immense opportunité d'indexer certains articles de l'*RCI* dans L'IEEE *Xplore*. Nous travaillerons sur ces domaines dans les prochains mois. À l'avenir, nous visons à publier des numéros thématiques couvrant des domaines aussi vastes que les systèmes d'alimentation, la gouvernance des données et de nombreux autres sujets.

Nous sommes tous particulièrement ravis du Congrès des sections 2020 à Ottawa, en Ontario. Un certain nombre d'événements phares se profilent également à l'horizon: la Conférence Canadienne de Génie Électrique et Informatique (CCCEE) à London, en Ontario; le Sommet sur la vision, l'innovation et les défis (VIC) de l'IEEE à Vancouver, en Colombie-Britannique; la conférence Photonics North à Niagara Falls, Ontario; et la Conférence sur l'énergie électrique et l'énergie (EPEC) à Edmonton, en Alberta, pour n'en nommer que quelques-uns.

Mise à jour COVID-19: veuillez visiter les sites Web de la conférence pour les dernières mises à jour.

Veuillez continuer à partager vos histoires, photos, commentaires et, bien sûr, vos préoccupations. On peut me joindre à mjakhan@ieee.org ou icr@ieee.ca. ■

A Nobel Prize Inspired by Radar Technology

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The Royal Swedish Academy of Sciences awarded the 2018 Nobel Prize in physics to Arthur Ashkin, Gèrard Mourou and **Donna Strickland** in recognition of their ground-breaking contributions to laser physics. As a student-advisor duo, Donna Strickland and Gerard Mourou explored if they could implement an already existing concept in Phased Array Radar [1], i.e. the chirped pulse amplification (CPA), in generating a very short laser pulse ($\Delta t < 1$ *psec).* Amplifying a high energy short pulse of electromagnetic wave, necessary for radar operation, would lead to amplifier saturation. Instead, if the pulse passes through a positive-dispersion delay line, the higher frequency component propagates with a higher group velocity. This spreads the pulse in the time domain, i.e. the pulse has a high frequency front and a slowly oscillating tail. Each frequency in the so-called ***chirped*** pulse can now be amplified independently as the energy has already been spread. After getting reflected from the target, the received pulse is then passed through a negative-dispersion medium wherein the group velocity difference due to initial positive dispersion is compensated and a sharp high-power pulse is recovered[1] [2].

Implementation of this idea in the optical regime was the subject of a three-page paper [3] by Mourou and Strickland (her first paper) in 1985. As it is shown in Figure 1, the initial optical pulse is stretched after passing through a grating. The stretched pulse is then amplified and compressed using a pulse compressor. The distributed energy over longer time is then focused within a very short time span. Hence, a very high power pulse is achieved. Later, they published their work in *IEEE Journal of Quantum Electronics* [4], and reported the application of CPA to achieve petawatt power pulses of 1 psec duration. Most probably, she was not imagining at that time that this work would bring her a Nobel Prize. However, the impact of the work was great at the time of publication, and remains of a huge importance today. A recent interview with one of her graduate students [5] reflects that she is still actively working on CPA method, and coaxing it into applications that will have industrial impact [6].

Donna Strickland, a professor of physics at the University of Waterloo, Canada is the third woman who won the Nobel Prize in physics. Her predecessors are: Marie Curie (1903) and Maria Goeppert-Mayer (1963). Professor Strickland is the first Canadian woman who won this prize in Physics. We, the Canadian members of IEEE, warmly congratulate her and wish her success. In an interview with Swedish National

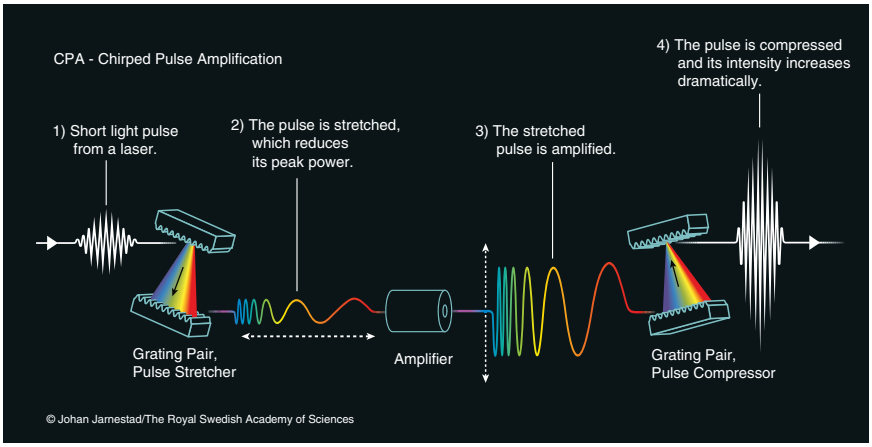

Figure 1: Optical Chirped Pulse Amplification Method. (Permission granted by the Royal Swedish Academy of Sciences).

[1]Readers may find it interesting to know that Canada was the very first country that actively developed antiaircraft Radar for WWII efforts leading to the large production of portable units. Refer to the excellent recount of Radar R&D and production efforts by NSERC, written by Brian Mendes [2].

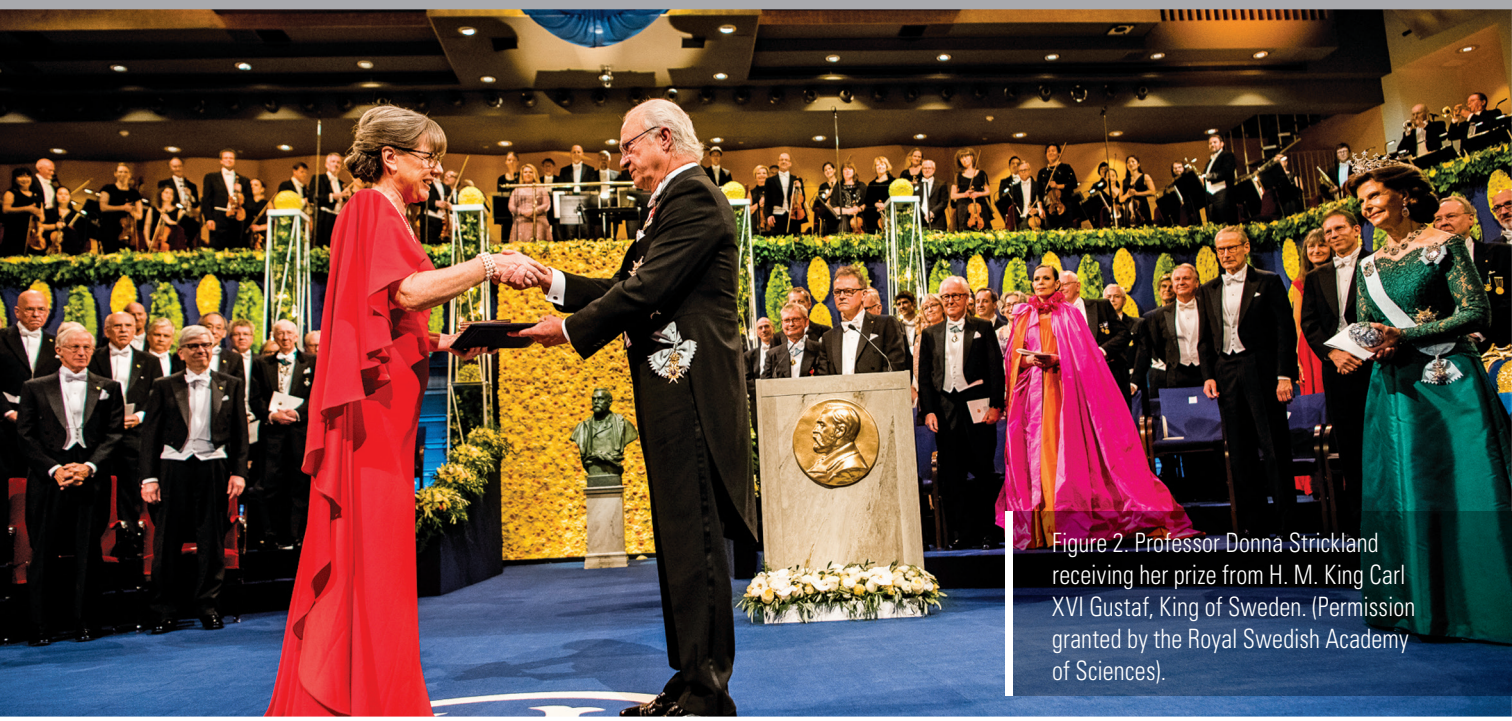

Figure 2. Professor Donna Strickland receiving her prize from H. M. King Carl XVI Gustaf, King of Sweden. (Permission granted by the Royal Swedish Academy of Sciences).

TV (SVT2), she mentioned the spirit of "hard working," being able to see the "big picture" and having a mindset of "revolutionary thinking." Still she recalls her supervisor's advice: "*Be revolutionary, not evolutionary!*" This will certainly inspire the next generation of Canadian researchers.

Such landmark achievements make us think if we are providing today's students with the skills of discerning manifestations of a concept in different fields. Are we teaching and supervising them to be revolutionary? We are seeing research projects are getting increasingly specialized and time constrained. Emphasis on the quantity of publications (as a part of project deliverables) has also increased. Inflexible scope of research funds, impatient venture capitalists and business-oriented mindset in funding fundamental research may leave us with less time and freedom for high quality thinking, teaching and supervision.

The history of the Nobel Prize shows that the laureates are mostly those who see the inter-relationship between seemingly different fields of science and engineering. Getting inspired by Radar technology [1], [2], or using the techniques of finding Eigenmodes of a microwave waveguide with discontinuity to solve a problem in quantum field theory—are only a few examples[2] [7]. Nobel laureate Arthur Ashkin was experimenting with his laser tweezers idea at Bell Laboratories as he was given the freedom and flexibility to do so [8]. Interestingly, the project was not even a part of the lab's mission statement or any proposal. See P. A. M. Dirac's comment on his engineering education as another interesting example [9].

These anecdotes should keep us enthused and inspire us to move forward without compromising the quality of research—regardless of the unpredictable dynamics in the industry, economy or politics. There are, however, glimpses of hope. Several programs and events promoted by various Canadian entities may well produce interdisciplinary ***science-aware engineers*** and ***scientists with engineering mindset.*** To name a few, the Center for Teaching Excellence (CTE) at the University of Waterloo[3], Education and Training in Optics and Photonics[4] (ETOP 2019) at the University of Laval (sponsored by the IEEE photonics Society), and IEEE Canada's Teacher In-Service Program (TISP), Try Engineering program and Women in Engineering (WIE)—are all harbingers of better days for education. In short, we must aspire to have researchers and educators with "revolutionary" mindset like Donna Strickland, who can contribute immensely to Canada and to the rest of the world. ■

[2]Julian S. Schwinger was an American physicist and a legendary teacher who contributed to microwave engineering (waveguides and transmission line theory) and quantum electrodynamics (QED). He won the Nobel Prize in physics in 1965.

[3]CTE at the University of Waterloo: https://uwaterloo.ca/centre-for-teaching-excellence/

[4]ETOP 2019: http://etop2019.copl.ulaval.ca/about-etop2019.html

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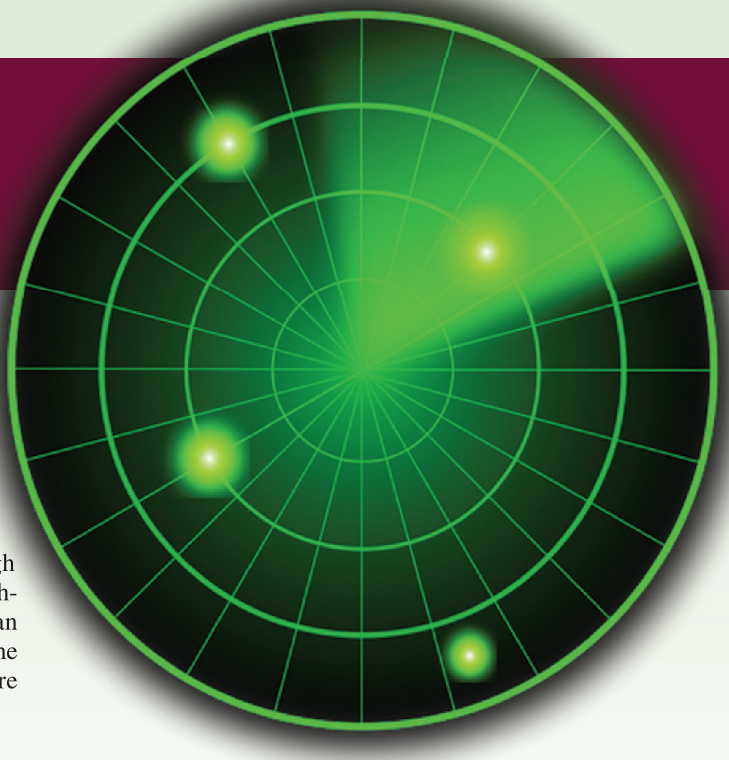
High-Frequency-Radar Ocean

Remote Sensing on the Atlantic's Edge

by Reza Shahidi, Weimin Huang, and Eric W. Gill



When many people think of radar, a World War II technology, the first thing that may come to mind is films, such as *The Hunt for Red October*, and monitoring airspace for incoming threats. In fact, there are many applications that are much more mundane. Among them are the monitoring of large swaths of the ocean and extracting of ocean parameters, such as significant wave height, period, and direction, from the area being covered. Although the theoretical underpinnings are highly technical and mathematical, we provide a high-level overview of how radar can be used to monitor the ocean surface and discuss some of the practical issues that come into play when such systems are used (Figure 1).

Figure 1: Our perception of radar technology.

How It Works

In this article, we concentrate on the use of high-frequency (HF) radar for the purposes of extracting ocean-surface parameters. HF radar is defined as a radar that has a transmission frequency between 3 and 30 MHz. These frequencies correspond to wavelengths in the decametre range (10–100 m), and, hence, such radars are said to transmit in the decametre band.

Generally, HF radar systems that are used for ocean remote sensing are coherent, meaning that the received signal contains both magnitude and phase information. This implies that the radar can detect shifts in frequency, based on the Doppler principle, the same principle that causes a siren to seem to change pitch as an ambulance or other emergency vehicle approaches or moves farther away from a stationary observer.

The principal principle (say that 10 times fast) behind the use of HF radar for ocean-parameter extraction is the phenomenon of Bragg scattering [1]. Although this type of scattering is primarily considered in the context of crystallography, where it is used to determine the structure of crystal lattices, it can also be used, in essence, to determine the "structure" of the ocean at a given time. In the case of the ocean, a simplifying assumption is that, at any time, its

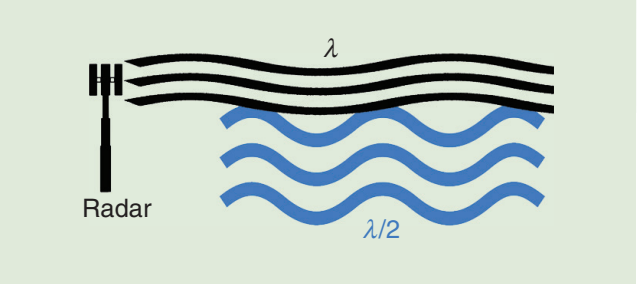


Figure 2: An example of Bragg scattering of HF radar electromagnetic waves from the ocean surface.

surface is periodic in time and space (Figure 2). Thus, it will behave like a crystal lattice when electromagnetic energy from a radar impinges on it. There will be destructive and constructive interference, based on the spatial period of the ocean waves; it can be shown, as in Figure 2, that the highest amount of scatter will occur when the spatial wavelength

of the ocean waves is half the wavelength of the electromagnetic energy transmitted by the radar for grazing incidence.

Based on oceanographic principles, if ocean waves are assumed to be due to gravity, the spatial wave period determines their velocity. This means that, for a given transmission frequency, the Doppler spectrum will, in general, exhibit two large peaks at known Doppler shifts.

These peaks are known as Bragg peaks, as they are caused by Bragg scattering. Assuming a backscatter geometry, one peak corresponds to ocean waves travelling directly toward the receiver, while the other corresponds to waves travelling directly away. An example of a Doppler spectrum calculated from HF radar field data, recorded at one of our radar sites at Argentia, Newfoundland, and Labrador, is shown in Figure 3. Note that there is also a peak having a Doppler shift close to zero due to direct-path electromagnetic energy transmitted from the transmitter to the receiver array without reflection from the ocean surface. One very practical useful fact is that the principal wave direction can be roughly determined from the ratio of the intensities of these two Bragg peaks. These first-order Bragg peaks correspond to a single scatter, where the spatial period of the ocean wave causes resonance between the ocean surface and the electromagnetic waves transmitted by the radar. If one looks more closely at the Doppler spectrum in Figure 3, especially on the right side of the spectrum, one can see smaller-magnitude peaks to each side of the main first-order Bragg peaks. These smaller peaks correspond to higher-order Bragg peaks (second order and greater), often resulting from multiple scatters of the radar's electromagnetic energy from the ocean surface.

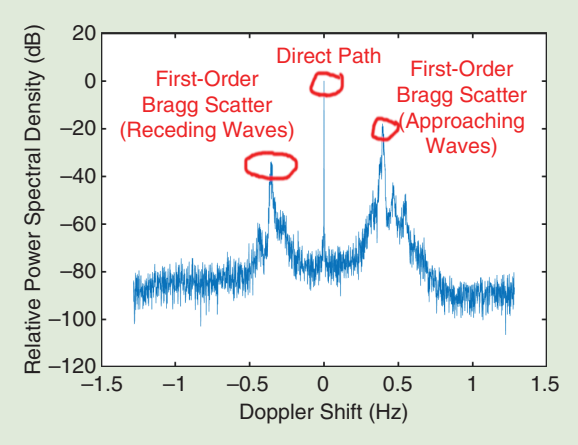


Figure 3: An example of a Doppler spectrum calculated from HF radar field data acquired at Argentia, Newfoundland, and Labrador.

Recent work by the radar group at Memorial University of Newfoundland has led to simplified methods for the extraction of significant wave height from HF radar data. Instead of forming the Doppler spectrum from the HF radar data and then extracting the significant wave height from this spectrum, our recent research allows us to deal directly with the received electrical signals without significant amounts of processing [2]. Such research is ongoing. Other research has extended the previously developed theory so that it is not restricted in its applications to small wave heights and small wave slopes [3].

Applications

One obvious question is why would we want to know ocean-surface parameters at all? Applications include measurement of ocean circulation, waves and currents, vessel tracking, search and rescue, and marine navigation. The use of HF radar systems is more economical than the traditional method of measuring ocean parameters, namely, the deployment of a large array of wave buoys [4]. Additionally, HF radar systems can aid in the detection of contaminant spills, such as oil spills, and marine ecosystem and fishery applications [5]. There are also potential applications that are yet to be found.

A System in Action

The radar group at Memorial University of Newfoundland has one fully deployed radar site at Argentia and another one close by at St. Bride's. The system at Argentia consists of a two-element monopole transmitter array and a 12-element receiver array (Figure 4). The

(a) (b)

Figure 4: (a) A two-element transmitter array and (b) a 12-element receiver array at Argentia, Newfoundland, and Labrador.

transmission frequency is 13.385 MHz, and the bandwidth of the chirp signal that is transmitted can be varied, yielding different spatial resolutions.

Ultimately, the goal is to have a fully bistatic configuration so that we would be able to transmit at one radar site and receive at the other. Such a bistatic configuration offers more information than a radar situated at a single site and also does not lead to contamination of the Doppler spectrum with direct-path energy from the transmitter to the receiver, as seen in the Doppler spectrum of Figure 2.

In the meantime, it is important that we all keep safe and healthy. Please use common sense and keep your distance, not only when observing the ocean but in your daily interactions, as we all battle the COVID-19 pandemic. ■

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The Internet Protocol of the Future

by Matthew Wilder

IMAGE LICENSED BY INGRAM IMAGE.

Internet Protocol (IP) version 6 (IPv6) has a bright future in Canada and across the world. A quarter of Canadians now have IPv6 as part of their access to the Internet (according to Google IPv6 stats). As an increasing share of the population, in Canada and across the world, gains access to IPv6, the benefits of IPv6 rise more and more. This is because, as with any network protocol, there is a "network effect" at work, meaning that the value of IPv6 is rising exponentially as more IPv6 users come online.

Look no further than the COVID-19 crisis and our appropriate measure of social distancing to appreciate how our networked world is rapidly scaling up. Working from home, streaming online media, and connecting with loved ones over video chat have become routine for virtually all of us. This event underscores the general trend of how networks have played an increasingly central role in our productivity, entertainment, and connection as a society.

Our networked world is scaling rapidly, and this trend promises to continue for decades to come. Whether it is 5G wireless networks, the Internet of Things (IoT), vehicular mobile communications, network function virtualization, software-defined networks, or any technology that we wish to scale, the limits of IPv4 have been proven, and IPv6 alone offers the volume of

addresses to underpin scalable architectures. Although IPv4 has been globally exhausted, offering roughly 4 billion (2^{32}) IP addresses, IPv6 effectively offers countless IP addresses, or 2^{128} for those interested in calculating the number. Each Internet service provider (ISP), business, and home network with IPv6 has more IP addresses available to it than the entire IPv4 Internet.

A Tale of Two Protocol Versions

It was the best of protocols, it was the worst of protocols, it was the protocol of wisdom, it was the protocol of foolishness, it was the protocol of abundance, it was the protocol of scarcity. To borrow from the immortal phrasing used by Dickens, the juxtaposition of IPv6 with IPv4 is the best way to understand these two versions of what is, arguably, the most influential protocol ever designed.

But first, a little history.

The IP sits at the center of the protocol stack responsible for routing each and every packet across the Internet, whether that packet travels over wires or through the air and whether that packet carries several encoded pixels of your Netflix stream or your secure online banking interactions.

When Vint Cerf, noted father of the Internet, wrote the standard of IPv4 in 1983, he probably could not have imagined the Internet operating over wireless connections, video streams, or online banking. The Internet was created primarily to connect university networks across the United States. There were no plans for global connectivity, no plans for complete commercial integration. And certainly no plans for every man, woman, and child to have access to the Internet in their pocket at any time, used as their primary means of communicating, staying informed, and even moving about.

Given the intended scope of the Internet at the time, the choice to define the IPv4 packet header with a 32-bit "source address" and 32-bit "destination address" seemed fine for the applications imagined. On this side of the choice, we can see how that limited the total scale of the Internet to, at most, 4 billion endpoints, which is not enough to go around in a world with a population nearly double that figure. We clearly need more IP addresses. In 2020, we can see demand for orders of magnitude greater than our population now that the significance of the IoT has begun to take form.

The problem with exhausting IP addresses became clear to the engineers responsible for the IP when, in the 1990s, the protocol became successful, and many organizations began adopting it. These protocol architects in the Internet Engineering Task Force responded with IPv6, giving it 128-bit addresses to allow the Internet to scale well beyond imaginable limits.

The Transition to IPv6

IPv6 enjoys strong support from ISPs across the globe. All major ISPs in Canada have either made IPv6 available to their clients or are in the process of doing so. Ibrahim Gedeon, chief technology officer (CTO) of TELUS, says of the protocol, "IPv6 offers a new paradigm for address scalability. For some, it is the evolution of IPv4; for TELUS and, I hope, many others, it is the redefinition of the connected world at the physical layer—one that is private and secure, but very reachable."

Despite the growth in IPv6 adoption amongst users (which many in the industry refer to as *eyeball networks*), there is a lag in IPv6 adoption amongst much of the Internet's content. The Canadian Internet Registration Authority (CIRA), the organization responsible for administering the ".ca" domains, urges organizations to move on from IPv4. CIRA CTO Jacques Latour has stated, "The writing is on the wall for IPv4. It's served us well, but it's time to shut it down and bring in IPv6."

The need for IPv4 will not evaporate immediately, however. The lack of interoperability between IPv4 and IPv6 means that end users will continue to need IPv4 access while the world's content becomes accessible with IPv6. Given the long tail of content that exists—including the fact that, in some sense, other end-user networks are also, at times, the "content"—there is no end in sight to the need for IPv4 access. The result is that, rather than an instantaneous switch from IPv4 to IPv6, end users can expect the addition of IPv6 to their service. The operation of IPv6 and IPv4 is known as *dual stack*.

To Boldly Go

Many readers will be familiar with the words of *Star Trek* captains describing the commission of the *USS Enterprise*: "To boldly go where no one has gone before." It is ironic, then, that the segment of the Inteernet that lags the most in IPv6 adoption is that of enterprises—from small and medium business right up to the largest businesses.

Enterprises have a great deal of inertia to overcome that, perhaps, consumer networks and devices do not. An Internet subscriber who has Internet access at home or on his or her mobile device typically thinks little or nothing about the IP addresses that make the Internet work. Consumer networks are dynamically assigned IP addresses; enterprises, on the other hand, have a great deal of static network configuration, in part because of network security and in part because of the unique requirements of many enterprise applications. Each static connection needs the attention of staff to add IPv6. Attention means time, and time is money.

The result is that, generally, only enterprises that need scale are investing in IPv6 deployment so far. Those that have not are facing the costly option of purchasing IP addresses from a grey market.

Engineers at Bell Canada have observed that "although, at first, IPv6 seems like an arduous task for large and established enterprises whose networks have solely been based on IPv4 since day one, in the long run, it will, in fact, simplify the network. Along with simplification inherently comes savings! It is the inevitable, it is the future of IP—that's what we have implemented and continue to do."

IPv6 and the Future of Internet Technologies

Although much deployment lies ahead of us, the promising trends of the last few years give us much to look forward to. At a time when our expectations of technology are sky high, we must fully embrace the protocol of which we can truly say—the sky's the limit. ■

About the Author

Matthew Wilder is an engineer whose passion is to see Internet technology improve lives. He works at TELUS as a network engineer, having held responsibilities including network standards, planning, architecture, security, and systems architecture. He received his M.B.A. degree from the University of Victoria and his B.ASc. degree in electrical engineering from the University of British Columbia. He currently serves as the treasurer of the IEEE Vancouver Section.

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IMAGE LICENSED BY INGRAM IMAGE.

Security, Privacy, and Trust for the Internet of Things: Research Needs in 2020 and Beyond

by Gautam Srivastava

With billions of connected constrained Internet of Things (IoT) end devices sharing massive amounts of sensitive personal data, security is a legitimate concern, especially where related technologies are inadequate. For the first time, IoT technology is creating a societal paradigm shift in which the Internet is reaching out into real-world physical objects that are interconnected and smart, but there are high levels of doubt among individual users. In a recent international poll that included Canada, 53% of people expressed a lack of trust for connected devices and were deemed lacking in protecting privacy and responsibly handling sensitive information [1]. This tells us that human understanding of and experience using interacted smart things and systems have not developed at the same pace as has the technology itself, thus creating challenges with enormous technical and security implications. IoT end devices are mostly small and have limited power, processing, and memory capabilities. These devices are not quite ready, with secure protocols that require a high computational load to execute. Further, devices run a myriad of protocols due to the lack of standardization within IoT. Combined, these problems create a situation where functionality is traded for security, privacy, and trust (SPT) (see Figure 1). Through proper research and development, teams in Canada have a unique opportunity to discover novel solutions to these unsolved problems and develop innovative technologies that will advance Canada's position in this field.

In my opinion, three broad research areas could be the focus of Canadian researchers in the coming years. Those are 1) blockchain for the trust of IoT end devices, 2) light cryptography for the privacy of IoT end devices, and 3) machine learning (ML) for the security of IoT end devices. In essence, we can ask ourselves the following questions.

- *Question 1: How can blockchain provide end-device trust while maintaining a light footprint for IoT devices?* In IoT, security requires a strong device identity with a light footprint. We create trust when institutional alignment can be verified. We have seen blockchain technology advance past the financial world. Now, we need to see how it may steer SPT in an ideal direction.
- *Question 2: How can we provide privacy of the data generated/transmitted/stored by IoT end devices using light cryptographic tools?* IoT end devices can produce and share massive amounts of sensitive personal data. These data items have to be transmitted, processed, and potentially stored. This brings data privacy questions to the forefront.
- *Question 3: Can ML techniques provide a new avenue for security in IoT end devices?* The participating end devices in IoT networks are usually resource constrained, which makes them alluring targets for cyberattacks. In this regard, extensive efforts have been made to address security issues in IoT networks primarily through traditional cryptographic approaches. The first two questions also have significant relevance to this issue. The unique characteristics of IoT devices render the existing solutions insufficient to encompass the entire security spectrum of IoT networks. This is, at least in part, because of the resource constraints, the massive real-time data generated by IoT devices, and the extensively dynamic behaviour of the networks. ML techniques have recently been leveraged to cope with different security problems. These techniques are able to provide embedded intelligence in IoT devices and networks.

The research on IoT device trust and blockchain is limited and fairly recent, proliferating at most over the past three years. Most work focuses on leveraging blockchain technology to benefit IoT in

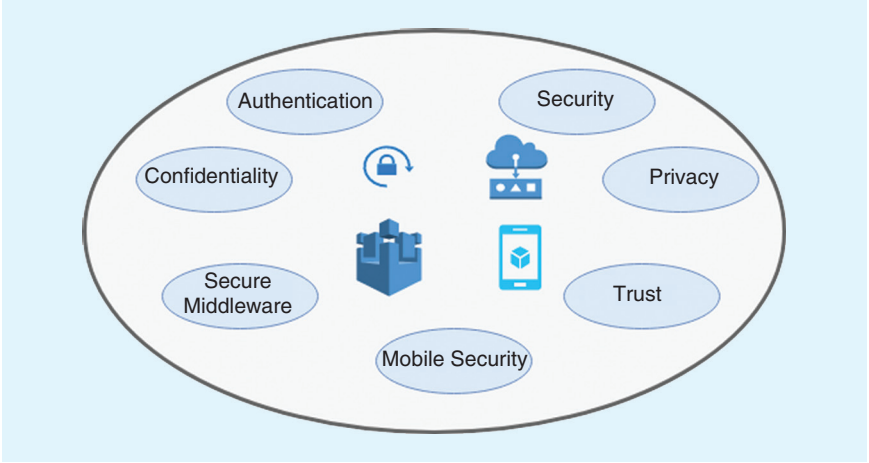

Figure 1: The IoT SPT challenges.

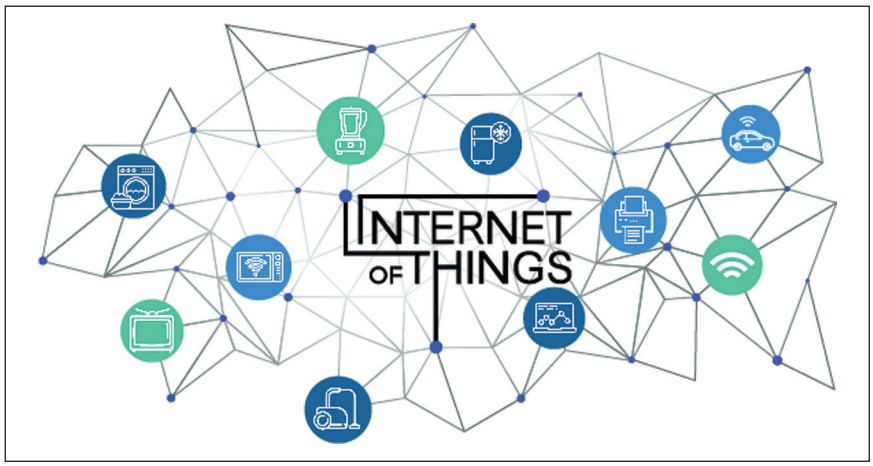

Figure 2: The future of smart technology. (Source: https://pixabay.com.)

general, not specifically on trust for IoT end devices. There are small pockets of work on using blockchain technology in a variety of use cases, from smart homes to hospitals (see Figure 2). However, it is still unknown how these systems could behave in the real world as the problem is still in its infancy. What is known is that blockchain technology can provide the means for authenticating anything. We have already, as a society, seen its power in Bitcoin, Ethereum, and other cryptocurrencies. The real question becomes: Can this translate well into IoT? There are several limitations with blockchain that deserve attention. Blockchains can grow to be long chains taking up high storage levels. These are not energy efficient nor computationally efficient. Yes, these are all negative qualities of blockchain when posed in an IoT framework. That being said, these cons can easily be transformed into pros with the right research teams asking the right questions.

There is a small body of research focused on IoT security using light cryptographic methods, but it does not address key security features such as data confidentiality, authenticity, and user authentication. These are all crucial for IoT end-device SPT. We have seen light crypto proposed in many scenarios, but there needs to be more research focused on industrial applications.

Due to their constrained nature, IoT end devices are ideal candidates to breach the security of not only the devices themselves but also of the networks to which the devices are connected. ML techniques including supervised learning, unsupervised learning, and reinforcement learning have been widely applied to improve IoT security as a whole. The general approach here is to train the algorithms on a testable data set to help assess what network traffic is malicious and what network traffic is normal. Then, have these algorithms, in real time, assess incoming traffic and flag the packets deemed malicious. Seems easy enough, right? Well, there's a catch. These devices are constrained, so all this processing needs to be done in an efficient manner. Moreover, it all needs to occur in real time. We cannot wait days to confirm breaches; we need to know now. This makes this direction of research highly impactful.

The potential for technological impact of the research directions discussed previously can be high. The research questions as posed will have a positive impact on Canadians by addressing unsolved IoT end-device security (ML), privacy (light cryptography), and trust (blockchain) problems that have plagued IoT devices. Transferring any newly developed technology to the industry would provide a meaningful opportunity to develop strategic partnerships between Canadian universities and their industry partners. The outcome of the first question will offer better solutions to IoT device trust, while still maintaining a light energy and computational footprint and preserving functionality. Question 2 will address the public's skepticism and privacy concerns by creating a private exchange of personal data that is created and/or shared by IoT end devices. ML techniques are coming to the forefront in many interdisciplinary fields and can be leveraged for IoT device security. With a holistic approach, IoT devices will be able to detect intrusion attempts in real time using state-of-the-art learning algorithms that utilize information on normal/benign versus malicious/abnormal network traffic and potentially other data-labeling techniques as available in other applicable scenarios. ■

Reference

[1] N. Lindsey, "Consumers still concerned about IoT security and privacy issues," *CPO Mag.*, May 13, 2019. [Online]. Available: https://www.cpomagazine.com/data-privacy/consumers-still-concerned-about-iot-security-and-privacy-issues/

About the Author

Dr. Gautam Srivastava (srivastavag@brandonu.ca) is an associate professor of computer science at Brandon University, Manitoba. His research interests include security, privacy, cryptography, data mining, artificial intelligence, blockchain technology, social networks, and graphs. He is a Senior Member of the IEEE.

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Submission of full papers	**May 30th, 2020**
Submission of workshop and panel session proposals	**April 30th, 2020**
Submission of tutorial proposals	**May 30th, 2020**
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IEEE Canadian Foundation

IEEE Canadian Foundation Launches 25/25 Campaign

To celebrate IEEE Canada's 25th anniversary, the IEEE Canadian Foundation (ICF) has initiated a special 25/25 donation campaign across Canada. IEEE Canada members, industry partners, and government organizations are requested to contribute $25 or more as a token of celebration.

Donations will be used to increase the amount and number of scholarships, support special projects, and fund McNaughton Learning Resource Centers at universities and colleges. The objective is to motivate students to perform extracurricular activities, enhance their quality of education, and enable advanced projects individually or as a team, paving their career path.

Every Gift Counts—Many Hands Make Light Work

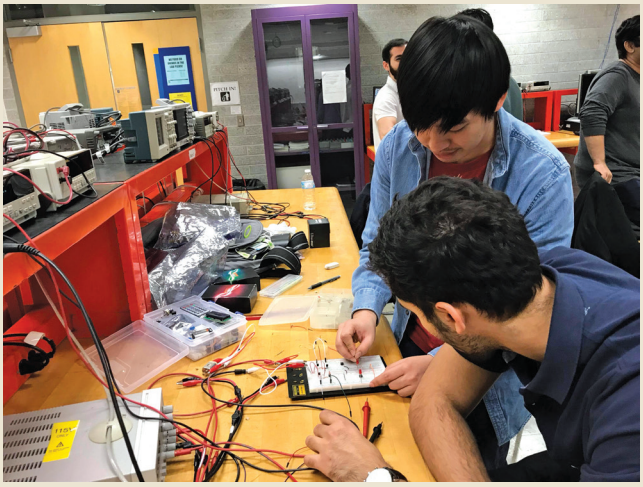
For first-time donors, every new $25 donation will be graciously accepted. For returning donors, please consider a $25 increment to your current level of donation. The ICF will forward a receipt to all donors for a donation of $25 or more. To donate, please visit: www.canadahelps.org/en/charities/ieee-canadian-foundation/.

The ICF, a registered charity in Canada, is the philanthropic partner of IEEE Canada. The ICF is incorporated as a nonprofit in the Province of Ontario and is supported solely by donations and not through IEEE membership dues or other revenues. Its all-Canadian volunteer Board manages and disburses the funds in support of IEEE interests in Canada. To learn more, visit www.ieeecanadianfoundation.org.

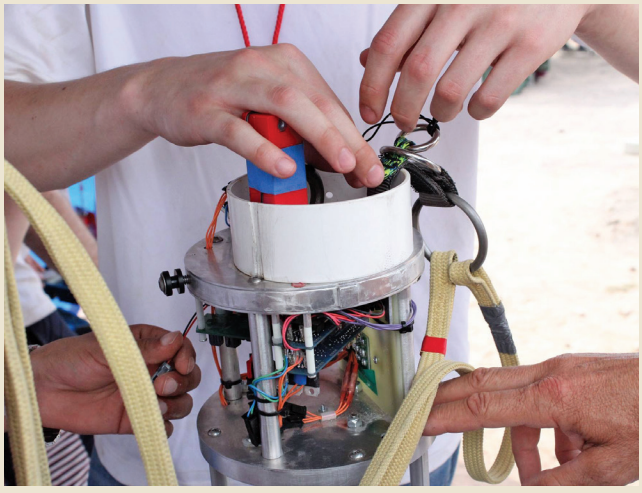
COVID-19 update: The ICF remains committed to supporting our programs, donors, and grantees. Thank you for your ongoing support during these unusual and challenging times.

Anader Benyamin-Seeyar
Vice President,
Development, ICF

Dario Schor (left), IEEE Canada Winnipeg Section, with ICF Scholarship recipient Kevin Lamothe, University of Manitoba, Winnipeg.



Students at the McNaughton Learning Resource Centre, Ryerson University, Toronto.



The University of British Columbia, Vancouver, Rocket Club avionics team at work.

IEEE Canadian Foundation
Fondation Canadienne de l'IEEE

To the Families and Friends of Flight PS752 Victims

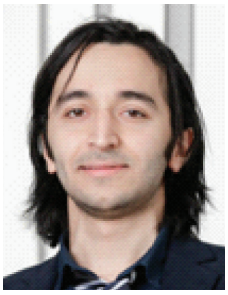
IEEE Canada extends sincere condolences to all of those affected by the tragic crash of the Ukraine International Airlines Flight PS752 on 8 January 2020 in Tehran.

Most of the 176 passengers on board were bound for Canada, among them 85 students, researchers, medical and engineering practitioners, and academic faculty living and working in Canada. A list of their names and affiliations has been compiled by the Canadian Science Policy Centre to remember these incredible people whose lives ended far too soon (https://researchmoneyinc.com/articles/remembering-the-passengers-on-flight-752/).

The horrific crash has caused a tremendous loss across Canada, at many academic institutions, and within the IEEE community. Five of the victims were IEEE members from Canada. They were outstanding volunteers, members, and friends, and will be terribly missed.

Iman Aghabali

Iman Aghabali, IEEE Graduate Student Member, was a Ph.D. student at McMaster University in Hamilton, Ontario. He received his B.Sc. degree in electrical engineering from Sharif University of Technology, Tehran, in 2015 and his M.Sc. degree in 2017 from the University of Tehran. In 2017, he joined McMaster University's McMaster Automotive Resource Center (MARC) as a Ph.D. student. His research interests were centered on the design and control of power electronic converters in hybrid electric vehicles.



Iman Aghabali.
(Source: globalnews.ca.)

Mojgan Daneshmand and Pedram Mousavi

Mojgan Daneshmand and Pedram Mousavi, professors at the University of Alberta, and their two daughters were among the victims. Mojgan Daneshmand and Pedram Mousavi contributed in many ways to the IEEE.

Mojgan Daneshmand.
(Source: ualberta.ca.)

Mojgan Daneshmand, IEEE Senior Member, was an associate editor for *IEEE Transactions on Antennas and Propagation Letters* and for *IEEE Canadian Journal of Electrical and Computer Engineering*. She was also a cochair of the IEEE Joint Antennas and Propagation Society/Microwave Theory and Techniques Society Northern Canada Chapter. In 2016, she received the IEEE Antennas and Propagation Society Lot Shafai Mid-Career Distinguished Achievement Award "for pioneering contributions to microwave-to-millimeter, wave microsystem-based antenna and microwave technologies for communication and sensing, and being a role model for women in engineering."

Pedram Mousavi, IEEE Senior Member, was also an associate editor for *IEEE Antennas and Wireless Propagation Letters*. He was leading a cutting-edge research program in the area of

Aux familles et amis des victimes du vol PS752

L'IEEE Canada présente ses sincères condoléances à tous ceux qui sont touchés par le tragique accident du vol PS752 d'Ukraine International Airlines le 8 janvier à Téhéran.

La plupart des 176 passagers à bord étaient à destination du Canada, dont 85 étudiants, chercheurs, praticiens en médecine et en génie et professeurs universitaires vivant et travaillant au Canada. Une liste de leurs noms et affiliations a été compilée par le Centre canadien de politique scientifique pour se souvenir de ces personnes incroyables dont la vie s'est terminée bien trop tôt.

L'accident horrible a causé une perte énorme à travers le Canada, dans de nombreux établissements universitaires et au sein de la communauté de l'IEEE. Cinq des victimes étaient des membres de l'IEEE du Canada. Ils étaient des bénévoles, des membres et des amis exceptionnels, et ils nous manquent terriblement:

Iman Aghabali

Iman Aghabali, de l'IEEE GSM, était étudiant au doctorat à l'Université McMaster à Hamilton. Il a obtenu son B.Sc. en génie électrique de l'Université de technologie de Sharif, Téhéran en 2015, et son M.Sc. diplôme en 2017 de l'Université de Téhéran. En 2017, il s'est joint au McMaster Automotive Resource Centre (MARC) de l'Université McMaster en tant qu' étudiant au doctorat. Ses intérêts de recherche étaient centrés sur la conception et le contrôle de convertisseurs électroniques de puissance dans des véhicules électriques hybrides.

Mojgan Daneshmand et Pedram Mousavi

Mojgan Daneshmand et Pedram Mousavi, professeurs à l'Université de l'Alberta, et leurs deux filles faisaient partie des victimes. Mojgan Daneshmand et Pedram Mousavi ont contribué à bien des égards à l'IEEE.

Pedram Mousavi.
(Source: ualberta.ca.)

Mojgan Daneshmand de l'IEEE SM, était rédacteur en chef adjoint des transactions sur les antennes et les annales de propagation et du Journal Canadien de Génie Électrique et Informatique de l'IEEE. Elle a également été coprésidente de la section conjointe AEE/MTTS du Nord du Canada de l'IEEE. En 2016, elle a reçu l'IEEE Antennas et la société de propagation lot Shafai mi-carrière prix d'excellence et de distinction "pour ses contributions prisonnières à micro-ondes à millimètre, les technologies d'antenne et de micro-ondes à base de microsystèmes d'ondes pour la communication et détection, et d'être un modèle pour les femmes dans l'ingénierie."

Pedram Mousavi de l'IEEE SM, était également rédacteur en chef adjoint des antennes de l'IEEE et des lettres de propagation sans fil. Il dirigeait un programme de recherche de pointe dans le domaine des systèmes sans fil et des réseaux de

wireless systems and sensor networks. Pedram and Mojgan both were also key members of the steering committee for the upcoming IEEE International Symposium on Antennas and Propagation and North American Radio Science Meeting in Montréal this coming July.

capteurs. Pedram et Mojgan avaient tous deux également été des membres clés du comité directeur du prochain Symposium international de l'IEEE sur les antennes et la propagation et de la Rencontre radiophonique nord-américaine à Montréal en juillet prochain.

Mansour Esnaashary Esfahani

Mansour Esnaashary Esfahani, IEEE Graduate Student Member, was a Ph.D. candidate in the Civil and Environmental Engineering Department at the University of Waterloo, Ontario. His research interests were focused on developing methodologies to analyze the net environmental impacts and cost performance for adaptive building reuse versus the renewal of built infrastructure. While in Iran, he was married a few days before boarding Flight PS752 to return to Canada. The University of Waterloo has established a memorial fund to honor his memory.

Mansour Esnaashary Esfahani. (Source: therecord.com.)

Mansour Esnaashary Esfahani

Mansour Esnaashary Esfahani de l'IEEE GSM, était un candidat au doctorat au Département de génie civil et environnemental de l'Université de Waterloo. Son intérêt de recherche s'est concentré sur le développement de méthodologies pour analyser les impacts environnementaux nets et la performance des coûts pour la réutilisation adaptative des bâtiments par rapport au renouvellement des infrastructures construites. Pendant son séjour en Iran, il s'est marié quelques jours avant d'embarquer sur le vol PS752 pour revenir au Canada. L'Université de Waterloo a créé un fonds commémoratif pour honorer sa mémoire.

Zahra Naghibi

Zahra Naghibi, IEEE Graduate Student Member, was a Ph.D. candidate at the University of Windsor and worked as a research assistant at the university's Turbulence and Energy Lab. She was the cochair of the IEEE Windsor Section Young Professionals Affinity Group in 2019 and had been elected the chair of the Windsor Section Young Professionals Affinity Group for 2020. At the IEEE Windsor Section AGM 2019, Zahra received an Outstanding Service Award.

We mourn this enormous loss of talent, aspiration, and potential. ■

Zahra Naghibi. (Source: globalnews.ca.)

On behalf of IEEE Canada,
President Jason Gu
President-Elect Robert Anderson
Past-President Maike Luiken

Zahra Naghibi

Zahra Naghibi de l'IEEE GSM, était candidat au doctorat à l'Université de Windsor, et elle a travaillé comme assistante de recherche au Laboratoire de turbulences et d'énergie de l'université. Elle était coprésidente de la section Windsor de l'IEEE, Groupe d'affinité des jeunes professionnels, 2019, et avait été élue présidente du Groupe d'affinité des jeunes professionnels de la section Windsor pour 2020. Lors de l'AGA 2019 de la section Windsor de l'IEEE, Zahra a reçu un prix pour service exceptionnel.

Nous pleurons cette énorme perte de talent, d'aspirations et de potentiel. ■

Au nom de l'IEEE Canada,
Jason Gu, président
Robert Anderson, président élu
Maike Luiken, ancienne présidente

A picture from the IEEE Canada Spring Board Meeting held on February 28 to March 1, 2020 in Toronto.

Celia Desmond

Celia Desmond
President, World Class Telecommunications
Region 7 Parliamentarian
c.desmond@ieee.org

The question is sometimes posed to me "Why do you volunteer and do so much work for the IEEE?" Good question. In fact, how did this start and progress to many years of volunteer work?

Early in my career, when I was promoted to manage a group of engineers, my predecessor suggested that joining a technical committee in the IEEE Communications Society (ComSoc) would be a good idea, as I could get valuable information for my job. I did this and found that not only did I meet very impressive people, including the authors of my favorite textbooks at the time, but it was also fun and interesting to help organize sessions for conferences. My company was generous enough to allow me to attend the conferences, where I learned more about the technologies we used. Gradually, I moved up in the two committees that I joined to chair one of them, and I was then elected to the board of governors of ComSoc. This also gave me good management experience that was useful for my work. Eventually, I rose to be the president of ComSoc and Division director.

Simultaneously, I decided to become involved locally. I joined the Engineering Management Society (EMS), as it was called then (as of 1 January 2015, it became the IEEE Technology and Engineering Management Society), and became the EMS Ottawa Chapter chair, eventually working up to the Ottawa Section chair position. Here, again, I was gaining both knowledge and experience relevant to my job, and I was meeting people who have become my colleagues and friends. That lead to a parallel path to the administrative committee of the Management Society in the IEEE.

The local work allowed me to move up in the Region, gradually growing in responsibility, until I became the Region director/IEEE Canada president in 2000. With every position, I gained experience and connections. Of course, this was very satisfying, and it encouraged me to continue with this work. In the Engineering Management Society, I became the director of membership and held several vice-president (VP) positions. Of course, all of this provided the same satisfaction as the local work. It also expanded my contacts to being worldwide and provided opportunities to travel and see many new locations.

From there, with director-level and Society experience in the Technical Activities Board (TAB), I rose to TAB VP. This board has more than 60 members—all extremely intelligent and dedicated. The experience of chairing such a board is something that cannot be easily gained anywhere else. Based on my experience at the Region, Division, and VP levels, I was later elected IEEE secretary, providing me with further experience on the IEEE Board of Directors. It was a great learning experience not available to most engineers, and I found it to be a humbling one, as the people I have met are so highly impressive.

Recently, I have also had the opportunity to work with the Young Professionals in the IEEE. Again, I found a reservoir of highly energetic, likeable, and inspiring people. What a lucky opportunity to be able to work with them! I highly value all of my time and work for the IEEE and would recommend to anyone that they become actively involved. ■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In Memoriam

Friends We Have Lost

Leonard A. Bateman

Leonard A. Bateman, O.C., IEEE Life Senior Member, passed away on 7 December 2019. Mr. Bateman received his B.Sc. degree in electrical engineering in 1942 and his M.Sc. degree in 1948 from the University of Manitoba. He joined Winnipeg Hydro in 1952 and moved to Manitoba Hydro in 1956, rising to the position of chairman and chief executive officer in 1972.

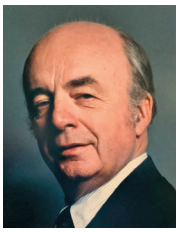
Mr. Bateman was recognized with the Order of Canada and the Order of Manitoba for his work with hydro development in Manitoba and high-voltage dc (HVDC) internationally. He was the first Canadian ever invited to chair a CIGRE committee, the committee on HVDC, and was actively engaged with the work of CIGRE from 1968 to the late 1980s. He set up his own company, Bateman and Associated Ltd., in 1979, and served clients in the United Kingdom, Brazil, South Africa, Sweden, Switzerland, and Canada who were seeking his expertise in HVDC. He was awarded the National Gold Medal in 1994 by the Canadian Council of Professional Engineers for his contributions to the profession. Among other accolades, he received the Queen's Golden Jubilee Medal in 2003. His service to the profession included a six-year term on the Council of the Manitoba Association, starting in 1952, and another four-year term starting in 1982 as well as rising to serve as president of many national engineering organizations.

He will be lovingly remembered by his daughters, Donna Blakeman Welch (Terry Panych) and Joyce Bateman (Darrell Hancock), and his five grandchildren, Cameron Bateman (Daisy), David Bateman (Miriam) and children (his great-grandchildren, Sebastian, Sophie, and Nicholas), Benjamin Bateman, Calvin Hancock (Brittany Tovee), and A.J. Hancock, his only granddaughter. ■

Leonard A. Bateman, O.C., membre senior de l'IEEE à Vie, est décédé le 7 décembre 2019. M. Bateman a obtenu son B.Sc. diplômé en génie électrique en 1942 et son M.Sc. diplômé en 1948 de l'Université du Manitoba. Il s'est joint à Winnipeg Hydro en 1952 et a déménagé à Manitoba Hydro en 1956, accédant au poste de président et chef de la direction en 1972. M. Bateman a été reconnu par l'Ordre du Canada et l'Ordre du Manitoba pour son travail avec le développement hydroélectrique au Manitoba et le courant continu à haute tension (HVDC) à l'échelle internationale. Il a été le premier Canadien à être invité à présider un comité du CIGRE, le comité HVDC, et a participé activement aux travaux du CIGRE de 1968 à la fin des années 1980. Il a créé sa propre entreprise, Bateman and Associated Ltd., en 1979, et a servi des clients au Royaume-Uni, au Brésil, en Afrique du Sud, en Suède, en Suisse et au Canada qui recherchaient son expertise en HVDC. Il a reçu la Médaille d'or nationale en 1994 du Conseil canadien des ingénieurs pour ses contributions à la profession. Entre autres distinctions, il a reçu la Médaille du jubilé d'or de la Reine en 2003. Son service à la profession comprenait un mandat de six ans au Conseil de l'Association du Manitoba, à partir de 1952, et un autre mandat de quatre ans à partir de 1982 ainsi qu'une augmentation pour servir en tant que président de nombreuses organisations nationales d'ingénierie.

Il restera dans les mémoires de ses filles, Donna Blakeman Welch (Terry Panych) et Joyce Bateman (Darrell Hancock), et ses cinq petits-enfants, Cameron Bateman (Daisy), David Bateman (Miriam) et ses enfants (ses arrière-petits-enfants, Sebastian, Sophie et Nicholas), Benjamin Bateman, Calvin Hancock (Brittany Tovee) et AJ Hancock, sa seule petite-fille. ■

John Spencer MacDonald



John Spencer MacDonald, O.C., Ph.D., P.Eng, FCAE, IEEE Fellow, passed away on 26 December 2019. Best known as the cofounder of MacDonald, Dettwiler and Associates (MDA), he was a Canadian aerospace legend and a visionary entrepreneur, engineer, and academic.

Dr. MacDonald was born in Prince Rupert, British Columbia, in 1936. He received his undergraduate degree in applied science from the University of British Columbia (UBC) in 1959. He received his master's degree in 1961 and his doctoral degree in 1964 from the Massachusetts Institute of Technology (MIT), Cambridge, where he subsequently taught. He returned to Vancouver in 1965 to teach electrical engineering at UBC.

In 1969, Dr. MacDonald cofounded MDA, the company that designed the Canadarm mechanism on the International Space Station. He served as president and chief executive officer (CEO)

John Spencer MacDonald, OC, Ph.D., P.Eng, FCAE, boursier de d'IEEE, est décédé le 26 décembre 2019. Mieux connu comme cofondateur de MacDonald, Dettwiler and Associates (MDA), il était une légende de l'aérospatiale canadienne et un entrepreneur visionnaire, ingénieur et universitaire.

Monsieur MacDonald est né à Prince Rupert, en Colombie-Britannique, en 1936. Il a obtenu son diplôme de premier cycle en sciences appliquées de l'Université de la Colombie-Britannique (UBC) en 1959. Il a obtenu sa maîtrise en 1961 et son doctorat en 1964 de la Massachusetts Institute of Technology (MIT), Cambridge, où il a ensuite enseigné. Il est revenu à Vancouver en 1965 pour enseigner le Génie Électrique à l'UBC.

En 1969, Monsieur MacDonald a cofondé MDA, la société qui a conçu le mécanisme du Canadarm sur la Station spatiale internationale. Il a été président et chef de la direction (PDG) de MDA jusqu'en 1982 et président du conseil d'administration de 1982 à 1998, date à laquelle il est devenu président émérite. En plus de ses postes de professeur en génie

of MDA until 1982 and as chairman of the board from 1982 to 1998, at which time he became chairman emeritus. In addition to professorships in engineering at MIT and UBC, he served in an advisory capacity to various governments and on the boards of directors of numerous companies.

Dr. MacDonald was a Fellow of the Canadian Aeronautics and Space Institute and a Founding Fellow of the Canadian Academy of Engineering. He received many awards for his contributions to the technology industry including the British Columbia Technology Industry Association Impact Award for Person of the Year in 2008. He was the first-ever recipient of the Air Industries Association of Canada's Lifetime Achievement Award in 2018. In 2001, based on his observation in RADARSAT imagery showing shrinking Arctic sea ice due to climate change, Dr. MacDonald cofounded Day 4 Energy, a solar energy technology company, and served as its CEO until his retirement in 2014. From 2010 through 2016, he served as the chancellor of the University of Northern British Columbia.

Dr. MacDonald is survived by his loving wife and partner of 60 years, Alfredette, their two sons Neil (Ashly) and Jay (Kristin), and three grandchildren Lochlann, Tyne, and Tristan MacDonald. ■

à MIT et à l'UBC, il a exercé des fonctions consultatives auprès de divers gouvernements et au conseil d'administration de nombreuses entreprises.

M. MacDonald était membre de l'Institut canadien de l'aéronautique et de l'espace et membre fondateur de l'Académie canadienne du génie. Il a reçu de nombreux prix pour sa contribution à l'industrie de la technologie, notamment le prix Impact de la British Columbia Technology Industry Association pour la personne de l'année en 2008. Il a été le tout premier récipiendaire du prix pour l'ensemble des réalisations de l'Association des industries aériennes du Canada en 2018. En 2001, sur la base de son observation dans l'imagerie RADARSAT montrant la diminution de la glace de mer dans l'Arctique due au changement climatique, Monsieur MacDonald a cofondé Day4 Energy, une société de technologie de l'énergie solaire, et en a été le PDG jusqu'à sa retraite en 2014. De 2010 à 2016, il a servi comme chancelier de l'Université du Nord de la Colombie-Britannique.

Monsieur MacDonald laisse dans le deuil sa femme bien aimée et partenaire de 60 ans, Fredette, leurs deux fils Neil (Ashly) et Jay (Kristin), et trois petits-enfants Lochlann, Tyne et Tristan MacDonald. ■

IMPORTANT UPDATES

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

What does this mean?

- All IEEE Canada members will receive *ICR* in digital formats, either through the website or through the IEEE app.
- Members who have explicitly requested not to receive electronic communication will not receive the digital copies. Default mail delivery of print copies will be discontinued to those members in the future. Members are encouraged to opt in for print copies or modify their electronic communication preferences to receive digital copies.
- A print copy will be delivered only to those full-grade members who request it. This will be provided free of additional costs (included in the annual membership fee).

To opt in for print copies, view digital copies, and to receive other updates, please visit canrev.ieee.ca.

COVID-19 Update: Mail delivery of the Fall 2019 / Winter 2020 issue has been disrupted due to the on-going pandemic and business closures. Printing and delivery will resume as soon as these services become available.

IEEE Canada Members Win Engineering Institute of Canada 2020 Awards

The Engineering Institute of Canada (EIC), founded in 1887, announced the winning recipients of its 2020 senior engineering awards and fellowship inductees. The senior awards of the EIC are the highest distinctions made by the Institute and are awarded to deserving members of its 12 constituent societies. This year, seven IEEE Canada members won these prestigious awards.

The Julian C. Smith Medal recognizes achievement in the development of Canada. Up to two medals may be awarded each year. This year's medal recipients included

- *Robert Boily*, Ph.D., C.Q., F.R.S.C., president, Inforex, Laval, Quebec.

Up to 20 members of the EIC constituent societies are awarded EIC Fellowships by the Council of the EIC in recognition of their excellence in engineering and their service to the profession and society. The following IEEE Canada members were elected EIC Fellows:

- *Chi Yung Chung*, Saskatoon, Saskatchewan
- *Nazir P. Kherani*, Toronto, Ontario
- *Cyril S. Leung*, Vancouver, British Columbia
- *Xianbin Wang*, London, Ontario
- *Winnie Ye*, Ottawa, Ontario
- *Fei Richard Yu*, Ottawa, Ontario.

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Canadian Conference on Electrical and Computer Engineering

The 34th Canadian Conference on Electrical and Computer Engineering (CCECE2021) will be held in Halifax, Nova Scotia on May 2-5, 2021.

CCECE is the flagship conference where researchers, students, and professionals in the area of Electrical and Computer Engineering meet annually in a Canadian city to get up to speed with the latest developments, foray into new fields and emerging topics, network with colleagues to strengthen partnerships and foster new collaborations.

Industry 4.0 Theme

- **ethics and policy**
- **ocean observations**
- **emerging health care technologies**
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- **smart production**
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