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Next Generation Telecom

6G Unveiled — Unlocking the Blueprint

Energy Savings in Telecom Networks

Engineering Mega-Projects

IEEE Canada
The Institute of Electrical and Electronic Engineers Inc.

2025 IEEE Canada Electrical Power and Energy Conference (EPEC 2025)

"Path to Net-Zero: Smart Technologies for Sustainable and Clean Energy Grids"

15-17 October 2025, Waterloo, ON Canada

EPEC 2025 Theme

EPEC 2025 will emphasize the critical goal of achieving zero-emissions energy grids, which will serve as the backbone of a net-zero future.

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IMPORTANT DATES

Paper Submission:	**March 31, 2025**
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Camera-ready Paper:	**August 15, 2025**
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CALL FOR PAPERS

The 2025 IEEE Electrical Power and Energy Conference (EPEC 2025) will focus on the decarbonization of energy systems, highlighting the importance of smart energy technologies in moving towards a sustainable energy grid. EPEC 2025 will provide attendees with a vibrant platform to network with industry professionals, academics, regulators and researchers. Participants will have the opportunity to engage in thought-provoking discussions, share recent research findings, and forge valuable partnerships. Together, we will address the pressing challenges in energy sustainability, efficiency, and resiliency, driving forward the innovations that will shape the future of our clean energy systems. Prospective authors are cordially invited to submit original papers with contributions to technology and methods, mathematical modeling, applications and field tests, social and environmental impacts, and/or policy, in one of the following areas:

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Papers should be submitted via EDAS. Prospective authors should prepare their manuscripts in accordance with the standard IEEE camera-ready format (double column, 10-pt font) as well as the requirement set in EDAS. The maximum length of an EPEC paper without over-length charge is FIVE (5) pages. Authors are allowed to pay for up to TWO (2) additional pages with over length charge. Submitted papers must not have been previously published in or under consideration for publication in another journal or conference. The organizing committee of EPEC 2025 reserves the right not to review papers that either exceed the length limit or have been submitted or published elsewhere.

All submitted papers will be reviewed by the TPC team and judged on originality, technical correctness, relevance and quality of presentation. An accepted paper must be presented at the conference. All accepted papers of EPEC, after being presented onsite at the conference, will be included in the conference proceedings and submitted for inclusion in the IEEE Xplore Digital Library.

President's Message/Message du Président

Tom Murad
P.Eng., Ph.D., F.E.C., F.EIC, SMIEEE

2024–2025 IEEE Canada President and Region 7 Director
2024–2025 Président de l'IEEE Canada et Directeur de la Région 7

Once again, I am privileged to extend a warm welcome to each and every one of you as I am communicating with you at the last quarter of my two-year term as president of IEEE Canada and director of IEEE Region 7 (R7), after having the opportunity to work side by side with many of you during 2024 and 2025, and enjoying our collective growth and success.

In the previous editions of *IEEE Canadian Review* (*ICR*), I focused mainly on "the positive change," then, I focused more on those individuals who can make that positive change happen: IEEE Canada's volunteers. Now, I can proudly report that all these ideas and strategies that were implemented during the last two years proved to be fruitful, and we collaboratively have evidently achieved with tangible results a fabulous "culture change" journey, or at least the beginning steps of it.

By cultural change, I mean and refer to the process of transforming our shared values, beliefs, behaviours, and norms within IEEE R7 as an organization or IEEE Canada as a professional's community. In the context of professional associations, it's often essential for staying relevant, inclusive, and responsive to evolving environments.

Our new culture clearly supports diversity, equity, and inclusion (DEI), which builds a more welcoming, positive, purpose-driven, and representative culture that helps our organization remain competitive in attracting and retaining new members and actively participating volunteers in such a fast-changing professional engineering and advanced technology environment

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Une fois de plus, j'ai le privilège d'adresser un chaleureux accueil à chacun d'entre vous alors que je communique avec vous lors du dernier trimestre de mon mandat de deux ans en tant que président de l'IEEE Canada et directeur de la Région 7 (R7) de l'IEEE. Ces deux années m'ont offert l'opportunité de travailler aux côtés de nombreux d'entre vous en 2024 et 2025 et de célébrer ensemble notre croissance et nos succès.

Dans les précédentes éditions de la *revue canadienne de l'IEEE (RCI),* j'ai principalement mis l'accent sur *le changement positif*, avant de me concentrer sur les individus capables de concrétiser ce changement : les *bénévoles de l'IEEE Canada*. Aujourd'hui, je peux affirmer avec fierté que toutes les idées et stratégies mises en œuvre au cours des deux dernières années ont porté leurs fruits, et que nous avons collectivement accompli un remarquable processus de transformation culturelle, ou du moins les premières étapes de celui-ci.

Par changement culturel, j'entends le processus de transformation de nos valeurs, croyances, comportements et normes partagés au sein de l'IEEE R7 en tant qu'organisation ou de l'IEEE Canada en tant que communauté professionnelle. Dans le contexte des associations professionnelles, cette évolution est souvent essentielle pour rester pertinent, inclusif et réactif face aux environnements en constante mutation.

Notre nouvelle culture soutient clairement la diversité, l'équité et l'inclusion (DEI), créant un environnement plus accueillant, positif et axé sur une mission commune, tout en étant représentatif de nos membres. Cette approche renforce la compétitivité de notre organisation en matière d'attraction et de rétention de nouveaux membres,

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Next Generation Telecom

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President's Message/Message du Président

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while fostering innovation, promoting new ideas, and continuously improving.

This "work-in-progress" culture change could not have been possible without a well-defined clarity of vision, providing all the answers to the "why" questions. This vision is regularly shared with our stakeholders, i.e., members, volunteers, and partners while communicating all the stories, successes, and challenges related to the cultural shift, to achieve the optimum level of involvement in shaping the culture.

Culture change must start at the top. IEEE Canada leaders in the Board, Executive Committee, and Steering Committee in their new formations that carefully considered all "DEI "values and principles, are instrumental to embody the desired cultural values, reinforced by IEEE policies, and communicate them consistently, while tracking the progress in relation to behaviours, satisfaction, and engagement.

Success is rarely a solo achievement. Behind every great mission, every powerful movement, and every lasting impact, there is a team.

Behind every great mission, every powerful movement, and every lasting impact, there is a team.

But building a team isn't just about gathering people. It's about uniting *purpose*, *trust*, and *commitment*. It's about finding individuals with different strengths, different voices, and even different perspectives—and bringing them together with one shared goal.

A strong team isn't built on talent alone. It's built on respect. On listening. On lifting each other up, especially when things get hard. It's built when people care more about the mission than their ego, and when they believe that together, they can go farther than any one person alone.

As leaders, our role is to create that culture—one where everyone belongs, everyone is valued, and everyone contributes. We don't just assign tasks, we ignite purpose. We don't just manage people, we *empower* them.

Because when people feel seen, trusted, and inspired, in a completely safe environment free from gossip or conspiracies, they don't just show up—they bring their whole selves. And *that* is when the magic happens.

One of the best examples of our team culture change is the posting and opening all the available volunteer positions, previously filled by direct assignments, to all IEEE Canada's members (including the incumbents), creating an equal opportunity for all Region's members to feel involved in shaping the culture, not just recipients of top-down directives. These positions were posted (2026 positions are already posted) with a clear list of required skills and qualifications as well as performance expectations. This process included the specialty positions (with terms longer than one year), such as the editor-in-chief and associate editors of *IEEE Canadian Journal of Electrical and Computer Engineering*, that have been filled in 2025 (roughly 20 new associate editors were accepted this year) as well as *ICR*'s new

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ainsi qu'en favorisant la participation active des bénévoles dans un monde de l'ingénierie professionnelle et des technologies avancées en constante évolution. Elle stimule également l'innovation, encourage la promotion de nouvelles idées et assure une amélioration continue.

Ce « changement culturel en cours » n'aurait pas été possible sans une vision clairement définie, apportant toutes les réponses aux questions du « pourquoi ». Cette vision est régulièrement partagée avec nos parties prenantes, à savoir les membres, bénévoles et partenaires, en leur communiquant les histoires, les succès et les défis liés à cette transformation culturelle. L'objectif est d'atteindre un niveau d'implication optimal dans la construction et l'évolution de cette nouvelle culture.

Le changement culturel doit commencer au sommet. Les dirigeants de l'IEEE Canada, au sein du Conseil d'administration, du Comité exécutif et du Comité directeur, dans leurs nouvelles formations prenant soigneusement en compte « les valeurs et principes de la DEI », jouent un rôle essentiel dans l'incarnation des valeurs culturelles souhaitées. Ces valeurs sont renforcées par les politiques de l'IEEE et doivent être communiquées de manière cohérente, tout en assurant un suivi régulier des progrès en matière de comportements, de satisfaction et d'engagement.

Le succès est rarement une réussite individuelle. Derrière chaque grande mission, chaque mouvement influent et chaque impact durable, il y a une équipe.

Mais bâtir une équipe ne se résume pas à rassembler des personnes. Il s'agit d'unir une *vision commune*, une *confiance mutuelle* et un *engagement collectif.* C'est aussi savoir identifier des individus aux forces complémentaires, aux voix uniques et aux perspectives variées, puis les réunir autour d'un objectif partagé.

Une équipe solide ne repose pas uniquement sur le talent. Elle se construit sur le respect, l'écoute et le soutien mutuel, surtout face aux défis. Elle se forge lorsque les individus placent la mission au-dessus de leur ego, et lorsqu'ils sont convaincus qu'ensemble, ils peuvent aller plus loin que quiconque seul.

En tant que leaders, notre rôle est de façonner cette culture—une culture où chacun a sa place, est valorisé et contribue activement. Nous ne nous contentons pas d'attribuer des tâches, nous insufflons un sens et une mission. Nous ne nous limitons pas à gérer des personnes, nous les aidons à *s'épanouir et à se surpasser.*

Car lorsque les individus se sentent reconnus, en confiance et inspirés, dans un environnement totalement sain, exempt de rumeurs ou de manipulations, ils ne se contentent pas de simplement être présents—ils s'investissent pleinement. Et c'est à *ce moment-là que* la véritable magie opère.

L'un des meilleurs exemples de notre évolution culturelle au sein de l'équipe est l'ouverture de tous les postes bénévoles disponibles à l'ensemble des membres de l'IEEE Canada, y compris les titulaires en poste, alors qu'ils étaient auparavant pourvus par désignation directe. Cette initiative garantit une égalité des chances pour tous les membres de la région, leur permettant de contribuer activement à l'évolution de la culture, plutôt que d'être de simples bénéficiaires de directives descendantes. Ces postes ont été publiés (les postes pour 2026 sont déjà en ligne) avec une liste détaillée des compétences requises, des qualifications attendues et des objectifs de performance. Ce processus comprend également les postes spécialisés (dont le mandat dépasse un an), tels que celui de rédacteur en chef et rédacteurs associés du *Journal canadien IEEE du génie électrique et informatique*, qui ont été pourvus en 2025 (avec environ 20 nouveaux rédacteurs associés

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editor-in-chief and co-editors positions that are posted to be filled for 2026.

Another clear example on the positive impacts of the culture change is the growth of the number of candidates that were nominated in 2025 for the IEEE Canada Awards after the overall membership restructuring and process revamping of our Awards and Recognition Committee in 2024. The 2025 nominations were more than double those submitted in 2024, and these were spread over all the awards (exceptional laureates were selected for all of the posted awards this year). This new culture reflects the trust of our membership in our new transparent, diverse, and equal opportunity evaluation processes, recognizing their technical, intellectual, and academic achievements as well as their exceptional service to IEEE and our communities promoting advanced technologies in serving humanity.

Leadership is often defined by titles, positions, or accomplishments. But in our new IEEE Canada culture, we continuously communicate in all directions that real leadership, the kind that transforms people and communities, is defined by *action*.

True leaders don't just give instructions, they *show* the way. They live their values, they walk their talk, and they inspire others not with power, but with integrity. This is what we call *leadership by example*.

When a leader rolls up their sleeves, others follow. When a leader admits mistakes, others learn to be honest. When a leader listens before speaking, they create a culture of respect. And when a leader stands up for what's right, even when it's hard, they empower everyone around them to do the same.

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acceptés cette année). De plus, les postes de rédacteur en chef et co-rédacteurs de la RCI sont actuellement ouverts pour 2026.

Un autre exemple clair des impacts positifs du changement culturel est l'augmentation du nombre de candidatures soumises en 2025 pour les IEEE Canada Awards, suite à la restructuration générale de l'adhésion et à la réforme du processus menée par notre Comité des récompenses et reconnaissances en 2024. Les nominations de 2025 ont été plus de deux fois supérieures à celles de 2024, et elles ont été réparties sur l'ensemble des catégories de prix, avec des lauréats exceptionnels sélectionnés pour toutes les distinctions publiées cette année. Ce nouvel environnement reflète la confiance croissante de nos membres dans nos processus d'évaluation transparents, diversifiés et équitables, qui reconnaissent leurs accomplissements techniques, intellectuels et académiques, ainsi que leur service exceptionnel à l'IEEE et aux communautés œuvrant à la promotion des technologies avancées au service de l'humanité.

Le leadership est souvent défini par des titres, des fonctions ou des réalisations. Cependant, dans notre nouvelle culture de l'IEEE Canada, nous transmettons constamment un message clair : le véritable leadership, celui qui transforme les individus et les communautés, se mesure avant tout *par l'action*.

Les vrais leaders ne se contentent pas de donner des instructions, *ils montrent* la voie. Ils incarnent leurs valeurs, les appliquent avec cohérence et inspirent les autres, non pas par le pouvoir, mais par l'intégrité. C'est ce que l'on appelle *le leadership par l'exemple*.

Lorsqu'un leader retrousse ses manches, les autres suivent. Lorsqu'un leader reconnaît ses erreurs, il enseigne l'honnêteté.

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IEEE Canadian Review

La revue canadienne de l'IEEE

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

Its **principal objectives** are:

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

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President's Message/Message du Président

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In a world full of noise and performance, leadership by example cuts through with quiet strength. It says, "Watch me, not because I'm perfect, but because I'm consistent, committed, and courageous."

Whether we are leading a team, classroom, family, or community, we should always remember that our actions speak louder than any speech, title, or plan. People will forget what we said, and even what we did, but they'll never forget how we *led*.

Finally, we often hear about the importance of leadership, but this time, I want to talk about something equally important: the *exchange* or *transfer* of leadership. True leadership is not about holding on to power, it's about preparing others to lead. And now more than ever, it is time to intentionally pass the torch to new generations. Young people today are not just the leaders of tomorrow, they are already the innovators, organizers, and voices of today. They bring with them new energy, fresh ideas, and a fearless drive to challenge outdated systems. When we exchange leadership with them, we are not giving up control, we are gaining evolution.

In a world full of noise and performance, leadership by example cuts through with quiet strength.

This doesn't mean abandoning experience. It means blending wisdom with vision. It means that seasoned leaders become mentors, not gatekeepers. And it means giving youth not just a seat at the table, but a voice that is heard and a role that matters.

This is how we build sustainable communities, resilient organizations, and a future that belongs to *everyone*. So let us lead by example by empowering those who are ready to carry the mission forward. Because when we invest in new leaders, we don't just preserve our legacy, we multiply its impact. This explains our focus this year on extensive students, Young Professionals, and Women in Engineering leadership and empowerment programs and workshops, with restructuring our student activities teams, aiming to build and sustain IEEE Canada for the future.

With that, and in closing, 2025 continues to show all the signs of success and growth, with our dedicated and hardworking team of volunteers and contributors, and conducting various exciting events. The IEEE Canada Board and I encourage you all to continue being a part of this exciting journey, and joining our fabulous team to enrich our experiences and achievements for further and better success and growth.

By the time you read this article, I may have passed the torch to my successor, Dr. Wahab Almuhtadi. I wish him all the best in his new role contributing to the historical journey of IEEE Canada with his unique knowledge and experience. I encourage you all to support him as you supported me and give him the opportunity to use his leadership touch in steering the ship on the right course. ■

Tom Murad, P.Eng., Ph.D., F.E.C., F.EIC, SMIEEE
2024–2025 IEEE Canada President
2024–2025 Region 7 Director

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Lorsqu'un leader écoute avant de parler, il instaure une culture de respect. Et lorsqu'un leader défend ce qui est juste, même lorsque c'est difficile, il donne à chacun la force d'en faire autant.

Dans un monde rempli de bruit et de quête de performance, le leadership par l'exemple se distingue par une force tranquille. Il affirme : « Regardez-moi, non pas parce que je suis parfait, mais parce que je suis cohérent, engagé et courageux. »

Que nous dirigions une équipe, une classe, une famille ou une communauté, nous devons toujours nous rappeler que nos actions ont plus de poids que n'importe quel discours, titre ou plan. Les gens oublieront ce que nous avons dit, et même ce que nous avons fait, mais ils ne manqueront jamais de se souvenir de la manière *dont nous avons dirigé*.

Enfin, on parle souvent de l'importance du leadership, mais cette fois-ci, je veux aborder un sujet tout aussi crucial : *la transmission du leadership*. Le véritable leadership ne consiste pas à s'accrocher au pouvoir, mais à préparer les autres à diriger. Aujourd'hui plus que jamais, il est temps de passer le flambeau aux nouvelles générations de manière intentionnelle. Les jeunes ne sont pas seulement les leaders de demain, ils sont déjà les innovateurs, les organisateurs et les voix du changement aujourd'hui. Ils apportent une énergie nouvelle, des idées audacieuses et une volonté inébranlable de remettre en question les systèmes obsolètes. Quand nous partageons le leadership avec eux, nous ne renonçons pas au contrôle, nous embrassons l'évolution.

Cela ne signifie pas abandonner l'expérience, mais fusionner la sagesse avec la vision. Les leaders expérimentés doivent devenir des mentors, et non des gardiens du pouvoir. Cela implique également d'offrir aux jeunes bien plus qu'une place à la table—il faut leur accorder une voix qui compte et un rôle qui a de l'impact.

C'est ainsi que nous bâtissons des communautés durables, des organisations résilientes et un avenir qui *appartient à tous*. Menons donc par l'exemple en valorisant ceux qui sont prêts à porter la mission plus loin. Car lorsque nous investissons dans de nouveaux leaders, nous ne nous contentons pas de préserver notre héritage, nous amplifions son impact. Cela explique notre priorité cette année : développer des programmes et ateliers de leadership et d'autonomisation pour les étudiants, les Jeunes Professionnels et les Femmes en Ingénierie, tout en restructurant nos équipes d'activités étudiantes afin d'assurer un IEEE Canada solide et pérenne pour l'avenir.

Ainsi, pour conclure, l'année 2025 continue de montrer tous les signes de succès et de croissance, grâce à notre équipe de bénévoles et contributeurs dévoués qui travaillent avec engagement et passion, tout en organisant divers événements enthousiasmants. Le Conseil de l'IEEE Canada et moi-même vous encourageons tous à rester impliqués et à rejoindre notre formidable équipe, afin d'enrichir nos expériences et réalisations pour atteindre un succès et une croissance encore plus grands.

Au moment où vous lirez cet article, il est possible que j'aie transmis le flambeau à mon successeur, Dr. Wahab Almuhtadi. Je lui souhaite beaucoup de succès dans son nouveau rôle, où il apportera sa connaissance et son expérience uniques à l'IEEE Canada, poursuivant ainsi notre parcours historique. Je vous invite tous à lui accorder le même soutien que vous m'avez offert, et à lui donner l'opportunité de marquer de son empreinte la direction à prendre pour maintenir le cap vers l'avenir. ■

Tom Murad, Ing., Ph.D., F.E.C., F.EIC, SMIEEE
2024–2025 Président de l'IEEE Canada
2024–2025 Directeur de la Région 7

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

Jahangir Khan, Ph.D., P.Eng., SMIEEE
mjakhan@ieee.org

I write this editorial with a heavy heart as news of Witold Kinsner's passing continues to pour in. At the time of writing, I am still processing the loss of a mentor, a leader, and an inspiration to many. My own journey with Witold began in 2018–2019, during a pivotal moment for *IEEE Canadian Review* (*ICR*). The publication was emerging from a brief hiatus and facing significant challenges ahead. Witold (then past president), Maike Luiken (then president), and Wahab Almuhtadi (then Publications and Communications Group chair, now president-elect) placed their trust in

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JE rédige cet éditorial le cœur lourd alors que les nouvelles du décès de Witold Kinsner continuent d'affluer. Au moment où j'écris ces lignes, je peine encore à assimiler la perte d'un mentor, d'un leader et d'une source d'inspiration pour tant de personnes. Mon propre parcours aux côtés de Witold a débuté en 2018–2019, à un moment charnière pour *la Revue Canadienne de l'IEEE (RCI)*. La revue sortait d'une brève interruption et faisait face à d'importants défis à venir. À cette époque, Witold (alors ancien président), Maike Luiken (alors présidente) et Wahab Almuhtadi (alors président du groupe Publications et

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

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me to take on the role of editor, a responsibility I embraced wholeheartedly.

During Witold's farewell speech in the winter of 2020, I, like the audience before him, was spellbound by his wisdom, passion, and eloquence. While speaking candidly about the hurdles and limitations of IEEE Canada's operations, he quoted Leonard Cohen's timeless words: "There is a crack in everything—that's how the light gets in." That sentiment stayed with me, shaping how I confronted challenges, both in my professional work and personal life. Rest in peace, dear Witold.

The beginning of 2025 was already marked by geopolitical turbulence following the inauguration of the new U.S. administration. The U.S.–Canada trade war sent shockwaves through our long-standing relationship with our southern neighbour, introducing uncertainty and challenges on multiple fronts. Given IEEE's roots as a U.S.-based organization, it was inevitably drawn into the crossfire—particularly from Canada—as new restrictions began to take shape.

Despite the present uncertainties, I firmly believe that this moment of disruption will pass. The decades-long bond between

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Communications, aujourd'hui président élu) m'ont accordé leur confiance pour prendre les rênes de la rédaction—une responsabilité que j'ai embrassée pleinement.

Lors du discours d'adieu de Witold à l'hiver 2020, j'étais, comme l'auditoire devant lui, captivé par sa sagesse, sa passion et son éloquence. Tout en abordant avec franchise les difficultés et les limites du fonctionnement de l'IEEE Canada, il cita les paroles intemporelles de Leonard Cohen : « Il y a une fissure en toute chose — c'est ainsi que la lumière entre. » Ces mots sont restés gravés en moi, influençant la manière dont j'ai affronté les défis, tant dans mon travail professionnel que dans ma vie personnelle. Repose en paix, cher Witold.

Le début de l'année 2025 a été marqué par une turbulence géopolitique, suivant l'investiture de la nouvelle administration américaine. La guerre commerciale entre les États-Unis et le Canada a ébranlé notre relation historique avec notre voisin du sud, entraînant incertitude et défis sur de nombreux fronts. Compte tenu des origines de l'IEEE, une organisation basée aux États-Unis, celle-ci s'est retrouvée inévitablement impliquée dans ces

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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. 6)

IEEE and Canada has weathered many challenges before, and I am confident that, in time, it will emerge even stronger.

I took a brief break from writing the "A Few Words From the Editor-in-Chief" column as David Michelson edited the Summer 2024 and Gautam Srivastava edited the Fall/Winter 2024 editions. Both guest editors did an envious job of bringing *ICR* to a new level. I truly appreciate their commitment, dedication, and hard work. This year, we recognized the immense contributions of David Michelson and David Whyte for tirelessly submitting articles, news items and various other items. Thank you David and David!

During Witold's farewell speech in the winter of 2020, I, like the audience before him, was spellbound by his wisdom, passion, and eloquence.

As we step into 2025, I prepare for my final year as editor-in-chief of *ICR*. A transition is on the horizon, and an announcement regarding the new editor will follow soon, if it has not already. I encourage everyone to stay tuned for updates on this important appointment. Enjoy the Spring 2025 edition, share your thoughts, and send your comments and contributions to icr@ieee.ca. ■

(Quelques mots du rédacteur en chef suite de p. 6)

tensions—en particulier du côté canadien, alors que de nouvelles restrictions commençaient à émerger.

Malgré les incertitudes actuelles, je suis convaincu que ce moment de turbulence finira par s'apaiser. Le lien historique et durable entre l'IEEE et le Canada a déjà surmonté de nombreux défis, et je suis certain qu'avec le temps, il en ressortira encore plus fort.

J'ai pris une courte pause dans la rédaction de la colonne « Quelques mots du rédacteur en chef », tandis que David Michelson a dirigé l'édition été 2024 et Gautam Srivastava l'édition automne/hiver 2024. Tous deux ont accompli un travail remarquable, faisant atteindre à la RCI un nouveau niveau d'excellence. J'apprécie sincèrement leur engagement, leur dévouement et leurs efforts. Cette année, nous avons également reconnu les contributions exceptionnelles de David Michelson et David Whyte, qui ont inlassablement soumis des articles, des actualités et divers autres contenus. Merci à vous deux, David et David !

Alors que nous entrons dans l'année 2025, je me prépare à ma dernière année en tant que rédacteur en chef de la RCI. Une transition se profile, et une annonce concernant le nouveau rédacteur en chef sera bientôt publiée, si ce n'est déjà fait. J'encourage tout le monde à rester à l'affût des mises à jour importantes sur cette nomination. Profitez pleinement de l'édition Printemps 2025, partagez vos réflexions et envoyez vos commentaires et contributions à icr@ieee.ca. ■

6G Unveiled: The Blueprint for Next-Generation Wireless Networks

by Ekram Hossain and Angelo Vera-Rivera

6G is emerging as the strongest candidate to become the staple for the next generation of wireless networks. By integrating a range of cutting-edge technologies from different fields, 6G is expected to offer widespread coverage, gigabits-per-second-level data rates, near-real-time latencies, contextual awareness, and enhanced energy efficiency. However, materializing this ambitious vision into reality will be far from simple. The convergence of these technologies will likely craft an outstandingly heterogeneous and complex system, bringing significant technical, economic, and societal challenges. This prompts a fundamental question: Is it truly possible to develop a system as sophisticated as 6G? Although arguments remain blurry and uncertain to this day, the potential of this technology promises to transform our understanding of connectivity and motivates us to continue looking for answers.

Setting the Stage: Why Does 5G Fall Short?

Despite its significant impact on wireless communications over the last decade, 5G technology still faces critical limitations that prevent it from keeping pace with the ever-growing demands for connectivity. Broad expectations for global coverage, contextual awareness, immersive experiences, ubiquitous intelligence, and carbon-neutral operation extend beyond the traditional "more bandwidth and less latency" conversation, surpassing the capabilities of current 5G networks. If we had to choose, we would say that the transmission, intelligence, and energy technologies used in 5G are the most significant factors limiting the system's ability to meet new connectivity demands.

First, 5G networks will predominantly operate on the millimeter-wave (mm-wave) frequency band, ranging from 24 to 100 GHz. Mm-wave propagation is challenging as signals in this range experience high path loss, are particularly susceptible to scattering and absorption, and have a reduced ability to bend around large and dense objects. As a result, 5G struggles to provide adequate coverage in dense urban and indoor areas, leading to significant coverage gaps. These gaps can result in inaccurate or incomplete network contextual information, which is a critical component for crafting hyperconscious and hyperresponsive systems.

Second, the decision-making capabilities of artificial intelligence (AI) are only partially exploited in 5G, even though they play a crucial role in orchestrating practical network solutions. One reason for this is the limited availability of adequate computing infrastructure across the network for AI processing. Additionally, there are excruciating security and privacy concerns related to training insecure AI algorithms with potentially sensitive subscriber data. As a result, AI was never formally introduced in the 5G mobile standard as a foundational component of the system.

Finally, 5G networks consume more energy than previous mobile generations to power massive antenna infrastructure, always-on network components, and communication interfaces with legacy systems. The increased energy consumption puts 5G at odds with the global trend toward carbon neutrality, aiming to reduce greenhouse gas emissions across multiple economic and industry sectors, which is a piece of a broader effort to address the increasing threat of climate change. Recognizing and addressing the transmission, intelligence, and energy shortcomings in 5G is vital to pave the way for future mobile generations. Technology advancements in these realms are necessary to keep up with the constantly rising connectivity demands of individuals, businesses, and industries.

Making The Case for 6G: Envisioning the Future of Global Connectivity

The mobile communications field is a wrecking machine. To this day, the 5G standard is still unfinished, yet academic circles, industry players, and standard developing organizations (SDOs) are already discussing the next iteration of mobile broadband systems: 6G networks. The communications community envisions 6G as a global ecosystem that integrates terrestrial and nonterrestrial networks (NTNs), providing coverage across Earth's low space orbit, air, ground, and sea domains. The system will extend frequency bands from the 5G mm-wave spectrum to the terahertz (THz) range, typically from 100 GHz to 10 THz. THz communications promise significantly greater bandwidth for ultra-fast data rates, theoretically reaching up to 200 Gbps despite the propagation challenges. Sensing is set to play a fundamental role in the ecosystem by enabling extensive contextual data collection for intelligent network functions and context-aware applications, giving connected things metaphorical

Figure 1: Integration of terrestrial networks and NTNs for 6G global coverage. The solid lines represent ground or undersea connections. Nonsolid lines represent air connections.

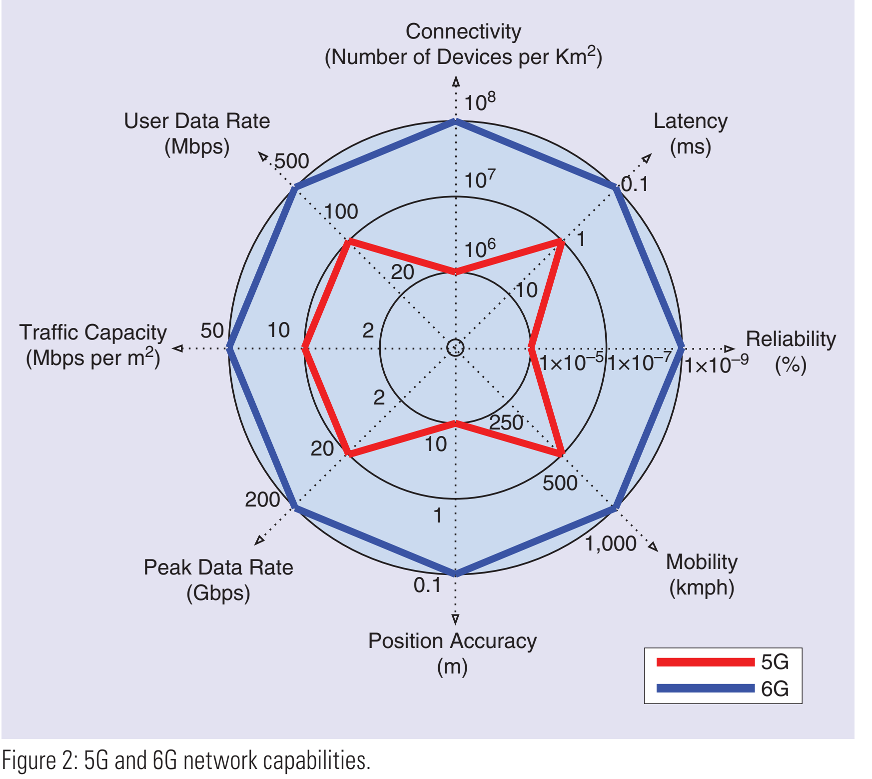

Figure 2: 5G and 6G network capabilities.

consciousness and awareness of their surrounding environment. AI will be natively integrated into the system to optimize network performance based on contextual data, laying the foundations for intelligent and autonomous networks. Data-driven network intelligence will facilitate self-organization, performance management, resource allocation, and user-centric applications, all of which enhance end-user experiences.

AI components will be combined with extended computing infrastructure distributed across the network locations, bringing decision making very close to end users. However, processing consumes significant energy, making the system's carbon footprint a major concern. 6G will prioritize reducing its carbon footprint by focusing on advanced low-power materials for antennas and sensors, utilizing renewable energy sources to power the infrastructure, and establishing strict implementation standards to ensure environmentally friendly networks. The ability to collect and process massive contextual data through the sensing and intelligence capabilities of 6G will facilitate AI-based digital representations of the world, which is one of the exciting possibilities within the 6G vision. Although digital twins and their physical counterparts will differ fundamentally, they will be interconnected, meaning that they will share dual properties and could coexist, influence, complement, and be transformed into one another. The digital ecosystem built around these twins will likely give rise to an economy based on AI-generated content (AIGC). This evolution will create a marketplace where AIGC-aided assets and services can be traded within 6G platforms under various emerging business models.

On a colorful note, the idea of a surreal coexistence of our physical world and its digital counterpart is not new. Author Neal Stephenson introduced this concept in his 1992 science fiction novel *Snow Crash*. In it, he writes, "In the lingo, this imaginary place is known as the Metaverse. Hiro spends a lot of time in the Metaverse. It beats the sh*t out of the U-Stor-It." With this passage, Stephenson reveals his vision of a virtual world called *the Metaverse*. The novel follows the story of Hiro, a bankrupt computer hacker who creates a computer program to simulate a virtual-reality world online. In Hiro's Metaverse, individuals can immerse themselves in a fictional 3D universe that allows them to escape their dystopian reality. Casual readers might view 6G as just the next iteration in the evolution trajectory of mobile broadband networks, however, many ideas in the 6G vision extend far beyond mere communications. With 6G, everything can connect to everything in real time and at ultra-fast data transfer speeds, utilizing a global, reliable, conscious, intelligent, and secure mobile network with potential to facilitate new enriched realities where physical objects and their virtual representations can merge and coexist within the platform, creating surreal experiences for everyone.

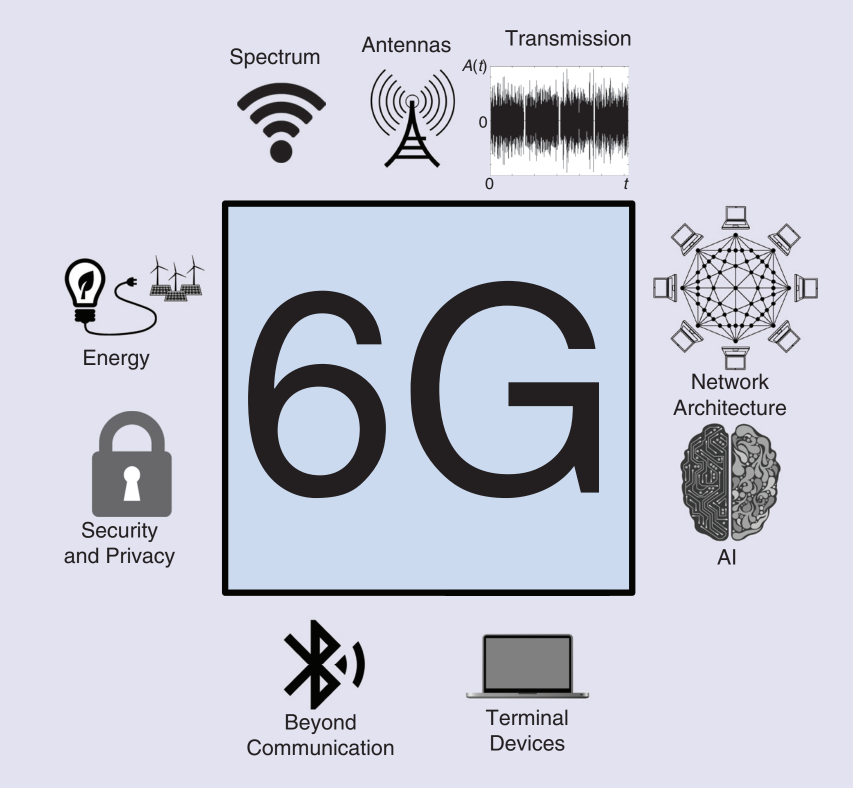

Figure 3: 6G research areas.

The 6G Landscape: Enablers, Obstacles, and Possibilities

In November 2023, the International Telecommunications Union (ITU), through their Radiocommunication Sector (ITU-R), released the recommendation report ITU-R M.2160-0 titled "Framework and Overall Objectives of the Future Development of International Mobile Telecommunications (IMT) for 2030 and Beyond." IMT is the generic term defined by the ITU to refer to mobile broadband systems. It includes IMT-2000, IMT-Advanced, IMT-2020, and IMT-2030, colloquially known as *3G*, *4G*, *5G*, and *6G*, respectively. The report outlines the overall technical goals for 6G and beyond networks and emphasizes four key design principles that reflect the vision for 6G: connecting the unconnected, ubiquitous intelligence, security and resilience, and sustainability. It defines six use cases and 15 technical requirements for the network, all aligned with these principles. The architecture for 6G must establish a clear structural design and organizational framework for hardware components, connections, protocols, and data flow planes to effectively serve massive, ultra-reliable, highly responsive, ubiquitous, intelligent, sensitive, and immersive mobile communication. A handful of research areas from many technological fields must converge to fulfill the vision and technical requirements set for the system. These include spectrum, antennas, transmission, network architecture, network intelligence, terminal devices, beyond communication, security and privacy, and energy.

Research on technology enablers is currently underway and making significant progress. However, realizing the system's full potential is not a trivial effort as it faces numerous technical, economic, and societal challenges. Research directions likely include the exploration of new carrier frequencies, use of metamaterial antennas, development of more efficient modulation and coding schemes, implementation of decentralized and trustful network orchestration, enhancement of AI methods, creation of zero-energy sensors, advancement of lightweight cryptography, and establishment of carbon-neutral infrastructure. 6G technology must move beyond the current 5G frontier to establish the groundwork for the next wave of innovation for wireless networks.

Despite challenging market conditions, investment continues to explore potential vertical applications, identify value sources, understand adoption drivers, and develop the critical technology to unlock the opportunities that 6G could bring to society, businesses, and industries. The development of 6G represents a long-term intellectual and financial commitment, requiring collaboration among the academic research community, industry sectors, and SDOs. The 3rd Generation Partnership Project (3GPP), the consortium responsible for creating and maintaining technical standards for mobile broadband systems, forecasts a timeline of almost a decade between the publication of the ITM-2030 framework in 2023 to the finalization of the first set of platform specifications. The 3GPP work on 6G will start in Release 19 with a requirements study, followed by a review of work items in Release 20, and will culminate in the first set of implementable standards in Release 21. Further advanced specifications are expected to be available in Releases 22 and 23. Until then, society has only a few years before 6G become fully inserted into our daily lives.

Although 6G is still a developing concept, we can envision potential applications across various vertical sectors. Still, achieving full technology adoption in society, businesses, and industries will require a long-term effort. Not all sectors will be able to integrate cutting-edge mobile technology into their operational models. Some may face challenges securing financial resources for deployment, while others may struggle to perceive how 6G integration could benefit their return on investment. In addition to financial constraints and limited interest, the different maturity levels of technology enablers will also influence the development and eventual adoption of 6G. For instance, quantum computing is still in the exploratory research phase. Reconfigurable intelligent surfaces, holographic radio, immersive reality, and renewable energy technologies are currently experimental, with only a few prototype pilots being tested. In contrast, technologies like NTNs, cloud and edge computing, AI, and cybersecurity are already scaling up with abundant commercial options. We anticipate that widespread deployments will impact many sectors once all technology enablers reach sufficient maturity for practical 6G implementations. This is expected to align with the release of the first set of standards, projected around 2030, following a pattern similar to previous mobile generations.

The digital gap between communities with access to communication technologies and those without creates a social divide that limits underserved populations from accessing information, public services, and economic opportunities. As a result, their legitimate aspirations for prosperity are restrained, hindering their ability to engage in economic advancements that could improve their quality of life. The global connectivity vision in 6G aims to fix this by providing widespread access to affordable communication services, significantly promoting the digital inclusion of neglected communities. This effort is essential to create unprecedented opportunities for new businesses and industry models across economic sectors. Industries like health care, transportation, entertainment, energy, manufacturing, logistics, and agriculture will have the chance to redefine their revenue streams and enhance their services through transformative applications that integrate 6G use cases into their operational models. 6G will likely unlock limitless innovation opportunities, but these can only be fully capitalized on with appropriate government legislation, skilled workforce, and public trust to ensure that 6G-based business models can flourish and thrive.

Embracing the 6G Road Ahead

In summary, 6G is anticipated to emerge as a transformative communications platform, offering global reach, Gbps-level data rates, near-real-time latencies, metaphorical consciousness, native intelligence, and almost perfect availability for applications that connect massive numbers of users. The network will evolve away from 5G restraints, advancing mobile communication aspects such as coverage, transmission capacity, response times, connectivity levels, reliability, security, and carbon footprint. 6G presents an opportunity for a wide range of new use cases, business models, and industry applications with the potential to significantly transform how we manage human life on our planet. The system's technical promises will require integration of various technologies and infrastructure, making the system extraordinarily heterogeneous and complex. Ultimately, the million dollar question at the beginning of this piece still holds: Is 6G really possible? The debates to find candidate technologies for the network will be long and exhausting, and it will take time before there is a consensus in the community about optimal implementation strategies. But even in an ocean of uncertainties, one thing is sure: eventually, plenty of reasonable research efforts will produce carefully engineered solutions to materialize the system's broad vision. ■

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Unlocking Energy Savings in Telecom Networks: A Path to a Sustainable Future

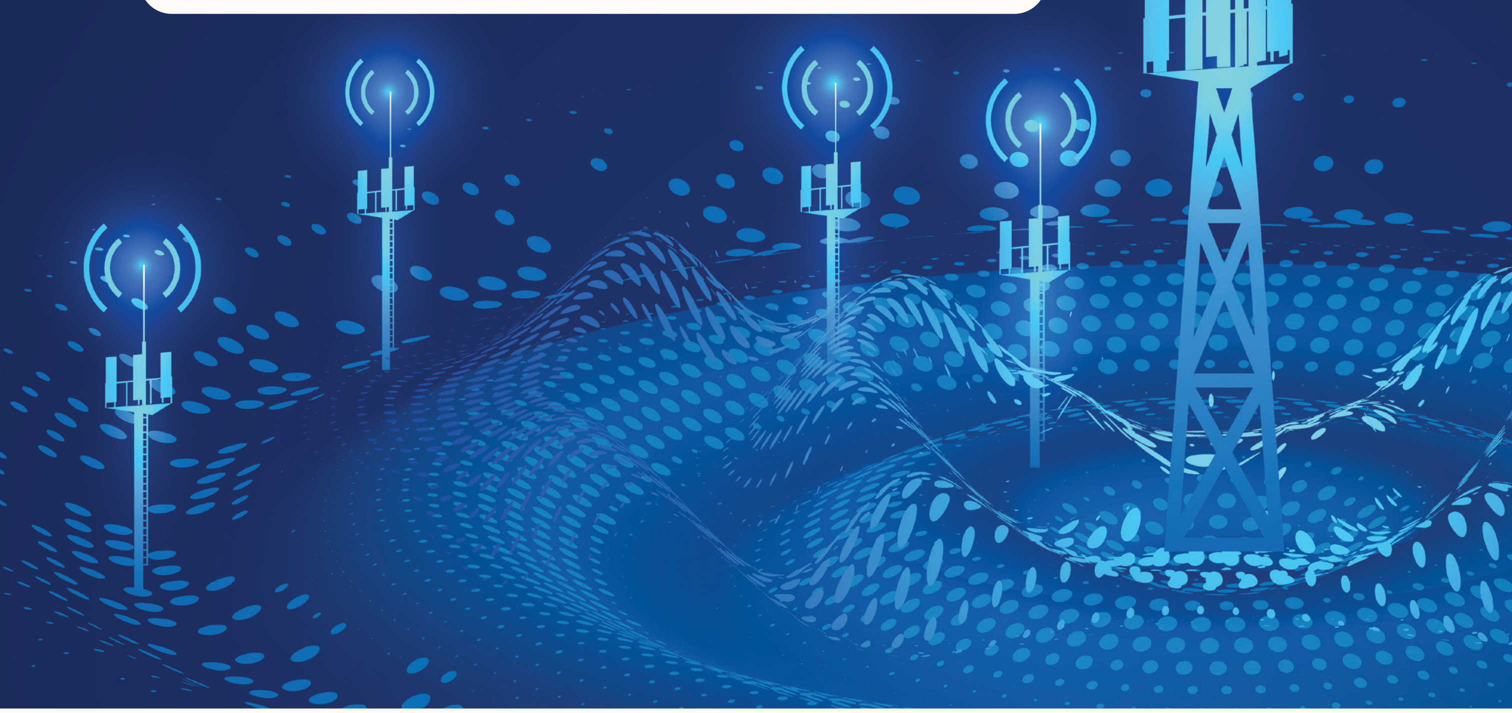
An Insight Into How Technology Can Revolutionize Energy Efficiency

by Ajay Lotan Thakur

Running a reliable telecommunications (telecom) network 24/7 is vital in today's world, where the number of users are increasing day by day. As each new technology emerges, operators must maintain both old and new technologies, leading to higher energy consumption. Mobile infrastructure is a significant contributor to the world's total power consumption, with energy costs for telecom operators accounting for upward of 5%–7% of operating expenses. The mobile radio access network (RAN) is a major component of this expense. As traffic grows exponentially and new 5G services are introduced, energy costs continue to rise, with each 5G site requiring two to three times more power than its 4G equivalent (see Figure 1).

There is a clear and pressing need to optimize power utilization in telecom networks to balance the economic value that these networks bring with the cost and environmental impact that they impose. Reducing power consumption not only reduces operational cost for operators but also helps in mitigating the environmental impact.

Operators can reduce energy consumption in telecom networks through



various strategies. Using energy-efficient hardware, adopting technologies like software-defined networking (SDN), network function virtualization (NFV), and cloud-native products can lead to more efficient network management. The use of artificial intelligence (AI) and machine learning (ML) in managing network efficiency is another promising strategy. These technologies enable dynamic adjustments to network operations based on real-time data, optimizing power usage and reducing overall energy consumption.

This article examines the challenges, opportunities, and key participants involved in improving the energy efficiency of telecom networks.

Understanding 5G Technology

5G wireless technology, is the latest advancement in mobile communication networks. Unlike its predecessors, 5G offers significantly higher data speeds, reduced latency, and the ability to connect a vast number of devices simultaneously. 5G brings in various new use cases and possible wide expansion of devices that will connect to network.

To better understand the potential of 5G, it is essential to explore its three main pillars:

1) *Enhanced mobile broadband* (*eMBB*): eMBB focuses on providing high-speed Internet access with low mobility. It ensures that users can enjoy seamless streaming, gaming, and other data-intensive applications without interruptions.
2) *Massive machine-type communication* (*mMTC*): mMTC aims to connect a large number of low-power devices with extended coverage. This use case of 5G is important for the Internet of Things, where numerous sensors and smart devices communicate with each other to create intelligent systems.
3) *Ultra-reliable and low-latency communication* (*URLLC*): URLLC is designed for applications that require extreme reliability and minimal latency. This pillar is vital for critical use cases such as autonomous vehicles, remote surgery, and industrial automation (see Figure 2).

Energy Consumption Challenges

One of today's most critical challenges is reducing energy consumption and minimizing carbon footprints. Traditional mobile networks have high energy demands due to the continuous operation of base stations and infrastructure. Although 5G offers significant energy-saving potential, there are several challenges to its full realization. 5G technology relies on higher frequency bands, which experience greater signal transmission loss, necessitating a denser deployment of radio networks to maintain coverage and performance. Here, the various challenges are discussed in detail.

Regulatory Compliance

Regulatory frameworks mandate that telecom networks ensure 24/7/365 high reliability for uninterrupted connectivity. Service outages can disrupt critical emergency communications, impacting public safety and economic activities. To enforce compliance, strict penalties are imposed for downtime beyond allowed thresholds. These regulations drive continuous monitoring, redundancy, and proactive maintenance in telecom infrastructure.

Figure 1: Operators run multiple generations of network simultaneously.

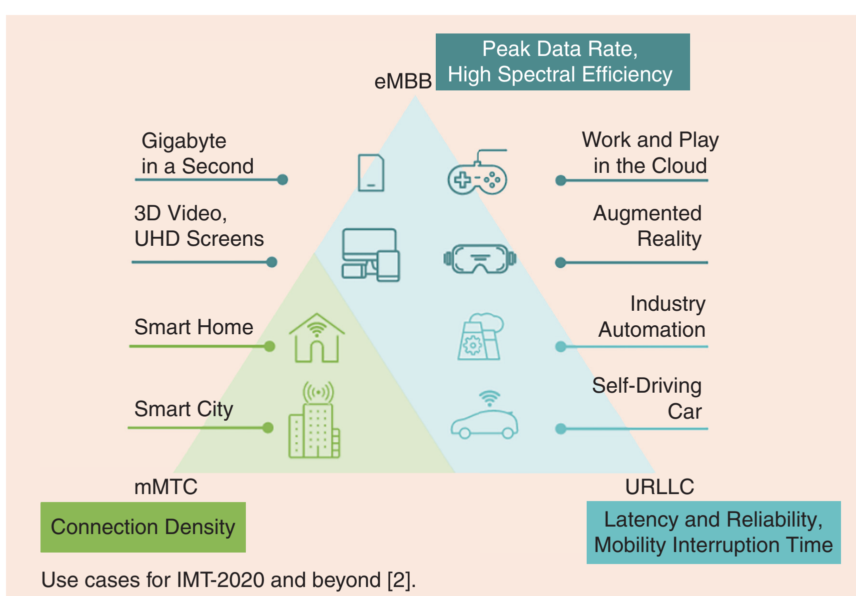


Figure 2: The 5G use-cases pyramid. UHD: ultra-high-definition.

Running Multiple Generations of Networks Simultaneously

Telecom networks must support legacy technologies like 3G and 4G while deploying newer technologies like 5G to ensure continuous service availability. This parallel operation increases energy consumption as older infrastructure remains active alongside modern networks. Maintaining outdated systems demands additional resources for hardware, power, and operational maintenance. Phased technology transitions and network optimizations are essential to balance energy efficiency with service continuity.

Multiple Proprietary Hardware

Telecom operators face challenges managing proprietary hardware from multiple vendors as each requires dedicated rack space, power supply, and cooling. This fragmented setup complicates power management as every unit demands separate monitoring, configuration, and maintenance. The lack of standardization results in inefficient resource utilization and increased energy consumption.

The Role of Base Stations

Base stations, integral to mobile networks, consume a substantial amount of energy. These stations are responsible for transmitting and receiving signals between mobile devices and the network. In a typical network, base stations operate continuously, regardless of the demand, leading to significant energy wastage during nonpeak hours.

Balancing Performance and Sustainability

One of the primary challenges is striking a balance between performance and sustainability. Although energy-efficient practices are essential, they should not come at the expense of network performance. Ensuring that 5G networks can deliver high-speed, reliable connectivity while minimizing energy consumption requires careful planning and optimization.

Adapting to Changing Network Demand

Network demand can vary significantly based on factors such as time of day, user activity, and geographic location. Adapting to these changing demands in real time is crucial for optimizing energy usage. This requires advanced monitoring and analytics capabilities to ensure that network resources are allocated efficiently.

Opportunities for Energy Savings With 5G

The transition to 5G offers significant energy-saving opportunities. Here are the key ways that 5G can drive a more energy-efficient future.

SDN, NFV, and Cloud-Native Aspects in 5G

5G networks leverage advanced technologies such as SDN and NFV. These technologies allow for greater flexibility and scalability in managing network resources. By virtualizing network functions and decoupling them from physical hardware, 5G networks can optimize resource allocation, leading to more efficient energy usage.

Open RAN Evolution

Radio networks have undergone a significant transformation in recent years with the adoption of Open RAN, driving innovation and flexibility in the telecom industry. By applying SDN and NFV principles, Open RAN enables greater control and programmability in the RAN infrastructure. This shift allows vendors to develop innovative applications that can dynamically adjust network behavior based on traffic patterns and demand. Additionally, it promotes the deployment of virtualized network functions on commercial off-the-shelf hardware, reducing dependency on proprietary equipment. This evolution enhances interoperability, reduces costs, and fosters a more energy-efficient and scalable network.

Dynamic Network Management

One of the most significant advantages of 5G is its ability to dynamically manage network resources. Unlike traditional networks, where base stations operate continuously, 5G networks can intelligently adjust their operations based on demand. This means that base stations can be shut down or put into low-power mode during nonpeak hours, significantly reducing energy consumption.

AI-Driven Energy Optimization

AI is essential for optimizing energy consumption in 5G networks by analyzing traffic patterns and predicting demand. AI enables proactive network adjustments by identifying low-activity periods and dynamically managing power levels. The mobile network's dynamic nature, influenced by factors like weather, holidays, and remote work, presents opportunities for optimizing power consumption. AI can forecast demand shifts and adjust the network to optimize energy use in response to changing conditions. RAN optimization strategies, such as cell sleeping and cell zooming, further enhance power efficiency. These techniques allow the network to adjust capacity based on real-time traffic demands. Overall, AI-driven optimizations can lead to substantial energy savings in 5G networks.

Case Study: Aether—An Open Source 5G Platform

To illustrate the potential of 5G in unlocking energy savings, let's take a closer look at Aether and Sustainable Mobile and RAN Transformation 5G (SMaRT-5G), an open source 5G platform developed by the Open Networking Foundation (ONF).

Contributors and Funding

Aether has garnered support from various universities, companies, and individual contributors. Notable contributors include Purdue University, Stanford, Princeton, and Cornell University as well as organizations like Intel Labs, Canonical, RIMEDO Labs, IOS-MCN, Iowa State University, and GS Lab. The project received a US$30 million grant from the U.S. government and transitioned to the Linux Foundation in February 2024.

The U.S. National Telecommunications and Information Administration selected Aether's SMaRT-5G initiative for funding under the Wireless Innovation Fund [5]. A US$2 million grant was awarded to fund a collaborative effort through 2025 to research, develop, and validate accurate and effective test methods and to create metrics and models to measure the energy efficiency of 5G network components as well as the effectiveness of end-to-end Open RAN energy optimization strategies, supporting SMaRT-5G.

Overview of Aether

Aether provides a comprehensive end-to-end platform for deploying and managing private 5G networks, offering flexibility and scalability. Organizations can utilize Aether to operate on unlicensed or private spectrum bands, empowering them to take full control of their 5G infrastructure. Core components like SD-Core and SD-RAN can be used independently or integrated as a unified solution.

SMaRT-5G is a key initiative within Aether that is aimed at developing an open, SDN-programmable 5G mobile platform that enables dynamic control over power consumption across the entire 5G network, including both RAN and core. The platform features a control loop that adjusts power consumption in real time, based on traffic capacity and quality-of-experience (QoE)

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targets. This control loop continuously tracks network performance and fine-tunes power usage. In addition, it also utilizes ML models to analyze historical traffic data, predict future capacity needs, and feed this information change power settings. By anticipating traffic changes, this predictive approach ensures that the network adapts to demand shifts while maintaining optimal QoE, resulting in more energy-efficient operations and reduced environmental impact.

Energy Efficiency in Aether

Aether exemplifies the energy-saving potential of 5G through its innovative approaches to network management. By leveraging SDN and NFV, Aether can dynamically allocate resources based on demand, ensuring optimal energy usage.

Aether provides sample applications that can be used as guiding principles for innovation. One such sample application change in camera resolution uses VISION AI and changes the network configuring based on any human movement in the camera feed.

The Aether SD-RAN project provides a software development kit to write the application for the radio network. One such example is the energy-saving radio application, which intelligently turns the cell on and off.

In summary, Aether and the SMaRT-5G initiatives from ONF offer a robust framework for the open source community to drive continuous innovation in 5G networks.

Contributor to the Solution

Collaboration among industry stakeholders, researchers, and policy makers will be essential in advancing an energy-efficient agenda. By working together, we can develop and implement best practices, standards, and technologies that promote sustainable 5G networks.

Working With Standards Bodies

Telecom networks can optimize their energy consumption if feedback is provided on potential changes to existing standards. For example, adjustments can be made to reduce the frequency of signaling toward user equipment or optimize periodic signaling intervals, leading to lower energy use. Operators should conduct in-depth energy studies to identify areas where improvements can be made, such as minimizing unnecessary network activity. By incorporating these findings into the various standards, telecom operators can significantly enhance network efficiency.

Infrastructure Vendors

Sustainability in telecom networks can be achieved through hardware upgrades that incorporate energy-efficient components such as low-power processors and advanced cooling systems. Additionally, implementing power-saving settings, like dynamic scaling and sleep modes, further reduces energy consumption while maintaining optimal network performance.

Telecom Software Solution Vendors

Telecom software solution vendors must leverage the latest advancements in software architecture, programming languages, and operating system features to reduce the power consumption of their solutions. By adopting efficient coding practices, optimizing resource utilization, and incorporating energy-saving algorithms, vendors can significantly reduce the energy footprint of their software. Additionally, integrating low-power features and dynamic scaling into network management tools will further contribute to sustainability goals. In this way, software vendors play a pivotal role in providing energy-efficient solutions that help telecom operators to minimize operational costs and environmental impact.

Research Community

Open source projects empower users and communities to innovate in the area of energy-efficient 5G networks, driving sustainability in telecom. Continued R&D will open new opportunities to optimize network operations and reduce energy consumption. These open platforms provide a solid foundation for universities and students, supporting their projects and accelerating advancements in energy-saving technologies for telecom networks.

Conclusion

Telecom operations' sustainability requires a multifaceted approach as energy savings can be achieved through various strategies. Operators must leverage all available levers, including upgrades to new architectures, to unlock substantial energy savings. Embracing cloud-native technologies, AI-driven optimization, and innovative network management approaches offers significant potential for enhancing energy efficiency in 5G networks. By adopting these advanced technologies, telecom operators can not only reduce their energy consumption but also contribute to a more sustainable and environmentally responsible future. Sustainability in telecom is an ongoing effort that requires continuous innovation and adaptation to emerging technologies. ■

Acknowledgment

Figure 1 in this article was generated with the assistance of Microsoft Copilot. ChatGPT was used for paraphrasing content after the first draft was ready.

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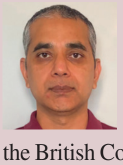
About the Author



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Silicon's War: Engineering and the Evolution of Warfare

by Mehrdad Safaei


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The study of history provides critical insights into patterns of human behavior and technological evolution. By analyzing past events, engineers and policy makers can identify trends and parallels that shape future developments. In 2025, engineers across all disciplines face a rapidly transforming global landscape marked by technological disruptions, geopolitical shifts, and emerging challenges such as drought, famine, climate crises, and armed conflict.

At the heart of these challenges is technological innovation, driven by engineers, which has consistently redefined the nature of warfare and power dynamics throughout history. From the trebuchet in medieval times to modern autonomous systems and hypersonic atomic missiles, the intersection of engineering and geopolitical strategy has played a pivotal role in shaping human history. This article explores the evolving role of technology in warfare, focusing on key domains such as aviation and space supremacy, data centers, data security, and autonomous ground forces. Through an engineering lens, it highlights how these fields are poised to influence future conflicts.

Aviation and Space Supremacy

Aviation supremacy has long been a cornerstone of military power, enabling nations to exert influence and secure strategic advantages. The emergence of unmanned aerial vehicles (UAVs) and artificial intelligence (AI)-powered aviation systems marks a paradigm shift in how aerial dominance is achieved. Unlike traditional fighter jets, which require costly pilot training and are prone to human error, autonomous systems offer greater cost efficiency, reduced operational risk, and improved precision.

Recent conflicts such as those between Ukraine and Russia, and Israel and Iran have demonstrated the effectiveness of drone warfare. Hybrid drones, combining human oversight with autonomous capabilities, have been widely deployed for reconnaissance, targeted strikes, and electronic warfare, including radar disruption.

Looking ahead, military aviation is expected to transition from piloted aircraft to fully autonomous fighter jets and missiles. Advances in machine learning, real-time data processing, satellite connectivity, and quantum encryption will enable these systems to function with unprecedented speed and accuracy. This transformation is driven by two main factors:

- *Economic viability*: Autonomous systems lower the costs associated with training and maintaining human pilots.
- *Technical efficiency*: Removing the need for life-support systems allows for more streamlined designs, increasing payload capacity and enabling greater sensor integration. This results in higher precision and more adaptable capabilities.

Space supremacy

Quantum-encrypted, AI-driven systems rely heavily on secure, high-quality data centers that are free from cyber threats, as well as fast and stable connectivity. Space provides an ideal environment where these requirements can be met simultaneously.

Militarization in space is accelerating, despite international treaties intended at preserving its neutrality. The deployment of anti-satellite weapons, missile defense systems in low-Earth orbit, and satellite-based reconnaissance platforms is transforming space into a contested strategic domain.

Electrical, robotics, and nuclear engineers play a critical role in designing satellite communication systems, advanced sensors, and high-efficiency power systems that enhance situational awareness. Historical projects such as Project Orion, a pulsed nuclear fission spacecraft, may receive renewed attention due to advances in computational power and the growing need for technological superiority in both space and on Earth. These efforts also support broader scientific exploration and progress in nanotechnology.

As global competition for space supremacy intensifies, investment in satellite technologies and orbital defense systems will continue to grow. The militarization of the Arctic and the Moon, rich in untapped resources, further highlights the strategic importance of space-based innovation. The Arctic offers access to critical minerals and favorable conditions for space operations, while the Moon presents opportunities for hosting secure data centers and communication infrastructure essential to future aerospace and defense applications.

Data, Cybersecurity, and AI

Data have become a cornerstone of modern warfare, driving decision-making processes, enhancing weapon systems, and enabling predictive analytics. However, the integrity and security of data are paramount. High-quality training data for AI systems remains one of the major challenges today, particularly for machine learning applications in autonomous vehicles, robotics, and weaponry. Advanced computer simulation software, and potentially game engines in the near future, will help improve the accuracy of datasets for various training scenarios and applications.

Computer and electrical engineers specializing in cybersecurity are on the front lines of protecting data infrastructure. The rise of cyberwarfare, where adversaries target data centers, communication networks, and cloud-based systems, necessitates robust encryption, intrusion detection systems, and real-time threat analysis tools. Cybersecurity is not solely a software concern; it heavily depends on hardware design and innovation as well. The poisoning of datasets, in which malicious actors introduce flawed data to compromise AI models, is an increasing threat. Today, detecting Trojaned AI models and logic bombs is becoming more difficult due to sophisticated attack methods that combine both physical and digital approaches. It is worth noting that many cyberattacks function like one-shot weapons. Once used, they can be discovered and neutralized. Governments around the world are expected to form dedicated cyber defense teams and invest in talent not only for wartime operations but also to protect increasingly connected and internet-dependent societies.

Quantum computing, with its potential for exponentially greater processing power and stronger encryption, presents both opportunities and risks. While it promises revolutionary advancements in computational capability, it also threatens existing cryptographic systems, requiring the development of quantum-resistant algorithms. Engineers must collaborate across disciplines to design resilient data architectures capable of withstanding cyberthreats in both physical and digital domains.

In addition, misinformation and disinformation, particularly the spread of false narratives to influence public perception and policy, are potent tools in modern conflict. AI-driven social media algorithms amplify this problem by promoting sensational content. Engineers have a key role in creating algorithms that detect and mitigate disinformation, helping to protect democratic institutions and public trust.

Data and cybersecurity technologies are also advancing into extraterrestrial domains. As lunar bases and space outposts become reality, securing digital infrastructure on the Moon will be essential to maintain safe communications, data exchange, and coordination of autonomous systems. Future innovations will depend on advanced encryption methods and decentralized networks designed to handle high latency and harsh conditions. Notably, computer simulation platforms now allow users to train systems in virtual or digital twin environments, enabling rapid development of capabilities that would otherwise require years of real-world data collection. Software platforms, including game engines, will play a central role in generating digital twins and AI-powered analytics, transforming how data are collected, processed, and secured across both Earth-based and space-based environments.

Autonomous Ground Forces

The concept of ground forces is undergoing a fundamental transformation, with humanoid robots and autonomous vehicles poised to replace human soldiers in many combat roles. Robotics engineering, along with electrical and computer engineering, combined with advancements in AI, machine vision, LiDAR and microwave sensors, and power systems ranging from new batteries to emerging generators, is enabling the creation of autonomous combat units capable of performing reconnaissance, logistics, and direct engagement missions.

The design philosophy behind humanoid robots is driven by the need for compatibility with human-centric tools and environments. From firearms to transport vehicles, most military equipment is designed for human use. By replicating human form and dexterity, humanoid robots can integrate into existing infrastructures. However, over time, due to considerations of efficiency and cost, design is expected to shift toward machine-centric systems, potentially moving humans out of the operational loop. The future battlefield will likely feature fully automated combat units with interconnected AI systems for communication, coordination, and adaptive learning. Such units may include the following:

- *Autonomous armored fleets*: Equipped with AI for navigation and targeting, reducing the need for human operators while enabling coordination, communication, and execution of offensive and defensive tasks.
- *Mobile production and repair units*: Utilizing robotic arms and 3D printing technologies to conduct on-site repairs and manufacturing.
- *Energy supply vehicles*: Serving as mobile charging stations to extend operational durations.

Ethical concerns surrounding autonomous weapon systems (AWSs) are significant. The potential for these systems to operate without human oversight raises serious questions about accountability, decision-making authority, and the risk of unintended escalation.

Energy and Semiconductor Manufacturing

The technological race for dominance in warfare is underpinned by two critical resources: energy and semiconductors, both highly dependent on rare earth elements (REEs). The future of conflict will rely on sustainable energy solutions to power data centers and the AI industry, including advancements in solar and nuclear technologies to support autonomous systems and infrastructure. Electrical engineers are at the

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forefront of developing efficient photovoltaic systems, compact nuclear reactors, and advanced battery technologies.

Semiconductor manufacturing, essential for microprocessors and integrated circuits, is another strategic priority. Nations that control semiconductor supply chains hold significant leverage in technological and military arenas. Investments in domestic semiconductor production and research into next-generation materials, such as graphene and gallium nitride, will shape future technological competitiveness.

Path Forward: Engineering Tomorrow's World

Throughout history, engineers have played a transformative role in shaping the tools of warfare. From the invention of gunpowder to the development of modern explosives, steam engines, and digital computing, their innovations have altered the global landscape and the fabric of human conflict. The future of warfare, now on the brink of unprecedented technological evolution, will continue to be driven by the ingenuity of engineers. The ability to adapt, innovate, and ethically manage these changes will determine the direction of global peace and security.

To advance, engineers must embrace interdisciplinary collaboration, leveraging expertise from computer science, nuclear engineering, physics, and ethics to create holistic solutions. Computer simulations enable virtual training in digital twin environments, allowing the rapid modeling of complex scenarios where real-world data collection would be impractical. This accelerates innovation timelines and ensures preparedness for challenges that require both agility and foresight.

The path forward also requires a strong focus on sustainable and secure technological ecosystems. Investing in quantum-resilient encryption, renewable energy for autonomous platforms, and decentralized data architectures will help establish robust defenses in both terrestrial and extraterrestrial domains. Engineering the future means not only building powerful technologies but also ensuring their responsible and ethical use. By learning from the lessons of history and applying today's advancements, engineers can help build a safer, more ethical, and innovative world, one where technology serves as a stabilizing force and a tool for human progress. ■

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About the Author

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A Trilogy of Engineering Mega Projects Important to the Future of Our Planet: The Center of Our Solar System, Ground-Based Astronomy, and Ice Core of Antarctica

by Terrance Malkinson

Three engineeringly complex mega projects are in progress with the objective of improving our understanding of the origin and sustainability of our planet. The Parker Solar Probe Project will revolutionize our understanding of the Sun. The Extra Large Telescope Project will investigate the biggest astronomical challenges of our time. The European Project for Ice Coring in Antarctica Project has the objective of retrieving a continuous record of Earth's climate and atmosphere going back 1.2 million years. These mega projects as well as many others past, present, and future demonstrate the best in engineering excellence, the career opportunities provided by professional engineering education, and the importance of science and engineering to our future.

NASA's Parker Solar Probe

Our solar system is a gravitationally bound system comprising the Sun and the objects that orbit it. Formed roughly 4.6 billion years ago, the Sun is a massive star of hot plasma heated by nuclear fusion in its core. Energy radiates from its surface as visible light and infrared radiation. The Sun has been an object of veneration for many years by many cultures.

The history of solar exploration is marked by numerous expeditions and several milestones. 1) The NASA Orbiting Solar Observatory program was a series of eight satellites launched between 1962 and 1975. The satellites were designed to investigate solar electromagnetic, ultraviolet, X-ray and gamma-ray radiation. 2) The *International Sun-Earth Explorer-3* was designed and operated by NASA and the European Space Agency (ESA). It was placed in a halo orbit around the L1 Sun-Earth Lagrange point in 1978 and monitored the solar wind. 3) The joint ESA/NASA Ulysses mission made three orbits of the Sun in the 1990s. This was the first mission to survey the space environment above and below the poles of the Sun.

The current Parker Solar Probe project (https://science.nasa.gov/mission/parker-solar-probe/) originated in a 1958 report of the National Academy of Sciences' Space Science Board, which supported a solar probe to pass inside the orbit of Mercury to study the particles and fields in the vicinity of the Sun. In the early 2010s, plans were developed for the Solar Probe Plus. In 2017, the spacecraft was named the *Parker Solar Probe* in honor of astrophysicist Eugene Parker who, in the 1950s, proposed concepts about how stars give off energy (https://news.uchicago.edu/story/eugene-parker-legendary-figure-solar-science-and-namesake-parker-solar-probe-1927-2022).

Johns Hopkins University Applied Physics Laboratory designed and built the Parker Solar Probe spacecraft, which was launched in 2018 to make observations of the Sun's outer corona (https://parkersolarprobe.jhuapl.edu/The-Mission/index.php#introduction). Multiple gravity assists from Venus were used to produce an eccentric orbit, approaching within 6.1 million km from the surface of the Sun. At its closest approach in 2024, its speed was 690,000 km/h, making it the fastest object ever built on Earth.

The spacecraft's systems are protected from the extreme heat and radiation near the Sun by a 73-kg, 11.43-cm-thick carbon-composite shield mounted and autonomously positioned on the Sun-facing side of the spacecraft. By doing so, the probe's systems and scientific instruments are always located in the shield's shadow at 29 °C. Power for the mission is provided by two solar panels. One high-gain antenna downlinks science data. Two fan-beam antennas support command uplink and real-time health and status telemetry downlink during nominal operations. Two low-gain antennas support command uplink and real-time health and status telemetry downlink during contingency operations. Preliminary telemetry data was transmitted to Earth early in January 2025.

The missions primary goals are to 1) trace the flow of energy that heats the solar corona and accelerates the solar wind, 2) determine the structure and dynamics of the plasma and magnetic fields at the sources of the solar wind, and 3) explore the mechanisms that accelerate and transport energetic particles.

The probe has four main instruments:

1. The electromagnetic fields investigation instrumentation captures the scale and shape of the electric and magnetic fields of the Sun. The electric field around the spacecraft is measured with five antennae made of a niobium alloy. A search coil magnetometer, measures how the magnetic field changes over time. Fluxgate magnetometers measure the coronal magnetic field.

Deep-drilling efforts have historically focused on central Greenland, notably the highly successful Greenland Ice Core Project and the Greenland Ice Sheet Project.

2. The integrated science investigation of the Sun instrumentation uses two complementary instruments to measure particles across a wide range of energies. This will determine the particles' lifecycle, where they came from, how they became accelerated, and how they move out from the Sun through interplanetary space. The instruments are able to detect up to 100,000 particles per second.
3. The wide-field imager for the solar probe optical telescopes instrumentation obtains images of the corona and inner heliosphere. They will also provide images of the solar wind, shocks and other structures as they approach and pass the spacecraft.
4. The solar probe analyzer and the solar probe cup instrumentation counts electrons, protons and helium ions, measuring their properties including velocity, density, and temperature.

Why is this important? The Parker Solar Probe will provide insights about solar activity including solar flares, coronal mass ejections, and geomagnetic storms. It will help us to predict how space weather can cause disruptions on Earth. This information will help us to improve satellite communications, power grid issues, pipeline erosion, radiation exposure on airline flights and astronaut safety, to name but a few.

The European Project for Ice Coring in Antarctica

One of the most important sources of information about past climate change and the composition of our atmosphere comes from the analysis of ice cores obtained from the massive ice caps of Greenland and Antarctica. Deep-drilling efforts have historically focused on central Greenland, notably the highly successful Greenland Ice Core Project and the Greenland Ice Sheet Project. The recent successful European Project for Ice Coring in Antarctica drilled and recovered deep ice cores in Antarctica on 9 January 2025. High resolution records from Antarctica are needed to complement information obtained from the ice cores previously retrieved in central Greenland.

Scientists representing 12 institutions from 10 European nations, (Belgium, Denmark, France, Germany, Italy, The Netherlands, Norway, Sweden, Switzerland, and United Kingdom) have collected Antarctic ice samples in the hope of obtaining, for the first time, a continuous record of Earth's climate and atmospheric over the past 1.2 million years (https://www.bas.ac.uk/media-post/historic-drilling-campaign-reaches-ice-more-than-1-2-million-years-old/). This project, funded by the European Commission and coordinated by the Institute of Polar Sciences of the National Research Council of Italy, drilled a 2,800-m-long ice core and reached bedrock on 9 January 2025.

Two hundred days of drilling and ice core processing operations occurred during four field seasons in the harsh environment of the central Antarctic plateau at an altitude of approximately 3,200-m above sea level, and an average summer temperature of –35 °C from a carefully selected site called *Dome C*. This site met the criteria of having ice thick enough for a well-resolved climate record at the greatest depth.

The 2,800-m ice core samples are now being carefully transported to Europe using specialised refrigerated containers. Upon reaching their European research laboratory destinations, the samples will be analyzed, revealing Earth's climate and atmospheric history over the past 1.2 million years.

Why is this important? The extracted ice core will reveal historical atmospheric temperatures and preserved air samples, including greenhouse gases, spanning thousands of years. This ice core is the longest continuous climate sequence ever extracted. They will help scientists to create a more comprehensive picture of the plane's past and reveal important details

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about climate shifts over many years and what might happen in the future.

European Southern Observatory's Extremely Large Telescope

The European Southern Observatory (ESO) is considered to be the most productive intergovernmental science and technology astronomical observatory organization in the world, with its 16 member countries (https://www.eso.org/public/about-eso/).

Extremely large telescopes are considered to be the ultimate in ground-based astronomy, allowing for a deep exploration of our universe and giving new and better views of cosmic objects. Since 2005, the ESO has been working within its community and with industry to develop an extremely large optical/infrared telescope. The ESO's Extremely Large Telescope (https://elt.eso.org/) is a revolutionary ground-based telescope and, with its 39-m main mirror, will be the largest visible and infrared light telescope in the world. A giant dome will house the telescope and its interior structure. It plans to begin observations in 2028.

In April 2010, the ESO Council selected Cerro Armazones, a mountain in the Chilean desert at an altitude of 3,046 m and which best met the rigorous criteria for astronomical observations. Mandatory criteria included the number of clear nights and low atmospheric turbulence.

The telescope will have an innovative five-mirror optical design that will allow it to view the universe in unprecedented detail. The mirrors have different shapes, sizes, and roles and will work together seamlessly to deliver observations with extreme clarity. After the ELT's mirrors have collected, corrected, and stabilised the light from astronomical objects a suite of six primary instruments will allow astronomers to observe and study the cosmos in unique ways.

- The High Angular Resolution Monolithic Optical and Near-infrared Integral Field Spectrograph will disperse the light from astronomical objects into its component wavelengths, allowing a detailed analysis that goes beyond current spectrographs.
- The Multi-AO Imaging Camera for Deep Observations will take high-resolution images of the universe at near-infrared wavelengths, identifying exoplanets, resolving individual stars in other galaxies, and investigating the centre of the Milky Way.
- The Multiconjugate Adaptive Optics Relay For Observations will enable the telescope's instruments to take exceptional images by compensating for the distortion of light caused by turbulence in Earth's atmosphere, which often makes astronomical images blurry.

The ArmazoNes High Dispersion Echelle Spectrograph will allow astronomers to study astronomical objects that require highly sensitivity observation.

- The Mid-Infrared Imager and Spectrograph will encompass the infrared wavelength range and use the 39-m main mirror of the telescope to study a wide range activities ranging from objects in our solar system to distant active galaxies.
- The ArmazoNes High Dispersion Echelle Spectrograph will allow astronomers to study astronomical objects that require highly sensitivity observation. It will be used to search for signs of life in Earth-like exoplanets, find the first stars born in the universe, test for possible variations of the fundamental constants of physics, and measure the acceleration of the universe's expansion.
- The Multi-Object Spectrograph will enable astronomers to trace the growth of galaxies and the distribution of matter from the Big Bang to the present day.

Why is this important? The Extra Large Telescope will tackle the biggest astronomical challenges of our time. It will also make fundamental contributions to cosmology by probing the nature of dark matter and dark energy. Other key science areas include the study of stars in our galaxy and beyond, black holes, and the evolution of distant galaxies up to the very first galaxies in the so-called Dark Ages—the earliest epoch of the universe—only 380,000 years after the Big Bang. Astronomers are excited about unexpected new and unforeseeable questions that will occur because of the innovative capabilities of the telescope. ■

About the Author

Terrance Malkinson graduated from the University of Calgary in 1971 with a B.Sc. degree and earned his Information Technology Professional Certificate and his B. Tech. degree in 1999 and 2001, respectively, from the Southern Alberta Institute of Technology (SAIT). Immediately upon university graduation, he was recruited to join the University of Calgary as one of the founding members of the Faculty of Medicine. Over 26 years, he advanced up the technical ladder to positions of senior research practice, management, and educational leadership, supporting many graduate students and advancing medical knowledge. Following his public service at the University of Calgary, he worked at the General Electric Company (GE) as a manager and documentation specialist throughout GE's North American operations. He was involved in a number of roles within the advanced technology and education sectors locally, nationally, and internationally. He is a Senior Life Member of IEEE. He has authored more than 600 earned and well-respected research publications and presented the results of original basic and applied research at numerous local, national, and international professional meetings. He mentors undergraduate students, graduate students, postdoctoral fellows, academic staff, and visiting scientists. He was a member of the Editorial Advisory Board of The Institute (2010–2014), and vice-chair of communications for IEEE-USA (2004–2010). He was a pioneer in lifelong learning, advancing his career by pursuing continuing education opportunities at leading institutions. Of particular significance in his life was participation in many wilderness adventure leadership programs facilitated by Outward Bound Canada. In honour of his lifelong and many contributions to the University of Calgary, the Calgary community, and the advancement of scientific knowledge, he was inducted into the Order of the University of Calgary in 1997. He was elected to the Board of Governors of the IEEE Engineering Management Society (2004–2007) and was editor of *IEEE Engineering Management* (2003–2007). He is an associate editor and contributor to *IEEE Canadian Review* (1998-present). He was recently named SAIT Polytechnic's 2024 Distinguished Alumni in recognition of his demonstrated leadership skills, exceptional achievements in business and industry, outstanding contributions to the community, and a history of support for education. In 2025, he was named a Compelling Calgarian.

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History Matters

by David G. Michelson
IEEE Canada Historian

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

While historical fact is immutable, historical evidence is inherently fragile and often irreplaceable. Accordingly, efforts to preserve and interpret the past are among the most valuable of legacies.

IEEE history activities have three overarching goals: 1) to make the public aware of the contributions of our profession, 2) to promote pride in the profession among our members, and 3) to provide our members with the background and insights required to fully engage in discussions regarding public policy. In this column, we review 1) the 2025 priorities of the IEEE History Committee, 2) the 2025 priorities of the IEEE Canada History Committee, 3) 2025 conferences of interest to Canadian historians of technology, and 4) the new history of technology track of *IEEE Canadian Journal of Electrical and Computer Engineering* (*CJECE*).

2025 Priorities of the IEEE History Committee

The IEEE History Committee's 2025 priorities include both developing and strengthening our many existing programs such as Milestones, fellowships and prizes, REACH, and the new Global Museum and playing a leading role in the development of a broader IEEE history community that includes all those who play key roles in revealing the history of technology, including collectors, curators, archivists, public historians, academic historians, and practicing scientists and engineers. In support of this agenda, the IEEE History Committee will

- launch a new IEEE history website that will provide visitors with an outward-facing presentation of our programs and activities and complement the historical content that resides on the Engineering and Technology History Wiki (ETHW). It will also provide a technical foundation for future initiatives such as an online IEEE history magazine and a virtual component of the IEEE Global Museum. Funded by the IEEE New Initiatives Committee, the site will go live during the first quarter of 2025.
- launch online IEEE history training through the IEEE Individual Learning Network, which will acquaint proposers, advocates, reviewers, and others with the history and context of the program and the best practices that have evolved over the years, with an aim toward helping to ensure that the program delivers evermore consistently and effectively going forward. We anticipate that the training will become available in the second quarter of 2025.
- host the first IEEE History Summit this summer and providing a venue for the IEEE history community to share best practices for preserving and sharing the heritage of both the Institute and the profession, and involve collectors, curators, archivists, public historians, academic historians, and practicing scientists and engineers in pursuing the IEEE history mandate.
- host the second IEEE History Week, which coincides with IEEE Day in October 2025, and once again give both the Committee and the Center an opportunity to share our programs with the broader IEEE community and invite IEEE organizational units, e.g., Regions, Sections, and Societies) to participate in preserving and sharing their own heritage.

The IEEE History Committee looks forward to working with the broader IEEE history community to bring these initiatives to fruition and making a lasting contribution to IEEE's efforts to preserve and share the heritage of both the Institute and the profession.

2025 Priorities of the IEEE Canada History Committee

The 2025 IEEE Canada History Committee includes five members: David Michelson, chair (University of British Columbia); Scott Campbell (University of Waterloo); Colin Clark (Brookfield Renewable); Andrew Elliott (Library and Archives Canada); and Xianbin Wang (Western University). The Committee's 2025 priorities include 1) hosting a special session on

The effort to establish relationships between IEEE Canada Sections and local science and technology museums benefits both parties.

the history of technology at CCECE 2025, 2) providing history content for the new IEEE Canada website, 3) encouraging each of IEEE Canada's Sections to appoint historians who will be the focal point for efforts to update their Section's history on the ETHW and support those wishing to propose IEEE Milestones, and 4) encouraging IEEE Canada Sections to establish relationships with science and technology museums within their territories.

The effort to establish relationships between IEEE Canada Sections and local science and technology museums benefits both parties. Depending on the museum's needs, IEEE is well positioned to help 1) publicize the museum to the IEEE community; 2) encourage IEEE Members to volunteer their time, either as volunteers or as technical experts, to assist in interpreting their collections; and 3) jointly develop science, technology, engineering, and mathematics-oriented outreach programs. At the same time, museums are well positioned to help IEEE make the public aware of both IEEE and the contributions of our profession. The IEEE History Center has established a museums database in ETHW that can help the Committee, Sections, and museums to keep track of these relationships.

History of Technology Conferences in 2025

Several history of technology conferences of interest the IEEE Canada members will be held in 2025:

- CCECE 2025 will be held from 26 to 29 May 2025 in Vancouver. Building on the success of the 2024 event, the conference will once again feature a half-day special session on the History of Technology. Both abstracts (up to 250 words) and full papers (5–7 pages) that concern, but are not limited to, the following topics are welcome: 1) the history of electrical engineering, electronics, and computing, their applications, and their impact on social and economic development; 2) the people, programs, places, policies, institutions, and organizations that have shaped the history of electrical engineering, electronics, and computing; and 3) efforts to preserve and promote our technological history and heritage. Contributions from academia, government, industry, nonprofit organizations, and IEEE Members and organizational units (OUs) are all encouraged. For more details, visit https://ccece2025.ieee.ca/.
- The Canadian Society for the History and Philosophy of Science (CSHPS) will hold its 2025 conference at George Brown College in Toronto as part of the annual Congress of the Humanities and Social Sciences (30 May–6 Jun 2025). CSHPS is a Canadian forum that brings together historians, philosophers, sociologists, and a wide range of interdisciplinary scholars who are interested in exploring all aspects of science, past and present. More details can be found at: http://cshps.ca/.
- The IEEE History of Electrotechnology Conference (HISTELCON) will be held in Bonn, Germany from 30 September to 2 October 2025 in Bonn, Germany. Contributions from academia, government, industry, nonprofit organizations, and IEEE Members and OUs are all encouraged. For more details, visit https://2025.ieee-histelcon.org/. (IEEE Canada will host IEEE HISTELCON in 2027 in Ottawa.)
- The Canadian Science and Technology Historical Association hosts its biennial conference in odd years. The conferences are small but engaging and collaborative events that promote a high level of interaction and discussion. The next scheduled conference will be held in October/November 2025. For more details, visit https://cstha-ahstc.ca/biennial-conference/ when it becomes available.

History of Science and Technology and *CJECE*

Since 1976, *CJECE* has been publishing high-quality refereed scientific papers in all areas of electrical and computer engineering. It is indexed in both ISI and IEEE *Xplore*. *CJECE* recently introduced a track on the "History of Science and Technology" and invites paper submissions that present new and original results, techniques or concepts, and survey-style papers that provide a rigorous analysis of existing results. Manuscripts should have between six and 12 pages. For more details, visit http://journal.ieee.ca. ■

About the Author

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

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). Members can opt in for print or digital copies through IEEE membership renewal web page.

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IEEE Canadian Foundation

Why Scholarships Matter: Scholarships Are a Vital Resource

Scholarships provide financial assistance, reducing educational expenses, which allows students to focus more on studies and less on financial stress. Yes, money matters.

Beyond financial support, receiving a scholarship can enhance a resume, open doors to various opportunities, and provide a sense of personal accomplishment and motivation.

The benefits of scholarships include the following:

- *Scholarships relieve the burden of tuition fees*: Statistics Canada reports the average undergraduate tuition fee of Canadian students in engineering is CAD$9,272,[a] with considerable variation across Canada.
- *Scholarships strengthen curriculum vitae (CV) achievements*: Recognition by a prestigious and relevant, prominent organization such as IEEE shows that the recipient is ambitious and a high achiever. Some individuals keep the record of an IEEE scholarship on their CV, even more than 20 years later.
- *Scholarships open opportunities for advanced education*: A scholarship at the undergraduate level positions a person well for opportunities at higher levels.
- *Scholarships enable more focus on learning and campus activity*: Scholarships may reduce the student's need for part-time work, allowing the student to focus more while studying and engaging in IEEE activities on campus.
- *Scholarships help with networking*: Recipients of IEEE scholarships are encouraged (sometimes required) to attend in-person events such as Section AGMs to receive recognition and certificates. For some students, this may be their first opportunity to network with people at all stages of professional and advanced academic life.
- *Scholarships encourage philanthropy*: Students who are helped by philanthropy may go on to be more philanthropic by donating to "pay it forward" or even founding another scholarship.
- *Scholarships show that IEEE cares*: Scholarships present immediate benefits to students, with the potential to lead students to a lasting connection to IEEE.

Your Gift Helps

Gifts to the IEEE Canadian Foundation sustain our national programs, including our high-impact IEEE Canadian Foundation Scholarships.

Create a Lasting Legacy

Designed to be self-sustaining, a new scholarship may be established in your name or in the name of friends, family, colleagues, or a business. Investment in future generations can be aligned with donor values, interests, and priorities. For more information about how to donate, please visit www.ieeecanadianfoundation.org. ■

[a] https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3710000301.

IEEE Canadian Foundation Scholarship—Fall 2024 Awards

"Receiving the IEEE Canadian Foundation Scholarship has been an incredible honour and a significant support for my academic journey. This recognition has bolstered my commitment to the IEEE community, providing financial relief for tuition costs and inspiring me to deepen my engagement with IEEE activities. The award has motivated me to continue contributing meaningfully to the organization and the broader engineering field."

—*Winny Dariska Domkem Kameni*
Algonquin College

"Receiving an ICF [IEEE Canadian Foundation] scholarship has shown to me that the IEEE Canadian Foundation is invested in my future. This prize makes me feel proud of my work to extend the reach of the IEEE into my university, and motivates me to continue volunteering as I enter my professional career. This financial support has provided me a head start into my transition from school to a job in the industry, allowing me to focus on my goals as a young engineer. I am incredibly honored to be a recipient of this scholarship."

—*Graham Zelinski*
University of Saskatchewan

IEEE History

This has already been an extremely productive year for the IEEE History Committee and the IEEE History Center, the highlights of which have been:

- **the launch of a new IEEE History website, which will make IEEE History programs easier to find, to understand, and**
- **plans to hold the second IEEE History week from 6-10 October 2025, which encourage OUs to complete and share history projects that are currently underway.**

For more information:

https://history.ieee.org

https://historyweek.ieee.org/

HISTORY @ IEEE CCECE 2026

The IEEE Canadian Conference on Electrical and Computer Engineering (CCECE) 2026 in Montreal will feature a special track on the History of Technology. This is a great opportunity for those pursuing Science and Technology Studies (STS) in this field to share their work.

Both abstracts (up to 250 words) and full papers (5-7 pages) concerning, but not limited to, the following topics are welcome:

- *the history of electrical engineering, electronics, and computing, their applications, and their impact on social and economic development*
- *the people, programs, places, policies, institutions, and organizations that have shaped the history of electrical engineering, electronics and computing*
- *efforts to preserve and promote our technological history and heritage*

Contributions from academia, government, industry, non-profit organizations, and IEEE members and OUs are all encouraged. Full papers will be submitted to IEEE Xplore.

CSTHA I AHSTC

Canadian Science and Technology Historical Association

l'Association pour l'histoire de la science et de la technologie au Canada

Every two years—on the odd year—CSTHA hosts its biennial conference. The conferences are small, but engaging and collaborative events that promote a high level of interaction and discussion. The next scheduled conference will be held at York University in Toronto between 7-9 November 2025.

https://cstha-ahstc.ca/

IEEE Canadian Journal of Electrical and Computer Engineering

Since 1976, the IEEE Canadian Journal of Electrical and Computer Engineering (IEEE CJECE) has been publishing high-quality refereed scientific papers in all areas of electrical and computer engineering. It is indexed in both ISI and IEEE Xplore.

The IEEE CJECE invites submission of papers concerning the History of Science and Technology including:

1. **Papers presenting new and original results, techniques or concepts, and,**
2. **Survey-style papers providing a rigorous analysis of existing results.**

https://journal.ieee.ca

IEEE HISTELCON 2025

September 30 – October 2, 2025
Bonn, Germany

HIStory of ELectrotechnology CONference is the only IEEE conference that addresses the history of technology and its implications for modern society, industry and education. It is part of the R8 portfolio of conferences and was organized for the first time in France in 2008. The 2025 edition is the ninth. On March 31, 2024, an agreement between R8 and R7, R9 and R10 was signed to transform this conference into a multi-region event. From 2026 onward, it will rotate among the four regions and always with the Technical Co-sponsorship of the IEEE History Center and the IEEE History Committee.

https://www.ieee-histelcon.org

The International Union of Radio Science (abbreviated URSI, after its French name, Union Radio-Scientifique Internationale) has a long history of cooperating with IEEE to advance international cooperation in the study of electromagnetic fields and waves. This month's column focuses on the resurgence of interest in amateur radio among university students in Canada and the ways in which IEEE Canada can support this.

David G. Michelson
dmichelson@ieee.org
president@ursi.ca

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During much of the 20th century, amateur radio was a natural entry point for students who intended to pursue careers in radio engineering. In a tightly regulated radio regulatory environment, students viewed amateur radio as a unique opportunity to acquire practical experience with wireless technology and to exchange insights and experience with like-minded individuals. Employers tended to view an amateur radio certificate and licence as an indication of an applicant's practical experience and commitment to the field. Initiatives such as the Canadian Amateur Digital Radio Operator's Certificate that was offered between 1978 and 1996 sought to ensure that amateur radio would continue to provide opportunities to gain experience with leading-edge communications technologies and keep up with the rapid advances then taking place in computer communications over wireless channels.

By the 1980s, the relevance of amateur radio to students interested in pursuing a career in wireless technology became less certain as the fundamental nature of the amateur and commercial radio services continued to diverge. By the late 1990s and early 2000s, student involvement in amateur radio fell off even further as cellular telephony exploded and relatively inexpensive standards-based, licence-exempt short-range digital wireless technologies (Bluetooth, Wi-Fi, ZigBee, and so on) became available. Students suddenly had many opportunities to gain experience with and enjoy the convenience of wireless technology without the need to acquire an amateur radio licence. Already experiencing decline, many more university amateur radio clubs closed.

Starting in the mid- to late 2000s, student interest in amateur radio began to rebound. First, the introduction of the CubeSat concept in the early 2000s by Bob Twiggs of Stanford University and Jordi Puig-Suari of California Polytechnic University suddenly made it possible for university teams to consider developing and launching a small satellite. The medium of choice for communicating with such satellites was and continues to be amateur radio, simply because the regulatory path is so much more straightforward than other approaches. Aspiring CubeSat developers had strong reasons to get licensed and begin honing their skills by assembling their own Earth stations so that they could work existing satellites while designing and building their own satellites.

Second, the introduction of the WSJT software and its multiplicity of digital modes for weak-signal radio communication by Joe Taylor, in 2001, K1JT enabled possible for radio amateurs with relatively modest stations to make long-distance contacts via ionospheric propagation, meteor scatter, moonbounce, and so on, and gain first-hand insights into the effects of space weather on wireless propagation. Similarly, the introduction of GNU Radio, also in 2001, originally based on a fork of the Spectra code that was developed by the SpectrumWare project at the Massachusetts Institute of Technology, made it possible for more advanced students to, with comparatively modest effort, develop their own sophisticated software-defined radio applications by developing relatively simple applications that called routines in the sophisticated GNU Radio signal processing libraries. The release of a multiplicity of software-defined radio platforms during the past 20 years has provided developers with the freedom to select the platform that matches the cost-performance constraints of the project.

Third, during the past 20 years, universities began to formalize the organization and governance of student design teams formed to compete in intermural engineering design competitions. Such competitions focus on the design and operation of all manner of craft that operate in the air, on land, and in the water. As the operation of such vehicles moved from relatively restricted indoor environments to wide area outdoor environments, licence-exempt short-range digital wireless technology proved inadequate, but fully commercial wide area solutions often proved too expensive. Once again, amateur radio often filled the gap.

The foundation of amateur radio in Canada continues to rest on long-time participants in public service and recreational activities. However, this resurgence of interest in amateur radio among university students and IEEE student branches bodes well for the long-term viability of the amateur radio service.

THE CANADIAN BASIC QUALIFICATION SYLLABUS AND UPDATES TO THE QUESTION BANK

The Canadian Basic Qualification Syllabus is broken into the following eight sections:

1) Regulations and Policies
2) Operating and Procedures

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

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

3) Station Assembly, Practice and Safety
4) Circuit Components
5) Basic Electronics and Theory
6) Feedlines and Antenna Systems
7) Radio Wave Propagation
8) Interference and Suppression.

The current syllabus closely matches the proposal for Certificate "A" that the Department of Communications [now Innovation, Science and Economic Development Canada (ISED)] issued in 1985:

- Installation and operation of modern amateur stations, including proper interpretation of meter readings such as automatic limiter circuit and standing wave ratio and the adjustments that are necessary to prevent interference, proper grounding techniques, and correct installation practices from transceiver to antenna, including auxiliary devices such as low-pass filters and antenna tuners.
- Basic electronic theory, safety practices when working with simple circuits, and tracing and correcting interference problems such as audio rectification and receiver front end and overload.
- Antenna and propagation theory, including types of antennas, feedlines, and characteristics of propagation phenomena.
- International and domestic regulations that are applicable to the amateur service.

Working with Radio Amateurs of Canada, ISED updated the Canadian Basic Qualification Question Bank that was issued on 30 March 2023 and will start using the updated set of questions and answers effective 15 July 2025.

IEEE CANADA, THE 2025 IEEE CANADIAN CONFERENCE ON ELECTRICAL AND COMPUTER ENGINEERING, THE 2025 IEEE ANTENNAS AND PROPAGATION SOCIETY/INTERNATIONAL SYMPOSIUM AND NORTH AMERICAN RADIO SCIENCE MEETING, AND AMATEUR RADIO

The vast majority of training materials available to those who are preparing to write the basic qualification exam are aimed at a general audience. The updating of the basic question bank and the resurgence of interest in amateur radio among university students raises an obvious question: Is there a need and a place for amateur radio training materials that are aimed at IEEE Student Members rather than a general audience?

In the meantime, two major wireless conferences that are taking place in Canada in 2025, the IEEE Canadian Conference on Electrical and Computer Engineering (Vancouver), 26–29 May 2025, and the IEEE International Symposium on Antennas and Propagation and North American Radio Science Meeting (Ottawa), 13–18 July 2025, will print participants' amateur callsigns on their conference badges and hold amateur-radio-themed events and licence exams as part of the conference program. ■

About the Author

David G. Michelson is president of the Canadian National Committee of the International Union of Radio Science (2018–2026). He has led the Radio Science Lab at the University of British Columbia (UBC), Department of Electrical and Computer Engineering, since 2003. His current research focuses on verification and validation of wireless systems and the history of wireless technology. Prof. Michelson currently serves as a member of the Board of Governors of the IEEE Vehicular Technology Society, as faculty advisor for the ALEASAT CubeSat project, and as principal investigator of the Campus as a Wireless Living Lab project at UBC. He is licensed in Canada (basic, advanced, digital, and morse code) as VA7DM and in the United States as NC7V (extra class). He is an Innovation, Science and Economic Development Canada-accredited amateur radio examiner.

In Memoriam


Terry Branch

Terry Branch, Life Senior Member of IEEE, passed away on 26 October 2024. Terry was a distinguished electrical engineer and a dedicated member of the IEEE and Canadian engineering community. His commitment and passion for the field were evident in his every action.

He made his way to Canada in 1970 from Grenada, pursuing an education at the Radio College of Canada and, subsequently, a degree in electrical engineering from the University of Toronto. He served as the principal and manager of PDR Technologies, offering his expertise to major industrial plants since 1993. With an extensive background in electrical power systems, Terry led numerous projects across diverse industries, including mining, pulp and paper, food processing, and energy production, collaborating with companies such as The Iron Ore Company of Canada, Domtar, Fluor, and Trans Canada.

Beyond his professional achievements, Terry was deeply committed to advancing engineering standards and education. His work on the CSA Z463 standard on electrical systems maintenance and his engagement with the University of Toronto's Engineering Strategies and Practice program showcased his passion for developing both industry standards and future engineers. He was a long-standing contributor to technical committees, including more than 20 years with the Canadian Standards Association and the IEEE Industry Applications Society, where he demonstrated his unwavering commitment to safety, risk management, and technical excellence.

Beyond his professional achievements, Terry was deeply committed to advancing engineering standards and education.

An author and award-winning presenter, Terry shared his knowledge through numerous papers, winning the Best Mill Paper Award at an IEEE conference in 1988. His impact, however, extended far beyond his professional achievements. He mentored many, and his recent involvement in the new Group Mentoring initiative with IEEE Life Members is a testament to his dedication to the next generation of engineers. Furthermore, Terry provided inspiration and guidance to engineers near the end of their careers as Canada's life members coordinator until his passing. His legacy is not just in the colleagues that he inspired and the students that he mentored but in the lasting impact of his work on the engineering profession.

Terry will be remembered as a kind, passionate man who brought a room to life with his energy. Above all, he was devoted to his family. He is survived by his wife Sheila, brothers Denis and Willoughby, sister Carol-Ann, children Michael and Andrew, and grandchildren Ben, Ryan, Sydney, Nico, and Nora. ■

Terry Branch, membre senior à vie de l'IEEE, est décédé le 26 octobre 2024. Terry était un ingénieur en génie électrique remarquable et un membre engagé de l'IEEE et de la communauté des ingénieurs canadiens. Chaque action reflétait son engagement et sa passion pour le domaine.

Il est arrivé au Canada en 1970 en provenance de la Grenade, où il a poursuivi des études au Radio College of Canada, puis obtenu un diplôme en génie électrique de l'Université de Toronto. Depuis 1993, il occupait le poste de directeur et gestionnaire chez PDR Technologies, offrant son expertise à de grands complexes industriels. Fort d'une solide expérience dans les systèmes de puissance électrique, Terry a dirigé de nombreux projets dans des secteurs variés, notamment l'exploitation minière, les pâtes et papiers, la transformation alimentaire et la production d'énergie, en collaboration avec des entreprises telles que The Iron Ore Company of Canada, Domtar, Fluor et TransCanada.

Outre ses réalisations professionnelles, Terry était fortement engagé à faire avancer les normes d'ingénierie et l'éducation. Son travail sur la norme CSA Z463 concernant l'entretien des systèmes électriques, ainsi que son implication dans le programme de stratégies et de pratique en ingénierie de l'Université de Toronto, ont mis en avant son intérêt pour l'élaboration de normes industrielles et pour les ingénieurs à venir. Il a joué un rôle important dans plusieurs comités techniques pendant plus de 20 ans, en travaillant avec l'Association canadienne des normes et la IEEE Industry Applications Society, où il a montré son engagement inébranlable envers la sécurité, la gestion des risques et l'excellence technique.

Terry, un auteur et conférencier primé, a communiqué ses connaissances à travers de nombreux articles, et a été récompensé par le prix du meilleur papier lors d'une conférence IEEE en 1988. Son impact dépassait largement ses réalisations professionnelles. Il a été mentor de nombreux ingénieurs, et sa récente implication dans la nouvelle initiative de mentorat de groupe avec les membres IEEE à vie illustre son engagement envers la prochaine génération d'ingénieurs. Il a également accompagné des ingénieurs en fin de carrière dans son rôle de coordonnateur des membres à vie pour le Canada, fonction qu'il a assumée jusqu'à son décès. Son héritage ne réside pas seulement dans les collègues qu'il a inspirés et les étudiants qu'il a encadrés, mais aussi dans l'impact durable de son travail sur la profession d'ingénieur.

On se souviendra de Terry comme d'un homme bon, passionné, et dont l'énergie illuminait chaque pièce. Par-dessus tout, il était profondément dévoué à sa famille. Il laisse dans le deuil sa femme Sheila, ses frères Denis et Willoughby, sa sœur Carol-Ann, ses enfants Michael et Andrew, ainsi que ses petits-enfants Ben, Ryan, Sydney, Nico et Nora. ■

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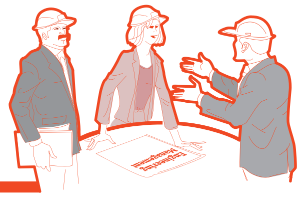
Biz Tech Report



by Terrance Malkinson

Our Canadian flag was inaugurated on 15 February 1965, 60 years ago. Today, more than ever, not only should we celebrate our flag but also remind ourselves what it represents: our values, resilience, sovereignty, and the values we all cherish—generosity, openness, respect. and equality.

In this Biz Tech Report, we celebrate the historical excellence of Canadian creativity, innovation, and entrepreneurship. Canada has much to be proud of and this selection of accomplishments represents only a small portion of achievements by many native-born Canadians, the many incredible people who immigrated to Canada, and Indigenous peoples. Their achievements often begin with an opportunity or a problem, both of which require creativity to resolve and courage to implement. Engineers have restless curiosity and determination to better the world. IEEE has a plethora of resources and a network of incredible people to help facilitate your creativity, innovation, and entrepreneurial dreams.

Education

An innovative vision for applied education as a response to unprecedented shifts in technology, our economy and communities were shared on 11 February 2024 in Calgary at the unveiling of the Southern Alberta Institute of Technology's (SAIT) CAD$150 million Real Futures fundraising campaign (see Figure 1) (https://calgaryherald.com/news/local-news/sait-fundraising-campaign-transform-campus-programs).

Established in 1916, SAIT is a global leader in applied education and research, serving 40,000 students annually through certificate, diploma, postdiploma, apprenticeship, applied degrees, baccalaureate degrees, corporate training, and continuing education courses. The world is changing rapidly, and SAIT education is being boldly proactive to ensure that students have the necessary skills to succeed and industry has the talent needed to thrive. SAIT welcomes participation by the community in formulating this bold, forward-thinking vision. The Institute will embrace fresh perspectives and reimagine education through new technologies, learning spaces, and ideas. The Real Futures campaign will transform the who, how, and what of education, preparing students to meet the moment, embrace change, and unlock future potential opportunities that will drive career success and propel the economy forward. Real Futures will facilitate SAIT's ability to deliver on the industry's talent needs. This will be the result of an even stronger "collaborative approach" with industry and community partners to advance applied education.

Real Futures will facilitate SAIT's ability to deliver on the industry's talent needs.

Artificial Intelligence

Canada's leading data centre provider, eStruxture Data Centers (https://www.estruxture.com/), will develop its next and largest facility in near Calgary. This CAD$750 million, 90-MW operation is expected to power up in 2026. The site is seen as possessing the essential requirements of high-speed Internet connectivity, land, and dependable power, which will all mitigate catastrophic data processing failures. The installation will increase data centre capacity related to health, finance, telecommunications, transportation, manufacturing, and more. The Alberta government also recently announced a new data centre strategy (https://www.alberta.ca/artificial-intelligence-data-centres-strategy) that is intended to provide a business-friendly environment for artificial intelligence (AI) data centres. Another proposal by Canadian entrepreneur Kevin O'Leary is to develop the world's largest AI data centre near Grande Prairie, Alberta. At an estimated cost of more than CAD$70 billion it would provide 7.5 GW of capacity.

The education sector is grappling with the growth of AI. Concern often focuses on ethical issues around student misconduct. This must be understood within a larger context. With the right mindset, AI can provide critical and engaged learning, benefiting the student and society. Our leaders of education and business understand the importance that knowledge of AI has for our economy, and the ethical issues in curriculum design and student evaluation.

Health and Wellness

It is well known that regular exercise improves our quality of life, enhancing cognition, creativity, innovation, and entrepreneurship. We are exercising more now than previously and this is occurring individually, often in one's own home rather than in a gym or through team sports. Experiencing exercise conveniently as individuals, they continued after the pandemic. The cost-effectiveness of individualized training and use of new technologies are appealing. We need to upgrade our community recreation facilities, particularly for individual activities including aquatics, field sports, and bicycling as well as a gathering place for our youth.

Gerard Vroomen started researching bike dynamics at the Eindhoven University of Technology. He took his knowledge to Canada to continue the research at McGill University. In 1995, Vroomen and Phil White founded Cervélo Cycles. The book, *To Make Riders Faster*, by Anna Dopico, tells the story of Vroomen and White meeting as engineering students and growing their company from a basement project in Montréal to a company that would forever change the cycling industry. Cervélo bikes are the bicycle of choice by cycling enthusiasts worldwide and have been ridden to victory at the Tour de France, the Olympics, and Ironman Triathlon. In 1921, Frederick Banting and Charles Best successfully isolated insulin for diabetes treatment, allowing people worldwide to lead normal lives. John Hopps's invention of the pacemaker for treating heart rhythm disorders improved the quality of life for patients. Norman Bethune developed innovative mobile medical units and pioneering battlefield surgical techniques that saved many lives.

Indigenous First Nations People

Canada's First Nations People pioneered a number of innovations that we use today. The Inuit, Yupik, and Aleut people were the first to use kayaks, thought to have been invented 5,000 years ago. The toboggan, a wood sled used to transport goods and people over snow and ice, was a First Nations innovation. The precursors to modern sunglasses were invented by the Inuit and the Yupik. Created from materials including driftwood, walrus ivory, bone, and caribou antlers, they offered protection against snow blindness. Canada's First Nations had been making their very own petroleum jelly compound for centuries by blending olefin hydrocarbons and methane.

Transportation

The Confederation Bridge, linking Prince Edward Island to mainland Canada, spans 12.9 km. The bridge was engineered, designed, and constructed to withstand extreme cold, high winds, and ice formations. The Vancouver SkyTrain is the longest (80 km) automated driverless transit system in the world on a fully grade-separated track. The St. Lawrence Seaway is a system of locks, canals, and channels that allows ships to travel from the Atlantic Ocean to the Great Lakes. The Seaway provides benefits to both Canada and the United States, fueling economic growth and promoting sustainable development. The Trans-Canada Highway stretches 7,821 km from Victoria, British Columbia, to St. John's, Newfoundland. The highway has been continuously upgraded, particularly through the rugged Rocky Mountains, as innovative highway engineering practices emerge. The transcontinental Canadian Pacific Railway was and is crucial for economic development and national unity. Building through the Rocky Mountains and dense forests presented engineering challenges. Frank Stronach started a small tool and die shop in a garage. Working 16-h days and innovating auto parts manufacturing, he grew Magna into a global automotive supplier, proving that dreamers can become industry leaders. Garrett Camp transformed how people move in cities worldwide, creating Uber to make transportation convenient and accessible. Canada is the birthplace of the snowmobile. The motorized sled was invented in 1922 by 15-year-old Joseph-Armand Bombardier, patented and commercialized in 1937 used for winter rescue operations and in rural areas for transportation. George Klein invented an electric wheelchair with a control system that could be operated with minimal hand strength and coordination. Canadian Robert Foulis created the first steam-powered foghorn, which was installed on New Brunswick's Partridge Island in 1859. His invention has saved lives around the world.

Figure 1: SAIT President and CEO Dr. David Ross speaks at the launch of the Real Futures fundraising campaign on 11 February 2025.

Communication

Alexander Graham Bell designed the first telephone in 1876. The walkie-talkie was first invented in 1937 by Canadian Don Hings to help pilots communicate effectively. The pager was invented in 1949 by Canadian-born Alfred Gross and revolutionized personal communication, particularly for doctors and emergency responders. Mike Lazaridis and Jim Balsillie created BlackBerry with a vision of mobile e-mail and messaging, which revolutionized mobile communications, proving that Canadian entrepreneurs could compete in global communication. Dax Dasilva created the retail management software company Lightspeed, which offers affordable solutions for independent businesses, powering more than 100,000 businesses. Reginald Fessenden revolutionized communication by making the first amplitude modulation radio broadcast in 1906, proving that radio could transmit complex audio content over long distances. Saul Klein was instrumental in developing Internet technologies that would shape e-commerce security and accessibility. Tobi Lütke created Shopify, the platform that powers more than a million online stores worldwide, transforming small businesses. Ann Cavoukian developed the globally recognized Privacy by Design framework and has been instrumental in protecting individual rights in the digital age as an advocate for ethical technology development. James Gosling revolutionized software development by creating the Java programming language in 1991. Geoffrey Hinton contributed machine learning and neural networks, establishing the groundwork for modern AI technologies. The world's most immersive cinema experience was conceived in 1968 by Canadian filmmakers Graeme Ferguson, Roman Kroitor, and Robert Kerr, together with engineer William Shaw. Hired to create a multiscreen movie at Montréal's Expo 67, they used multiple projectors to do the job. The technology was refined into a single projector the following year, and IMAX was born, making education an extraordinary visual experience.

Space

The Canadarm, used in space missions, has been critical in satellite repairs and the assembly of the International Space

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Station. Its technology has inspired robotics in surgery and manufacturing, allowing for precise and controlled operations in various fields. Canadian-designed and built instrumentation for the James Webb Telescope has exceeded all expectations. The first antigravity suit was developed in 1941 by a team led by Wilbur Franks at the University of Toronto's Banting and Best Medical Institute. The technology ultimately proved crucial for the U.S. space program. While in Canada, Arthur Clarke developed theories about satellite communication, establishing the foundation for modern global communication systems.

Other

At 553 m, the CN Tower in Toronto held the title of the world's tallest freestanding structure for 34 years. The tower's design and construction techniques revolutionized civil engineering. The Niagara Falls Hydroelectric Power Stations harness the power of Niagara Falls to provide clean and renewable energy to both Canada and the United States. Starting as a car salesman in Vancouver, Jim Pattison worked long hours selling and cleaning cars. He expanded into radio stations, grocery stores, and advertising, building one of Canada's largest private companies, proving that determination knows no bounds. A single mother with no post-secondary education, Arlene Dickinson worked her way up through determination and talent, transforming Venture Communications into one of Canada's largest marketing firms. Her success on Dragons' Den has inspired entrepreneurs across Canada. Robert Herjavec worked as a waiter while learning about computers. Through persistence and innovation, he built BRAK Systems into Canada's largest Internet security company. Donna Strickland developed chirped pulse amplification, used in laser technology, and won the Nobel Prize in Physics. Dani Reiss focused on quality and authentic Arctic heritage, manufacturing in Canada, and building the global luxury brand Canada Goose. The caulking gun was invented in 1894 by Theodore Witte of British Columbia. The bi-pin lamp fitting connector was created by Québécois innovator Reginald Fessenden for the 1893 World's Fair in Chicago. Egg carton packaging was invented in 1911 by newspaper publisher Joseph Coyle in British Columbia. While working as a graduate student at McGill University in the 1930s, William Chalmers invented Plexiglas, which has seen applications well beyond its initial concept. Electrical engineer Gideon Sundbäck was working for the Universal Fastener Company in Ontario when he came up with the idea for the first modern zipper. The snow blower was invented in 1925 by Québécois Arthur Sicard, a milkman who set his mind to creating a machine that could easily clear snow.

Canadians have much to be proud of, and we welcome your suggestions of success stories to promote in *IEEE Canadian Review* and in the Biz Tech Report. ■

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About the Author

Terrance Malkinson graduated from the University of Calgary in 1971 with a B.Sc. degree and earned his Information Technology Professional Certificate and his B. Tech. degree in 1999 and 2001, respectively, from the Southern Alberta Institute of Technology (SAIT). Immediately upon university graduation, he was recruited to join the University of Calgary as one of the founding members of the Faculty of Medicine. Over 26 years, he advanced up the technical ladder to positions of senior research practice, management, and educational leadership, supporting many graduate students and advancing medical knowledge. Following his public service at the University of Calgary, he worked at the General Electric Company (GE) as a manager and documentation specialist throughout GE's North American operations. He was involved in a number of roles within the advanced technology and education sectors locally, nationally, and internationally. He is a Senior Life Member of IEEE. He has authored more than 600 earned and well-respected research publications and presented the results of original basic and applied research at numerous local, national, and international professional meetings. He mentors undergraduate students, graduate students, postdoctoral fellows, academic staff, and visiting scientists. He was a member of the Editorial Advisory Board of The Institute (2010–2014), and vice-chair of communications for IEEE-USA (2004–2010). He was a pioneer in lifelong learning, advancing his career by pursuing continuing education opportunities at leading institutions. Of particular significance in his life was participation in many wilderness adventure leadership programs facilitated by Outward Bound Canada. In honour of his lifelong and many contributions to the University of Calgary, the Calgary community, and the advancement of scientific knowledge, he was inducted into the Order of the University of Calgary in 1997. He was elected to the Board of Governors of the IEEE Engineering Management Society (2004–2007) and was editor of *IEEE Engineering Management* (2003–2007). He is an associate editor and contributor to *IEEE Canadian Review* (1998-present). He was recently named SAIT Polytechnic's 2024 Distinguished Alumni in recognition of his demonstrated leadership skills, exceptional achievements in business and industry, outstanding contributions to the community, and a history of support for education. In 2025, he was named a Compelling Calgarian.

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IEEE | IEEE AP-S Antennas and Propagation Society | IEEE Canada | MTT-S | IEEE Newfoundland and Labrador Section

Call for Papers

ANTEM 2025

Antem2025.ieee.ca

July 20-23, 2025

Holiday Inn St. John's Conference Centre, St. John's, NL, Canada

IEEE 20th International Symposium on Antenna Technology and Applied Electromagnetics

"More Than Transatlantic"

List of ANTEM Topics

Antennas

- Antenna Theory
- Dielectric, Planar & Conformal Antennas
- Antenna Miniaturization & Integration
- Intelligent Reconfigurable Antennas
- Phased Arrays, Reflect-Arrays, and Lenses
- Reflector Antennas
- Wearable & Wireless Sensor Antennas
- On-Chip/In-Package Antennas
- Terahertz & Optical Antennas
- UWB Antennas & Systems

Field Theory & Computation

- Analytic & Numerical Methods
- Modelling & EM-CAD Tools
- Scattering & Diffraction
- Inverse Scattering & Remote Sensing
- Guided Waves
- Transients & Time Domain Electromagnetics

Radio Science

- Electromagnetic Metrology
- Fields and Waves
- Radiocommunication Systems & Signal Processing
- Electronics and Photonics
- Electromagnetic Environment & Interference
- Wave Propagation & Remote Sensing
- Ionospheric Radio & Propagation
- Waves in Plasmas
- Radio Astronomy
- Electromagnetics in Biology and Medicine

Electromagnetic Systems, Devices & Applications

- Propagation & Channel Modelling
- Next Generation Mobile Communication & Sensing
- Electromagnetic Metrology
- Machine Learning
- Satellite/CubeSat Radio Communication Systems
- Terrestrial & Ionospheric Radio Communication
- Automotive Radar & Imaging Systems
- Software Defined Radio
- MEMS & Micromachining for RF Systems
- Microwave-to-THz Devices, Circuits & Imaging
- MIMO Systems
- Photonic Devices & Circuits
- Vehicular Electromagnetics
- Wireless Power Transmission
- Electromagnetic Energy Harvesting
- Biomedical Imaging & Sensing
- Electromagnetic Field Measurement
- Electromagnetic Properties & Material Characterization
- Electromagnetic Interference & Compatibility
- Spectrum Management & Spectrum Policy

New Phenomena & Engineered Media

- Bio-electromagnetics
- Nano-electromagnetics
- EBG/Metamaterial Structures
- Frequency Selective Surfaces

Important Dates

Full Paper Submission
Jan. 17, 2025

Notification of Acceptance
Mar. 1, 2025

Final Paper Submission
Apr. 1, 2025

Early Bird Registration Deadline
May 1, 2025

Conference Date
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