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Spring Into Action

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Quest for Ethical Artificial Intelligence

IEEE Canada
The Institute of Electrical and Electronic Engineers Inc.

President's Message/Message du Président

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

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

Dear esteemed IEEE Canada members, as we embark on another year of camaraderie and collective growth, I am honored to extend a warm welcome to each and every one of you. It is with great pride and humility that I assume the role of president of IEEE Canada and director of IEEE Region 7, responsibilities I hold with deep reverence and commitment.

The world around us is evolving at an unprecedented pace, presenting both opportunities and obstacles. Yet, I am confident that with our collective expertise and unwavering resolve, we are well equipped to navigate these uncharted waters and emerge successfully.

If I can think about one expression that should mark my term (2024–2025), it's "*positive change*." Change and positive transition within volunteer-based organizations are pivotal for the growth, personal development for our community, and creation of positive outcomes for humanity. As part of my journey with you, I will also support changes that will make us more efficient,

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Chers membres de l'IEEE Canada, alors que nous entamons une autre année de camaraderie et de croissance collective, je suis honoré de souhaiter la bienvenue à chacun d'entre vous. C'est avec beaucoup de fierté et d'humilité que j'assume le rôle de président de l'IEEE Canada et de directeur de la région 7 de l'IEEE, responsabilités que j'assume avec beaucoup de respect et d'engagement.

Le monde qui nous entoure évolue à un rythme sans précédent, présentant à la fois des opportunités et des obstacles. Malgré tout, je suis fermement convaincu que notre expertise collective et notre détermination inébranlable nous permettent de naviguer dans ces eaux inconnues et de réussir pleinement.

Si je peux me permettre de penser à une expression qui devrait caractériser mon terme (2024–2025), c'est "changement positif". La croissance, le développement personnel de notre communauté et la création de résultats positifs pour l'humanité nécessitent un changement et une transition positive de la part des organisations

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Spring Into Action

BACKGROUND—IMAGE LICENSED BY INGRAM PUBLISHING

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reduce waste, and enable our volunteers and staff to get the very best from our nonprofit organization, IEEE Canada. Embracing change is essential to staying relevant, adapting to evolving needs, and maximizing impact in the communities we serve. Transition allows for new opportunities for reflection, renewal, and innovation, enabling volunteer committees to realign their strategies, streamline processes, and leverage their collective strengths more effectively.

Change and positive transition within volunteer-based organizations are pivotal for the growth, personal development for our community, and creating positive outcomes for humanity.

One of the key drivers of positive transition is enabling a *culture of openness, respect, caring, and collaboration* within volunteers managed by Operational Committees. By encouraging active participation, sharing diverse perspectives, and fostering a sense of ownership and accountability, empowered Operational Committees can harness the full potential of their members and drive meaningful change. I believe that to best serve our IEEE community, we may implement regular feedback mechanisms, organize brainstorming sessions, and establish new task forces to address specific challenges or opportunities.

Additionally, effective and open *communication* is essential to create trust, collaboration, stable operations, and engagement for all our community. Clear and transparent communication channels ensure that all members are kept informed and engaged throughout the process, reducing uncertainty and encouraging us to be the best we can be. Whether through regular meetings, newsletters, or digital platforms, keeping everyone on the same page facilitates teamwork, allows transitions, and enhances overall efficiency.

Moreover, I will support investing in *volunteer training and development* as I believe it is crucial for ensuring a smooth transition and maximizing the impact of committee members. Providing access to relevant resources, workshops, and mentorship opportunities not only equips volunteers with the necessary skills and knowledge but also empowers us, as volunteers, to take on leadership roles and drive positive change within our respective functions and Operational Committees.

Recognition of our Region professionals' achievements and award initiatives plays a crucial role in acknowledging excellence, inspiring innovation, and fostering a culture of continuous improvement within our organization. These initiatives, when implemented in transparent, fair, systematic, and meaningful ways, serve as powerful motivators, rewarding Region 7 active volunteers and teams from industry, academia, and government backgrounds equally for their dedication, ingenuity, and contributions to their respective fields. By honoring excellence, inspiring innovation, and fostering collaboration, these initiatives not only elevate individual professionals but also contribute to the growth, success, and sustainability of the industries and communities they serve. We will keep you updated on our revamped

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bénévoles. Je vais également soutenir les changements dans le cadre de mon parcours avec vous, pour être plus efficace, réduire le gaspillage et permettre à nos bénévoles et à notre personnel d'obtenir le meilleur de notre organisation à but non lucratif, IEEE Canada. Il est essentiel d'adopter le changement pour rester pertinent, s'adapter aux besoins changeants et maximiser l'impact dans les collectivités que nous soutenons. Les comités bénévoles peuvent réajuster leurs stratégies, rationaliser leurs processus et tirer parti plus efficacement de leurs forces collectives grâce à la transition, offrant ainsi de nouvelles possibilités de réflexion, de renouvellement et d'innovation.

La croissance, le développement personnel de notre communauté et la création de résultats positifs pour l'humanité nécessitent un changement et une transition positive de la part des organisations.

Un élément clé d'une transition positive est de promouvoir une *culture d'ouverture, de respect, de bienveillance et de collaboration* parmi les bénévoles supervisés par les comités opérationnels. En soutenant la participation active, en partageant des perspectives variées et en encourageant un sentiment d'appartenance et de responsabilité, les comités opérationnels compétents peuvent exploiter pleinement le potentiel de leurs membres et susciter un changement majeur. Je crois que pour mieux servir notre communauté IEEE, nous pouvons mettre en œuvre des mécanismes de rétroaction réguliers, organiser des séances de remue-méninges et établir de nouveaux groupes de travail pour relever des défis ou des opportunités spécifiques.

De plus, une communication efficace et ouverte est cruciale pour susciter la confiance, la collaboration, des opérations stables et l'engagement pour l'ensemble de notre communauté. Des voies de communication claires et transparentes assure que tous les membres sont informés et impliqués tout au long du processus, ce qui réduit l'incertitude et nous incite à donner le meilleur de nous-mêmes. Que ce soit au moyen de réunions régulières, de bulletins d'information ou de plateformes numériques, le fait de garder tout le monde sur la même longueur d'onde facilite le travail d'équipe, permet les transitions et améliore l'efficacité globale.

De plus, je soutiendrai l'engagement envers *la formation et le perfectionnement des bénévoles*, car je suis convaincu qu'ils sont indispensables pour garantir une transition fluide et maximiser l'engagement des membres du comité. En donnant accès à des ressources pertinentes, à des ateliers et à des occasions de mentorat, non seulement les bénévoles acquièrent les compétences et les connaissances nécessaires, mais ils nous habilitent aussi, en tant que bénévoles, pour assumer rôles de direction et favoriser un changement positif au sein de nos fonctions respectives et de nos comités opérationnels.

La ***reconnaissance*** des réalisations et des initiatives de récompenses des professionnels de notre région est essentielle pour reconnaître l'excellence, encourager l'innovation et promouvoir la culture d'amélioration continue au sein de notre organisation. Ces initiatives, lorsqu'elles sont mises en œuvre de manière

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plans for the IEEE Canada Awards and Recognition Committee for the years ahead.

With all that in mind, starting this year, we have restructured our multiple committees and consolidated them into four major *Operational Committees* with multiple functions and direct representation from geographical Sections to achieve matrix-type dynamics. In this case, we have positively transformed our flatly distributed resources into a more structured and empowered organizational chart operationally. These newly developed Operational Committees' leaders and functions' coordinators gathered in February with our Steering Committee and area chairs in first-of-its-kind workshop-type meetings, where IEEE Canada's respective operational plans for 2024 and beyond were discussed, and the respective key performance indicators (KPIs) and options for success and growth were identified.

Clear and transparent communication channels ensure that all members are kept informed and engaged throughout the process, reducing uncertainty and encouraging us to be the best we can be.

Technology associations like IEEE globally and IEEE Canada regionally serve as collaboration hubs of knowledge and networking, providing a platform for professionals from academia, industry, and government organizations to exchange ideas, share best practices, and stay updated on the latest advancements in their field.

Industry experts play a pivotal role in this collaboration, bringing practical experience, industry insights, and real-world challenges to the table. By actively engaging industry professionals and enterprises with IEEE Canada and the academic professionals within IEEE, they can contribute to the development of relevant curriculum to the job market, mentor aspiring talent, and collaborate on research projects that address industry needs and drive technological innovation. These collaborations enable a seamless transfer of knowledge and expertise, fueling innovation, driving economic growth, and shaping the future of industries. I believe that IEEE Canada can play a major role in leading such initiatives when we efficiently focus on attracting more industry professionals to be IEEE members and active volunteers, adding value to our Operational Committees. In 2024, a new industry engagement team of volunteers has taken charge and has started a progressive plan to shape IEEE Canada's engagement with industries and IEEE members from the industry sector.

IEEE Canada's propriety conferences play a crucial role in the growth and success of our organization, in addition to the numerous international IEEE conferences held successfully in collaboration with our Sections in various Canadian locations due to the popularity and leadership of our Canadian professionals and scholars.

These conferences obviously provide networking opportunities as a platform for professionals to connect, share ideas, and

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transparente, équitable, systématique et significative, créent de puissants facteurs de motivation et de récompense pour les bénévoles et les équipes actives de la région 7 de l'industrie, du milieu universitaire et du gouvernement pour leur dévouement, leur ingéniosité et les contributions à leurs domaines respectifs. En célébrant l'excellence, en stimulant l'innovation et en encourageant la collaboration, ces initiatives non seulement émanent des professionnels individuels, mais contribuent également à la croissance, au succès et à la durabilité des industries et des collectivités qu'elles servent. Nous vous tiendrons informé des modifications apportées à nos plans pour le Comité des prix et la reconnaissance de l'IEEE Canada pour les années à venir.

En gardant cela à l'esprit, à partir de cette année, nous avons réorganisé nos multiples comités et les avons regroupés en quatre grands comités opérationnels avec de multiples fonctions et une représentation directe des sections géographiques, pour établir une dynamique matricielle. Nous avons réussi à transformer de manière bénéfique nos ressources distribuées de façon équilibrée en un organigramme opérationnel plus structuré et plus autonome. Ces nouveaux dirigeants de comités opérationnels et coordonnateurs des fonctions se sont réunis en février avec notre comité directeur et les présidents de secteur lors de réunions de type atelier inédites, où les plans opérationnels respectifs de l'IEEE Canada pour 2024 et au-delà ont été discutés, et les indicateurs de rendement clés (IRC) et les options de réussite et de croissance ont été déterminés.

Les associations technologiques comme l'IEEE à l'échelle mondiale et l'IEEE Canada à l'échelle régionale servent de carrefours de collaboration et de réseautage, offrant une plateforme aux professionnels du milieu universitaire, de l'industrie et des organismes gouvernementaux pour échanger des idées, partager des pratiques exemplaires et rester à jour sur les dernières avancées dans leur domaine.

Les experts de l'industrie sont un pilier de cette collaboration, offrant une expérience pratique, des informations sur l'industrie et des défis concrets. En impliquant de manière active les professionnels de l'industrie et les entreprises avec IEEE Canada et les professionnels universitaires au sein de l'EEE, ils peuvent participer à la mise en place de programmes pertinents pour le marché du travail, encadrer les talents potentiels et collaborer à des projets de recherche qui répondent aux besoins de l'industrie et stimulent l'innovation technologique. Ces partenariats favorisent le partage continu des connaissances et de l'expertise, ce qui stimule l'innovation, stimule la croissance économique et façonne l'avenir des industries. Je suis persuadé que l'IEEE Canada peut jouer un rôle important dans la réalisation de telles initiatives, en s'attachant efficacement à attirer un plus grand nombre de professionnels de l'industrie pour devenir membres de l'IEEE et des bénévoles actifs, ce qui contribue à la valeur de nos comités opérationnels. En 2024, une équipe de bénévoles de l'engagement industriel a instauré un plan progressif visant à établir l'engagement de l'IEEE Canada envers les industries et les membres de l'IEEE du secteur industriel.

Les conférences de l'IEEE Canada jouent un rôle crucial dans la croissance et le succès de notre organisation, en plus des nombreuses conférences internationales de l'IEEE tenues avec succès en collaboration avec nos sections dans divers endroits au Canada en raison de la popularité et du leadership de nos professionnels et universitaires canadiens.

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build relationships, leading to collaborations, partnerships, and knowledge exchange, which can in turn benefit IEEE Canada and our members. Knowledge sharing through presentations, workshops, and panels, where experts share the latest research, trends, and best practices within the field, elevates knowledge transfer to a higher level and is essential for keeping members informed and competitive.

Conferences also provide visibility and branding, raising awareness of IEEE and its mission to attract potential new members and sponsors, and lead to revenue generation that can be reinvested to fund additional programs and initiatives. In addition, many other benefits are created, such as professional development, community building, innovation, and inspiration.

These collaborations enable a seamless transfer of knowledge and expertise, fueling innovation, driving economic growth, and shaping the future of industries.

With that in mind, I can proudly share that our IEEE Canada Conference Advisory Committee (CONAC) is successfully proceeding with overcoming the negative impacts of the COVID-19 pandemic and, starting in 2024, a progressive action plan to sustainably reconduct our Canadian Conferences, such as the 2024 IEEE Canadian Conference on Electrical and Computer Engineering (CCECE 2024) in August at Queen's University in Kingston, Ontario, followed by the 2025 International Symposium on Antenna Technology and Applied Electromagnetics (ANTEM 2025) in St. Johns, Newfoundland, and the 2025 Canadian Electrical Power and Energy Conference (EPEC 2025), followed by solid plans for 2026 and thereafter, where the conference locations will be rotated again between the three IEEE Canada areas.

Extending beyond our Region, IEEE Canada will also be hosting the 2025 International Humanitarian Technologies Conference in Edmonton, Alberta, in continuation of our collaboration with IEEE Regions 8 and 9. Also, we just reached an agreement with IEEE Regions 8 and 10 to join them in hosting the IEEE HISTory of ELectrotechnology Conferences (HISTELCONs), which are dedicated to aspects of the history of electrical engineering, electronics, computing, and their impact on social and economical and development. Presently, IEEE Canada is undertaking plans to be the potential host for HISTELCON 2027 in Ottawa.

I also believe that knowledge-based organizations like IEEE Canada can play a vital role in shaping public policy by leveraging our expertise, knowledge, and advocacy/advisory efforts to influence decision-making processes at local, national, and international levels. Therefore, this year, we decided to establish the IEEE Canada Public Policy Committee.

IEEE, comprising professionals and experts in various fields, is uniquely positioned to provide informed insights and recommendations on issues ranging from technology standards and regulations to research funding and industry best practices.

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Ces conférences offrent évidemment des opportunités de réseautage, comme une plate-forme pour les professionnels de se connecter, d'échanger des idées et d'établir des relations, conduisant à des collaborations, des partenariats et à l'échange de connaissances, ce qui peut à son tour profiter à l'IEEE Canada et à nos membres. Les présentations, les ateliers et les panels, où les experts partagent les dernières recherches, tendances et meilleures pratiques dans le domaine, aident à étendre le transfert des connaissances à un niveau supérieur et sont essentiels pour maintenir les membres informés et compétitifs.

Les conférences offrent également une visibilité et une image de marque, sensibilisent à l'IEEE et à sa mission pour attirer de nouveaux membres et sponsors potentiels et génèrent de revenus qui peuvent être réinvestis pour financer des programmes et des initiatives supplémentaires. En outre, de nombreux autres avantages sont créés, tels que le développement professionnel, le développement communautaire, l'innovation et l'inspiration.

Dans cette optique, je suis fier de vous annoncer que notre comité consultatif des conférences de l'IEEE Canada (CONAC) a réussi à surmonter les impacts négatifs de la pandémie de COVID-19 et, à compter de 2024, un plan d'action progressif pour la reconduction durable de nos conférences canadiennes, comme la Conférence canadienne sur le génie électrique et informatique 2024 (CCECE 2024) en août à l'Université Queen's à Kingston, Ontario, suivi du Symposium international sur la technologie des antennes et l'électromagnétisme appliqué de 2025 (ANTEM 2025) à St. Johns, Terre-Neuve, et de la Conférence canadienne sur l'électricité et l'énergie de 2025 (EPEC 2025), suivi de solides plans a partir de 2026; où les lieux des conférences seront permutés entre les trois régions de l'IEEE Canada.

Au-delà de notre région, l'IEEE Canada sera également l'hôte de la conférence internationale sur les technologies humanitaires 2025 à Edmonton, en Alberta, dans la continuité de notre collaboration avec les régions 8 et 9. De plus, nous avons récemment convenu de nous associer aux régions 8 et 10 de l'IEEE pour héberger les conférences ELectrotechnology Conferences (HISTELCONs), mettant l'accent sur l'histoire de l'ingénierie électrique, électronique, informatique ainsi que sur leur impact sur le développement social et économique. Actuellement, l'IEEE Canada est en train de planifier l'accueil de HISTELCON 2027 à Ottawa.

Je crois également que les organisations fondées sur le savoir comme IEEE Canada peuvent jouer un rôle essentiel dans l'élaboration des politiques publiques en tirant parti de notre expertise, de nos connaissances et de nos efforts de défense et de consultation pour influencer les processus décisionnels aux niveaux local, national et international. Par conséquent, cette année, nous avons convenu de mettre en place le Comité des politiques publiques de l'IEEE Canada.

L'IEEE, constitué de professionnels et d'experts dans différents domaines, est particulièrement bien positionné pour donner des idées et des recommandations éclairées sur des questions telles que les normes et réglementations technologiques, le financement de la recherche et les meilleures pratiques de l'industrie. L'une des contributions importantes peut être la formulation d'énoncés de position et de notes d'orientation qui peuvent façonner et élaborer des recommandations fondées sur des données probantes afin d'informer les décideurs sur les principaux enjeux qui ont une incidence sur nos industries respectives et les initiatives qui favorisent l'innovation, la croissance économique et le bien-être de la société.

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One significant contribution may be through the formulation of position statements and policy briefs that can shape and develop evidence-based recommendations to inform policy makers on key issues impacting our respective industries, and initiatives that are conducive to innovation, economic growth, and societal well-being. Additionally, IEEE could serve as a trusted source of information and expertise for policy makers, the media, and the public through our educational programs, seminars, and publications. IEEE Canada will take an instrumental advisory role in this important task directly or through our influential role as one of the largest members of the Engineering Institutes of Canada, and also by empowering our representation in the Partnership Committee for Science and Engineering in that direction.

As we embark on this journey together, let us remain guided by the spirit of collaboration, caring, courtesy, and cooperation.

During my term, IEEE Canada will play a significant role in supporting *Indigenous communities* by leveraging our expertise, resources, and networks to foster sustainable development, promote cultural preservation, and address pressing challenges faced by Indigenous peoples. Potential collaboration between IEEE Canada and Indigenous communities can lead to mutually beneficial outcomes, including capacity building, knowledge sharing, and the cocreation of solutions tailored to the unique needs and priorities of Indigenous populations. IEEE Canada can contribute to the realm of capacity building and skill development. By offering training programs, workshops, and educational resources, we will empower Indigenous community members with the knowledge and skills needed to pursue careers in technical fields such as engineering, IT, and environmental science. This not only enhances employment opportunities and economic empowerment within Indigenous communities but also ensures that they have the expertise to address local challenges and drive sustainable development initiatives that protect us all.

By harnessing the power of technology, Indigenous communities can enhance their resilience, improve their quality of life, and preserve their cultural heritage for future generations. This was the motivation behind our decision this year to establish the *IEEE Canada Indigenous Communities Standing Committee* under my direct supervision and also focus on attracting more engineering/technology professionals and students from the Indigenous communities' background to join as members and active volunteers who contribute to our Operational Committees.

As we embark on this journey together, let us remain guided by the spirit of collaboration, caring, courtesy, and cooperation. Let us embrace diversity and celebrate the unique perspectives that each of us brings to the table. Let us never lose sight of the profound impact that we can make when we unite for a common purpose.

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De plus, l'IEEE pourrait offrir des renseignements et une expertise fiable aux décideurs, aux médias et au public, grâce à nos programmes éducatifs, séminaires et publications. IEEE Canada jouera un rôle consultatif déterminant dans cette tâche importante directement ou par son rôle influent en tant que l'un des plus grands membres des Iécoles d'ingénieurs du Canada, et aussi en renforçant notre représentation au sein du Comité de partenariat pour les sciences et le génie dans cette direction.

L'IEEE, constitué de professionnels et d'experts dans différents domaines, est particulièrement bien positionné pour donner des idées et des recommandations éclairées sur des questions telles que les normes et réglementations technologiques, le financement de la recherche et les meilleures pratiques de l'industrie. L'une des contributions importantes peut être la formulation d'énoncés de position et de notes d'orientation qui peuvent façonner et élaborer des recommandations fondées sur des données probantes afin d'informer les décideurs sur les principaux enjeux qui ont une incidence sur nos industries respectives et les initiatives qui favorisent l'innovation, la croissance économique et le bien-être de la société.

Alors que nous entreprenons ce voyage ensemble, restons guidés par l'esprit de collaboration, de bienveillance, de courtoisie et de coopération.

Au cours de mon mandat, l'IEEE Canada jouera un rôle crucial en apportant son expertise, ses ressources et ses réseaux pour favoriser le développement durable, encourager la préservation culturelle et faire face aux défis urgents auxquels les peuples autochtones font face. Une collaboration potentielle entre l'IEEE Canada et les communautés autochtones peut produire des résultats mutuellement bénéfiques, en particulier en renforçant les capacités, en partageant les connaissances et en créant des solutions adaptées aux besoins et aux priorités uniques des populations autochtones.

IEEE Canada peut aider à renforcer les capacités et à développer les compétences. En proposant des formations, des ateliers et des ressources éducatives, nous fournirons aux membres des communautés autochtones les connaissances et les compétences requises pour évoluer dans des domaines techniques tels que le génie, la TI et les sciences de l'environnement. Cela renforce non seulement les opportunités d'emploi et l'autonomie économique au sein des communautés autochtones, mais assure également qu'elles disposent de l'expertise requise pour relever les défis locaux et entreprendre des initiatives de développement durable qui nous protègent tous.

L'exploitation du pouvoir de la technologie permet aux communautés autochtones d'améliorer leur résilience, d'améliorer leur qualité de vie et de préserver leur patrimoine culturel pour les générations à venir. C'est ce qui a motivé notre décision cette année de créer le *Comité permanent des communautés autochtones de l'IEEE Canada* sous ma supervision directe et de mettre l'accent sur l'attraction d'un plus grand nombre de professionnels de l'ingénierie et de la technologie et d'étudiants issus des communautés autochtones pour adhérer en tant que membres et bénévoles actifs qui contribuent à nos comités opérationnels.

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President's Message/Message du Président

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In the coming months and years, I look forward to working closely with each of you to chart a course toward a more prosperous and equitable future. Together, we will continue to build upon the rich legacy of our organization and leave an indelible mark on the world around us.

Thank you for your unwavering support and dedication. Together, there is no limit to what we can achieve. ■

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

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Alors que nous entreprenons ce voyage ensemble, restons guidés par l'esprit de collaboration, de bienveillance, de courtoisie et de coopération. Embrassons la diversité et célébrons les perspectives uniques que chacun d'entre nous apporte à la table. Gardons toujours à l'esprit l'impact profond que nous pouvons avoir lorsque nous nous unissons pour un but commun.

Je suis enthousiaste à l'idée de collaborer étroitement avec chacun d'entre vous pour assurer un avenir plus prospère et équitable au cours des mois et des années à venir. Ensemble, nous poursuivrons la construction du riche héritage de notre organisation et laisserons une empreinte indélébile sur le monde qui nous entoure.

Je vous remercie de votre appui et de votre dévouement indéfectible. Ensemble, il n'y a pas de limite à ce que nous pouvons accomplir. ■

Tom Murad, P.Eng., Ph.D., F.E.C., SMIEEE
2024–2025 IEEE Canada President
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A Few Words From the Editor-in-Chief / Quelques mots du rédacteur en chef

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With this Spring 2024 edition, *IEEE Canadian Review* (*ICR*) starts 2024 and looks forward to another exciting year. As the world around us changes, so are we. Under the leadership its the new president, Dr. Tom Murad, IEEE Region 7 has recently gone through a fundamental change in its operations.

The Region's organizational structure has been recently streamlined. The Publications and Communications Committee (PCC) now has a healthy mix of experience and

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L'édition du printemps 2024 marque le début de l'année 2024 pour IEEE Canadian Review (ICR) et se réjouit d'une année passionnante à venir. Comme le monde qui nous entoure évolue constamment, nous aussi. Sous la gouvernance de M. Tom Murad, le nouveau président, la région 7 de l'IEEE a récemment opéré un changement majeur dans ses opérations.

Récemment, la région a procédé à une rationalisation de sa structure organisationnelle. Le Comité des publications et des communications (CCP) a désormais une combinaison équilibrée

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

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enthusiasm. Have a look at the Region roster in this edition of *ICR*. The "President's Message" column also captures a fresh slate of activities geared toward positive changes in multiple areas that include culture change, effective communication, volunteer development, member recognition, industry engagement, conference events, Indigenous activities, and public policy. The *ICR* community surely looks forward to being part of this journey.

Terrance Malkinson writes a very unique piece on the 80th anniversary of D-Day.

This edition of *ICR* brings back Darioush Shiri's series article on microfluidity. A significant level of interest has been garnered through his writings. I am sure that this will continue. As the discussions, awareness, and debate continue to grow in the areas of artificial intelligence (AI), Mehrdad Safaei writes on the ethical aspects. I hope this will be food

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(Quelques mots du rédacteur en chef suite de p. 7)

d'expérience et d'enthousiasme. Consultez la liste des régions dans cette édition de l'IC pour obtenir plus d'informations. La colonne « Message du président » présente également une nouvelle liste d'activités axées sur des changements positifs dans plusieurs domaines, notamment le changement de culture, la communication efficace, le perfectionnement des bénévoles, la reconnaissance des membres, l'engagement de l'industrie, les événements de conférence, les activités autochtones, et la politique publique. Il est certain que la communauté de l'IC est impatiente de faire partie de ce voyage.

Dans cette édition de l'ICR, on retrouve l'article de la série de Darioush Shiri portant sur la microfluidité. Ses écrits ont suscité beaucoup d'intérêt. Je suis confiant que cela se poursuivra. Alors que les discussions, la sensibilisation et le débat ne cessent de se multiplier dans les domaines de l'intelligence artificielle (IA), Mehrdad Safaei se concentre sur les aspects éthiques. J'espère que cela encouragera beaucoup de personnes à réfléchir, et nous cherchons à publier plus sur l'émergence de l'IA.

Terrance Malkinson a rédigé une pièce unique pour célébrer le 80e anniversaire du jour J. Ce document établit un

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for thought for many, and we aim to publish more on the emergence of AI.

Terrance Malkinson writes a very unique piece on the 80th anniversary of D-Day. This article nicely ties Canadian war history to the Provincial Institute of Technology and Art, currently SAIT, located in Alberta.

Recently, *ICR* filled two vacant positions of vice editor-in-chief. I am pleased to announce that Dr. David G. Michelson and Dr. Gautam Srivastava have been appointed to these roles. Both of the new vice EiCs are known to our readers through their regular columns and many engagements with IEEE and IEEE Canada. We now look forward to refreshing the editors' panel.

Enjoy this edition of *ICR* and share your comments and feedback through icr@ieee.ca. ■

(Quelques mots du rédacteur en chef suite de p. 8)

lien entre la mémoire de la guerre canadienne et l'Institut provincial de technologie et d'art, connu sous le nom de SAIT, en Alberta.

Deux postes vacants de vice-rédacteur en chef ont été comblés récemment par ICR. C'est avec joie que je vous annonce que David G. Michelson et Gautam Srivastava ont été nommés à ces postes.

Nos lecteurs connaissent les deux nouveaux vice-ReC grâce à leurs chroniques régulières et à leurs nombreux engagements avec l'IEEE et l'IEEE Canada. Nous sommes impatients de rafraîchir le groupe de rédaction.

Profitez de cette édition de l'IC et partagez vos commentaires en utilisant l'icr@ieee.ca. ■

Superfluidity for Engineers, Part 3: Applications

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In this part of the *Superfluidity for Engineers* series, we see how superfluidity can be "listened to" by a microphone and how superfluid He is used to "watch" the sound!

Let me rephrase the previous paragraph. We will learn about superfluid He ultra-sensitive gyroscopes, which are 10^{10} times more sensitive than the classical ones, and the application of superfluid He in photographing sound propagation in crystalline solids. Conveying the essence of these applications to the reader without using too many technical details and historical anecdotes is attempted, but using a few equations is unavoidable.

Quantum Whistle

Quantum physics dictates that when the liquid becomes superfluid, each He atom loses its own identity, and a single wave function describes the whole condensate:

$$\psi = \sqrt{\rho_s}\, e^{i\phi}. \qquad (1)$$

The absolute magnitude of the wave function is the density of superfluid, i.e.,

$\psi \cdot \psi = |\psi|^2 = \rho_s$, and ϕ the is the phase of the wave function. Both the density and phase are, in general, functions of time and space. The hydrodynamic current density of superfluid is

$$\boldsymbol{j}_s = \rho_s \boldsymbol{v}_s \quad (2)$$

where $\boldsymbol{v}_s$ is the velocity vector. It can be proved [1] that the velocity of the superfluid flow in the condensate is proportional to the gradient of the quantum mechanical phase (ϕ).

$$\boldsymbol{v}_s = \frac{h}{2\pi m_4} \nabla \phi \quad (3)$$

where h is Planck's constant ($h = 6.626 \times 10^{-34}$ J.s), and m_4 is the mass of the ^{4}He atom.

Let's prepare two containers with different amounts of superfluid and bring them in contact with a narrow pipe, orifice, or, in technical terms, a weak link. The classical intuition says that the fluid must flow unidirectionally from the tall column to the short column of liquid. But nature does not always follow our intuition and always surprises us. Here is what happens. When the containers of superfluid are brought into contact, the wave functions of both sides of fluids overlap through the link [Figure 1(a)], and quantum physics dictates that the current flow is the sinusoidal function of the phase difference between the wave functions of two containers, i.e., $\theta = \phi_1 - \phi_2$.

$$\boldsymbol{I}_s = I_c \sin(\theta). \quad (4)$$

Furthermore, the rate of change of phase difference with time is proportional to the chemical potential difference between both containers ($\Delta\mu = \mu_1 - \mu_2$)

$$\frac{d\theta}{dt} = -\frac{2\pi}{h} \Delta\mu. \quad (5)$$

The chemical potential difference is a function of temperature and pressure difference. But when $\Delta T = 0$ (an assumption we make in this article), it is given by

$$\Delta\mu = \frac{m_4}{\rho} \Delta P \quad (6)$$

where ρ is the mass density of superfluid ^{4}He. This means that the chemical potential difference is proportional to the pressure difference between two containers. From now on, we call this *pressure difference* the *bias*. Therefore, (5) can be rewritten as

$$\frac{d\theta}{dt} = -\frac{2\pi m_4}{h\rho} \Delta P. \quad (7)$$

In the case of two cylinders, this pressure difference (bias) comes from the height difference [Figure 1(b)], but in other configurations of weakly linked containers, this pressure bias must be mechanically supplied, e.g., by a piezoelectric deformable diaphragm or a pump.

Let's regroup (4) and (7):

$$\boldsymbol{I}_s = I_c \sin(\theta) \quad (8)$$

$$\frac{d\theta}{dt} = -\frac{2\pi m_4}{h\rho} \Delta P. \quad (9)$$

These equations are called *Josephson* equations. In 1962, Brian David Josephson,

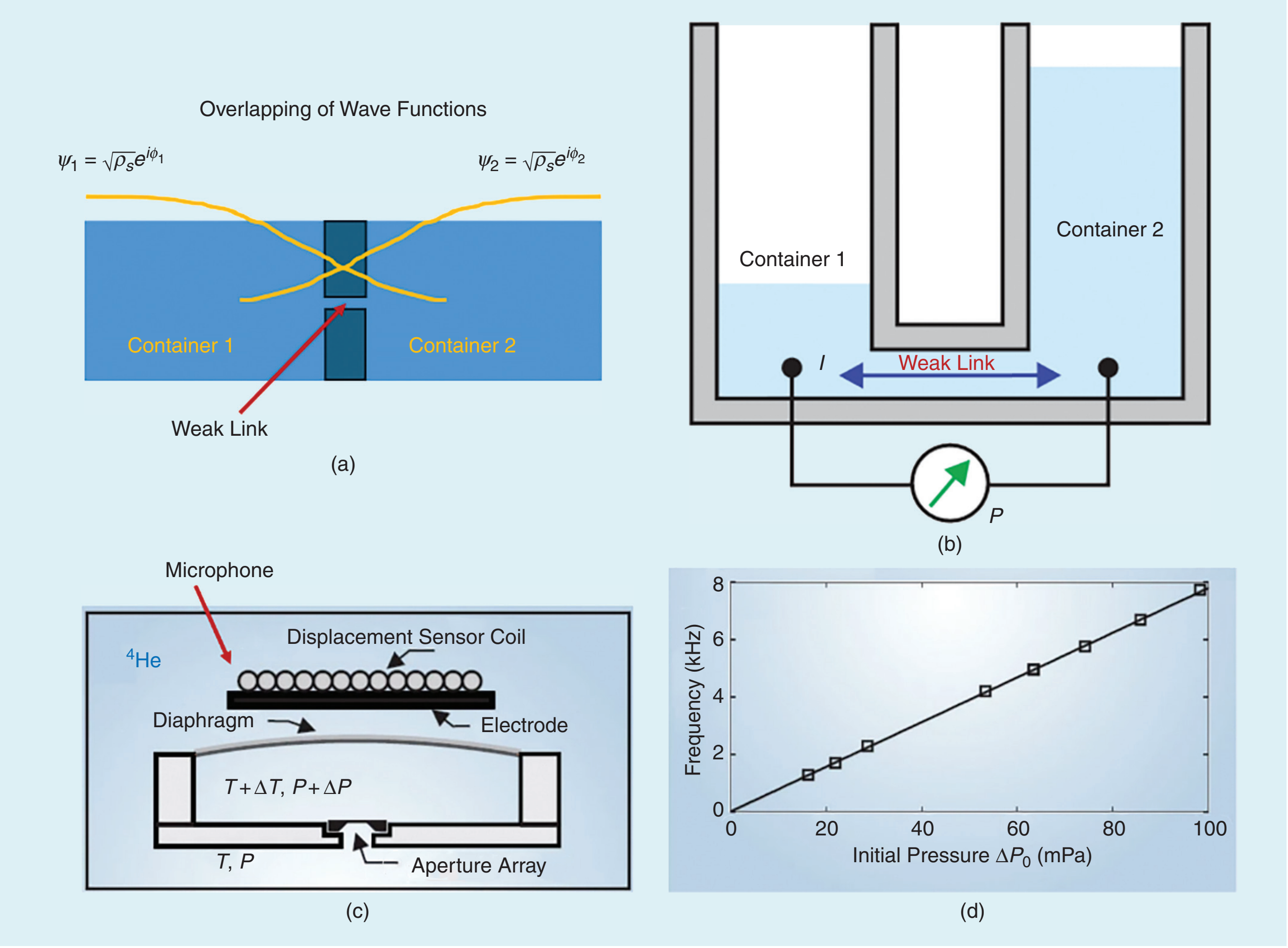

Figure 1: (a) The overlapping of wave functions of superfluid reservoirs through the aperture, orifice, or weak link. (b) Connected reservoirs or containers by a weak link. Here, the pressure difference comes from the height difference. (c) The implementation of (b) where a deformable diaphragm does the pressure bias. A microphone senses the oscillation of the fluid flow through the weak link or aperture. The aperture is made of an array of nanoholes on Silicon nitride. The whole device is immersed in superfluid ^{4}He. (d) The Josephson or whistling frequency as a function of applied pressure bias. Special thanks to Professor Richard Packard, UC Berkeley, for the permission and sharing reference [13].

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a Ph.D. student at the University of Cambridge, found these equations for superconductors' current/voltage relationship. In his case, the current is the result of overlapping the two macroscopic wave functions in two superconductors through the constriction, weak link, or a thin insulation layer. In superconductors, the current is the flow of electron pairs, called *Cooper* pairs. The chemical potential or pressure difference is a dc bias or voltage difference (ΔV) applied to the two ends of superconductors. The similarity of (8) and (9) to that of the superconducting Josephson junction shows that the condensation of electrons to create zero resistivity (superconductivity) and condensation of He atoms to create zero viscosity (superfluidity) have the same origin. The derivation of Josephson equations is easy but a bit lengthy. You can read and follow that in the last chapter of volume three of *The Feynman Lectures on Physics* [2].

Going back to Josephson equations for superfluid ^{4}He, we see that when a constant bias (pressure difference) is applied between the two containers ($\Delta P =$ const), the phase (θ) increases linearly with time, i.e., $\theta = -(2\pi m_4 / h\rho)\Delta P.t + \theta_o = \omega_J t + \theta_o$.

Due to this, the current flow oscillates with Josephson frequency $f_J = (m_4 / h\rho)\Delta P$ i.e., $I = I_c \sin(\omega_J t + \theta_o)$.

That means the superfluid flow oscillates back and forth with frequency f_J,instead of flowing unidirectionally from the high-pressure to the low-pressure part. This oscillation in flow can be transduced to an electrical signal using a microphone and can be heard with a speaker or headphones!

The classical intuition says that the fluid must flow unidirectionally from the tall column to the short column of liquid.

You can download and listen to the quantum whistle audio file at https://newsarchive.berkeley.edu/news/media/releases/2005/01/27_helium4.shtml

This effect was first observed by University of California, Berkeley researchers in superfluid ^{3}He below T = 1 mK [3], [4], and later, it was observed in ^{4}He at approximately T = 2 K [5]. Recall that the transition temperature of liquid ^{4}He is $T_\lambda = 2.17\ K$, meaning that staying a bit below this temperature is enough to see the aforementioned effect, called *Josephson oscillation* or *quantum whistle*. As we saw before, by pumping out the ^{4}He vapor away from the surface of liquid He at T = 4 K (evaporative cooling), the temperature is brought below the superfluid transition temperature (T_λ).

The experimental cell used to observe the quantum whistle in ^{4}He is shown in Figure 1(c), which is not the same as the cartoonish one in Figure 1(b), however, it is based on the same principle. The pressure bias is applied by the controllable diaphragm (assume $\Delta T = 0$). The weak link between two parts of fluid is made by a 50-nm-thick silicon nitride membrane containing 65×65 holes 70 nm in diameter. This nano-sift does the job of old-fashioned narrow pipes semiblocked by cloth or powder (see part 1 of this series [6]). A microphone picks up the oscillation of flow because the wobbling of the flow and diaphragm will change the microphone's transducer capacitor. Figure 1(d) shows how the frequency of flow oscillation (which is in the audible range) increases linearly by applying the pressure difference (bias) according to $f_J = (m_4 / h\rho)\Delta P$.

An electrical engineer should see this as a superfluid frequency modulator in which the modulating signal is the pressure bias. What is the use of this Josephson device or quantum whistle detector? Let's closely examine the properties of the quantum mechanical phase first.

We saw that the velocity of superfluid is proportional to the gradient of the quantum mechanical phase or $\boldsymbol{v}_s = (h / 2\pi m_4)\nabla\phi$. What do we learn from this? Let's imagine we are moving along a closed path or loop inside a superfluid, and we calculate the line integral of velocity on this close path (boldface variables are vectors):

$$\oint_{\text{loop}} \boldsymbol{v}_s.\boldsymbol{dl} = \frac{h}{2\pi m_4}\oint_{\text{loop}} \nabla\phi.\boldsymbol{dl}. \quad (10)$$

The right-hand integral is the total phase or phase difference accumulated on the closed loop [Figure 2(a)]. But, because the wave function must be single-valued on a single point (when points A and B are the same), this integral must be either zero or an integer multiple of 2π. This means that

$$\oint_{\text{loop}} \nabla\phi.\boldsymbol{dl} = \phi_B - \phi_A = 2\pi n$$
$$n = \text{integer}. \quad (11)$$

The left-hand side quantity in (10) is called the *circulation*. As you see, because of (11), it is only allowed to have quantized values, i.e.,

$$\oint_{\text{loop}} \boldsymbol{v}_s.\boldsymbol{dl} = \frac{2\pi nh}{2\pi m_4} = n\frac{h}{m_4}. \quad (12)$$

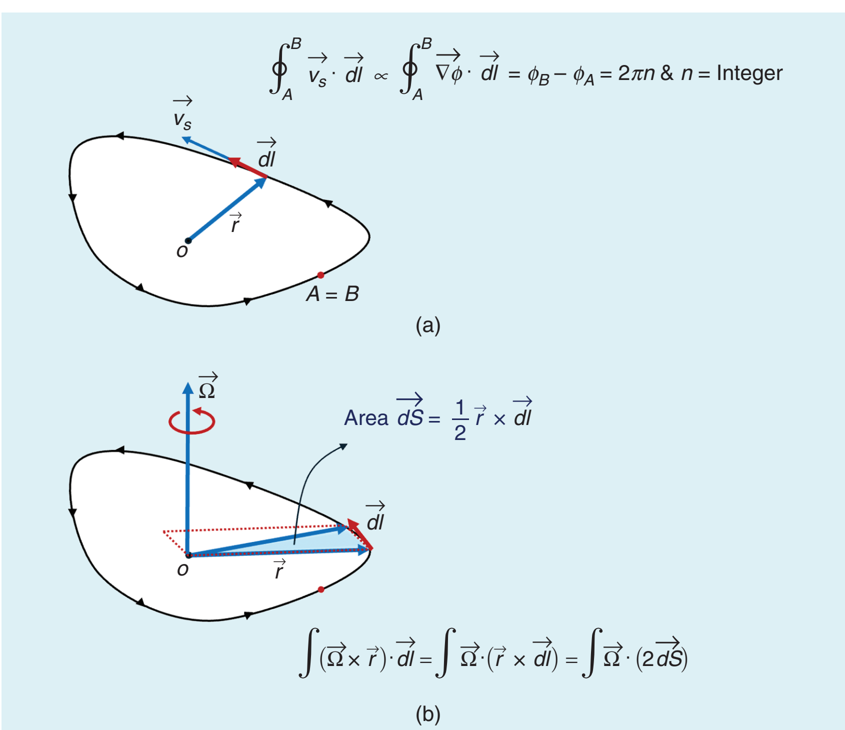


Figure 2: (a) A closed path or loop in the superfluid. The condition on the phase (single-valuedness of the wave function) imposes quantization on the circulation. (b) Rotation of the superfluid adds an extra component to the circulation/phase, which is proportional to the dot product of area and angular velocity vectors.

Hence, if you attempt to increase this circulation, e.g., by rotating the container, the integral value can only be increased by discrete packets (a vortex at a time), and the quantum of circulation or vorticity is (h/m_4). Recall the hexagonal array of vortices in a rotating superfluid container (see part 1 of this series [6]).

Gyroscope or SHe-QUID

What happens if we contact two of the cells shown in Figure 1(c) in parallel and make a loop, something like the one in Figure 3(a)? Here, each arm of the loop is made of a Josephson device. Both ends of the loop are connected to reservoirs and a mechanism of applying pressure bias, i.e., a deformable diaphragm. A microphone is installed at the bottom of the loop to sense the total current passed through the loop.

The total current at the top of the loop is divided between two arms [I_1 and I_2 in Figure 3(a)] and is recollected at the bottom end. Let's write KCL (KCL for fluids?! Yes. It is okay to pretend that this is an electric current, although it is a mass current, i.e., how many kilograms of ^{4}He atoms per second and thus the conservation of mass, not KCL). If we assume that both parallel arms are the same and the weak links are symmetric, then we have

$$\begin{aligned} I &= I_1 + I_2 = I_c \sin(\theta_1) + I_c \sin(\theta_2) \\ &= 2I_c \cos\left(\frac{\theta_1 - \theta_2}{2}\right) \sin\left(\frac{\theta_1 + \theta_2}{2}\right) \\ &= \tilde{I}_c \sin(\omega_J t + \theta_{\text{offset}}). \end{aligned} \quad (13)$$

Note that the aforementioned equation resembles the current-phase relationship of a single weak link or Josephson cell as in (8), except that the amplitude of the total current is modulated by the phase difference of two parallel weak links, i.e., $\tilde{I}_c = 2I_c \cos((\theta_1 - \theta_2)/2)$.

To find $\theta_1 - \theta_2$, we move around the loop in Figure 3(a) and write something like KVL for our hydrodynamic circuit. We start from point A and sum up all the phase drops (differences) along the path, come back to A again, and put the whole sum equal to $2\pi n$. The phase drops across each weak link are θ_1 and θ_2 and, for the rest of the path (called *rest*), it is the line integral of velocity, as we saw in (10)

$$\theta_1 - \theta_2 + \frac{2\pi m_4}{h} \oint_{\text{rest}} v_s \cdot dl = 2\pi n$$
$$n = \text{integer}. \quad (14)$$

Now, if the whole loop (and the superfluid within) rotates due to the rotation of the vehicle, laboratory, or the table on which the device is mounted, then the velocity that an He atom feels is $\boldsymbol{v}_s - \boldsymbol{\Omega} \times \boldsymbol{r}$. $\boldsymbol{\Omega}$ is the angular velocity vector normal to the plane of rotation, and $\boldsymbol{r}$ is the position vector of the atom [see Figure 2(b)]. By replacing this new velocity in (14) and using (10) and (11), it can be shown [7],

$$\theta_1 - \theta_2 = 2\pi n - \frac{4\pi m_4}{h} \boldsymbol{\Omega} . \boldsymbol{S} \quad (15)$$

where $\boldsymbol{S}$ is the vector normal to the area of the loop, and its value is equal to the area of the loop. This tells us that the amount of rotation of the loop modulates the amplitude of the total current detected by the microphone. Plug (15) in $\tilde{I}_c = 2I_c \cos((\theta_1 - \theta_2)/2)$ and we have

$$\text{amplitude of current} \propto 2I_c \cos\left(\frac{2\pi m_4}{h} \Omega . S\right). \quad (16)$$

A microphone is installed at the bottom of the loop to sense the total current passed through the loop.

Note that the quantity $\boldsymbol{\Omega}.\boldsymbol{S}$ is maximum when the area and angular velocity vector are parallel. This quantity is called *rotation flux* as it resembles the magnetic flux, which is $\Phi = \boldsymbol{B}.\boldsymbol{S}$ where $\boldsymbol{B}$ is magnetic flux density.

So, in physical terms, we have built a coherent source of superfluid flow oscillation called a *Josephson cell* or *whistle detector*, and then by adding two sources in parallel, we made an interferometer. The detector (here, a microphone) records the flow amplitude, which is modulated by the phase difference between two paths (sources). This phase difference comes from the external rotation, which is

$$\Delta\varphi_{\text{external}} = \frac{2\pi m_4}{h} \boldsymbol{\Omega} . \boldsymbol{S}. \quad (17)$$

This interferometry, which resembles the optical double-slit experiment, is the essence of this gyroscope operation, and for this reason, this device is called *Superfluid He QUantum Interference Device* (*SHe-QUID*). Figure 3(b) shows the cross section of the SHe-SQUID or gyroscope made by Hoskinson et al. [8] and Sato and Packard [9].

Feedback and Linearization

The relation between the external phase shift ($\boldsymbol{\Omega}.\boldsymbol{S}$) due to rotation and the output current amplitude in a superfluid gyroscope is nonlinear as it is a cosine function [see (16)]. Linearizing the gyro around its operating point is possible by applying negative feedback. For negative feedback, the detected signal is used to create a counter-rotation. A heater is added to apply the counter-rotation.

As we saw in the two-fluid model in part 1 of this series [6], ^{4}He under T_λ

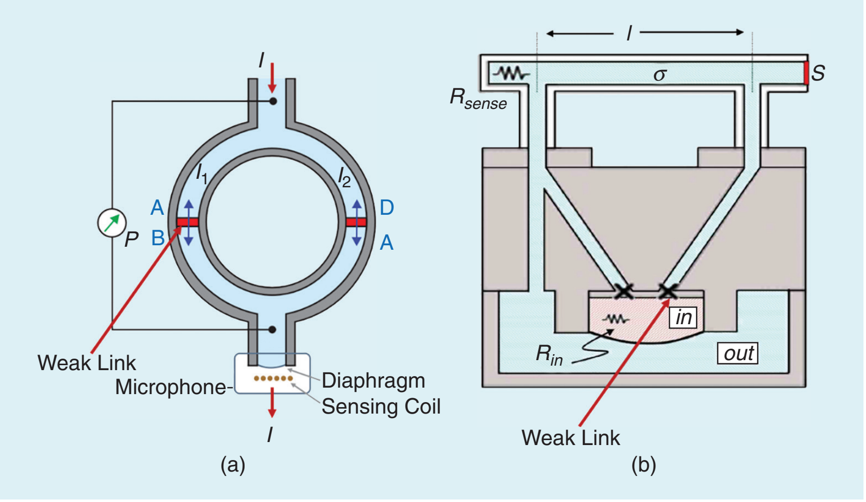


Figure 3: (a) Conceptual schematic of the interferometer by connecting two parallel Josephson cells. The amplitude of the total current is modulated due to the interference of two paths. (b) The engineering implementation of (a) where a deformable diaphragm applies the pressure bias. A resistor (R_{in}) applies negative feedback, i.e., it heats and compensates for the phase shift due to rotation (see the text). R_{sense} is for measuring the temperature. The horizontal arm is called the sense arm, with V-shaped groves forming the loop. The microphone is not shown here for clarity. Special thanks to professor Richard Packard, UC Berkeley, for the permission and sharing reference [13].

is modeled as a mixture of normal and superfluid parts, and the total current is $j = \rho_s v_s + \rho_n v_n$. The normal part is responsible for carrying heat and has entropy. In a steady-state condition, the total current density flow is zero ($j = 0$); hence, $v_n = -(\rho_s/\rho_n)v_s$. As $\boldsymbol{v}_s \propto \nabla\phi$, therefore, the normal velocity is also proportional to the phase difference as $v_n = -(\rho_s h/\rho_n 2\pi m_4)\nabla\phi$. Thus, it is enough to move the normal fluid component by applying heat (temperature bias) to compensate for an extra phase shift due to external rotation. As a result of this, no mechanical counter rotation is necessary for the negative feedback. Only a small resistor in the ^{4}He reservoir does the job [see the heater, R_{in}, in Figure 3(b)]. Figure 4(a) shows the fabricated SHe-SQUID gyroscope. The white plastic pipe corresponds to the top part of Figure 3(b) and contains the heater used to linearize the current-phase characteristics of the device [9]. The real device is shown in Figure 4(a). You may have guessed that this interferometric gyroscope looks like a phase-locked loop circuit, except that it has no frequency divider.

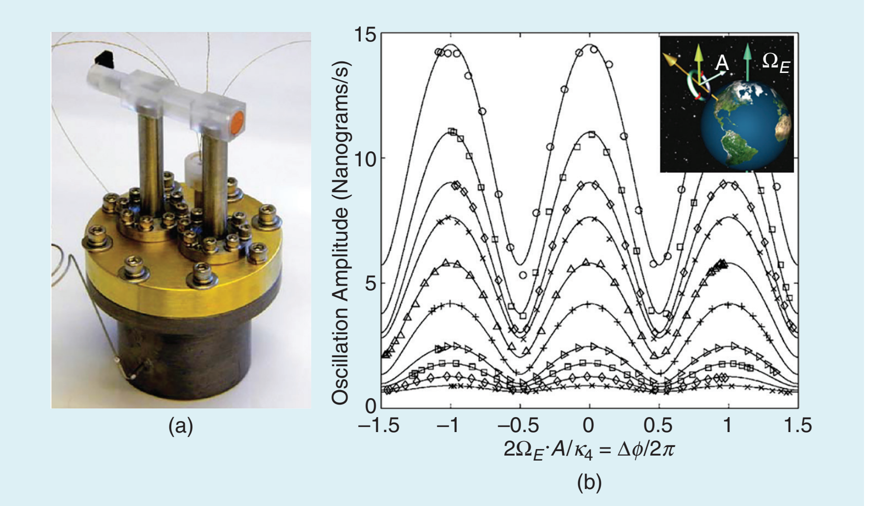


Figure 4: (a) The interferometer superfluid ^{4}He gyroscope. The device's height is roughly 7 cm. The plastic tube on top corresponds to the horizontal sense arm in Figure 3(b). (b) The result of measuring the Earth's rotation. Note the cosine form of current modulation versus the phase change resulting from the Earth's rotation. Solid lines are fit to (16). The gyro is more sensitive at lower temperatures (circles) because of more superfluid density. The inset shows the Earth's rotation vector direction with respect to the area vector of the loop. Permission granted by the American Physical Society (RNP/24/FEB/074990).

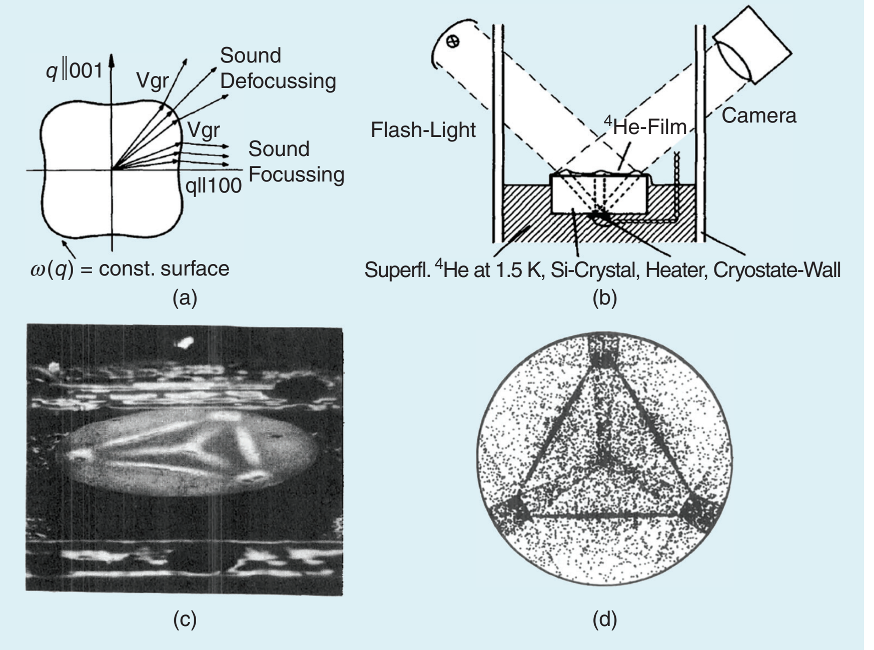


Figure 5: (a) Contours of constant sound frequency in a solid. The group velocity vectors must always be normal to the contour, and depending on the anisotropy, they can focus or diverge. (b) The experimental setup to capture the image of sound focusing using the fountain effect in superfluid ^{4}He. (c) The image was taken on the (111) plane of silicon crystal. This plane is the one that crosses all three *x*-, *y*-, and *z*-axes at the same distance from the center point (000). Silicon has the highest density of atoms along the normal vector on this plane. (d) The same data generated by simulation. Permission granted by Katelyne Desule, EDP Sciences, France.

You have probably surmised that the SHe-SQUID gyroscope works like an interferometric ring laser gyroscope (based on the Sagnac effect). If so, then what's wrong with a room temperature classical optical gyroscope? Two counter-propagating laser beams are sent into an optical fiber ring in this kind of gyroscope. The outcoming beams are interfering on a detector. If the ring rotates, e.g., due to the airplane's rolling, the laser beam, which is parallel to the rotation direction, leads the beam which is antiparallel to the rotation (this is called the *Sagnac effect*) [9]. Then, the phase difference ($\Delta\varphi$) between two beams creates a fringe pattern on the detector, e.g., a charge-coupled device camera, and from that, the rotation can be measured. The sensitivity of this gyroscope is given by

$$\Delta\varphi = \frac{8\pi}{\lambda c}\boldsymbol{\Omega}.\boldsymbol{S} \qquad (18)$$

where λ and c are the wavelength and velocity of the laser light in the fiber, respectively. To increase the sensitivity of the gyroscope and detect the slowest rotations possible, a larger area ($\boldsymbol{S}$) is required, which means a bigger and heavier gyroscope. Multiply this by three as, for inertial navigation, three gyroscopes are necessary, corresponding to rotation around the *x*-, *y*-, and *z*-axes, respectively.

This is where the superfluid He gyro shows its advantage. By calculating the ratio of (17) and (18), a number around 10^9–10^{10} is obtained. This shows that the superfluid gyro is at least 1 billion times more sensitive to rotation than the optical one, of course, at the price of a cryogenic system and its cost. But this high sensitivity allows the detection of the fluctuations in the Earth's rotation from which the precision of the GPS can be enhanced [11]. Figure 4(b) shows the detected signal in a ^{4}He gyroscope versus the rotational flux due to the Earth's rotation. The measurement has the cosine shape predicted by (16).

Further, the interferometric principle in SHe-SQUID can be used to sense other quantities through their effect on the quantum mechanical phase of the superfluid via rotation, temperature, or pressure. Seismology, geodesy, detection of errors in the Newtonian gravity model, and testing Einstein's general relativity model are among the applications.

Seeing the Sound

In the first part of this series [6], we learned that because the heat capacity of the superfluid is zero, it cannot tolerate any temperature difference. Therefore, the normal part of the superfluid moves from the low-temperature points toward the high-temperature points to equilibrate any temperature difference. Also, due to zero viscosity, superfluid creeps up on the walls of its container. Eisenmenger [12] used these properties for the first time to observe the propagation of sound in crystalline solids. Why does the propagation of sound in solids matter?

As we know, crystalline solids are made of atoms of mass m connected to each other by interatomic forces modeled as springs of stiffness (K). This simple mass and spring model gives a wealth of information about how fast atoms vibrate in the solid (recall $\omega = \sqrt{K/m}$), i.e., how the vibration of atoms (sound) propagates in the solid as waves of frequency ω and wave vector ($q = 2\pi/\lambda$). The group velocity of sound propagation in solids is determined from $v_g = ((\partial\omega(q))/\partial q)$, which is the main mechanism that tells us whether the solid is a good or bad conductor of heat. The stiffer the interatomic force (spring) between the atoms, the higher the vibrating frequency and, as a result, the higher the thermal conductivity. For material scientists, designing novel heat sinks and thermoelectric converters is all about finding or synthesizing a material with the best combinations of mass (m) and interatomic force (K) using experiments or simulations. In a 3D crystalline solid, the group velocity of sound is generally anisotropic, meaning that the group velocity value and direction are different along the x-, y-, and z- directions [Figure 5(a)]. Knowing this information is important for material scientists to understand how heat propagates in a material in different directions, i.e., to extract the thermal conductivity tensor.

Imaging the contours of sound propagation in solids was possible traditionally by exciting atoms using a heat pulse. This heat pulse excites the atoms and creates a packet of sound waves. Then, the traveled wave reaches different faces of solids and is observed using bolometer detectors (detectors that convert the received sound/heat wave to electricity). However, to see the whole image of sound focusing or defocusing on the sample's surface, the bolometer must be moved to different points on the sample's surface. Extraction of the sound velocity contour is then a coarse interpolation of taken images and is a time consuming process.

Superfluid ^{4}He can be used to image sound propagation in solids with very high resolution and without the need to repeat the measurement or make any changes to the setup. Figure 5(b) shows the simplified setup of this experiment

The stiffer the interatomic force (spring) between the atoms, the higher the vibrating frequency and, as a result, the higher the thermal conductivity.

[12]. In this method, the sample (crystalline solid) is half immersed in a container of superfluid ^{4}He at 1.5 K.

At this phase, a thin layer of superfluid creeps up and covers the top surface of the solid. A heat pulse generator is attached to the bottom surface of the sample. This is simply a resistance biased by the pulsed current. This pulse makes the atoms vibrate, and the created sound wave propagates inside the sample in different directions with different velocities. They create an interference pattern when they reach the top surface with different phase delays. If they combine constructively or focus on the top surface, they cause higher vibration of atoms, hence, hot spots on the top surface. Otherwise, they will leave cold spots. The thin, liquid He layer on hot spots becomes thicker as more fluid moves to these spots (recall the fountain effect [6]). The unevenness of the He layer's thickness on the sample can then be imaged by a camera and a light source.

A projector and a camera are installed obliquely to take a picture of the top He layer. The image is then the exact replica of the sound wave interference pattern on the top surface of the sample. This image shows the focusing and defocusing points and reveals how the sound wave propagates in the sample along different crystallographic directions. Figure 5(c) shows an image taken from a silicon crystal sample on the diagonal plane (111), and this agrees well with the image calculated theoretically (solving strain-stress equations) in Figure 5(d).

Conclusion

We first saw how the quantum physics of interacting superfluid reservoirs (overlapping their wave function) led to a quantum whistle or Josephson oscillation in the fluid flow. Using this effect as a source of the coherent wave and letting two of these sources interfere led to a device called SHeQUID or gyroscope, a device in which the phase difference due to external rotation modulates the amplitude of the detected mass current. SHeQUID has an electric analog called SQUID or superconducting quantum interference device. In SQUIDs, the electric current is modulated by the magnetic flux. The bias is the applied voltage instead of the pressure difference. The phase difference between the two arms of the SQUID loop is induced by the external magnetic flux $\Phi = \boldsymbol{B}.\boldsymbol{S}$. In SQUID, the magnetic field $\boldsymbol{B}$ is measured (used in magnetic resonance imaging devices in hospitals), but in gyroscope (SHe-QUID), the angular velocity $\boldsymbol{\Omega}$ is measured.

Second, we saw how the sound propagation in crystals can be photographed by superfluid He.

However, there are a few things I did not tell you. You may wonder why a superfluid gyroscope was first invented using ^{3}He at 1 mK before ^{4}He (at T = 2 K). After all, cooling ^{4}He and working at 2 K is easier than in 1 mK!

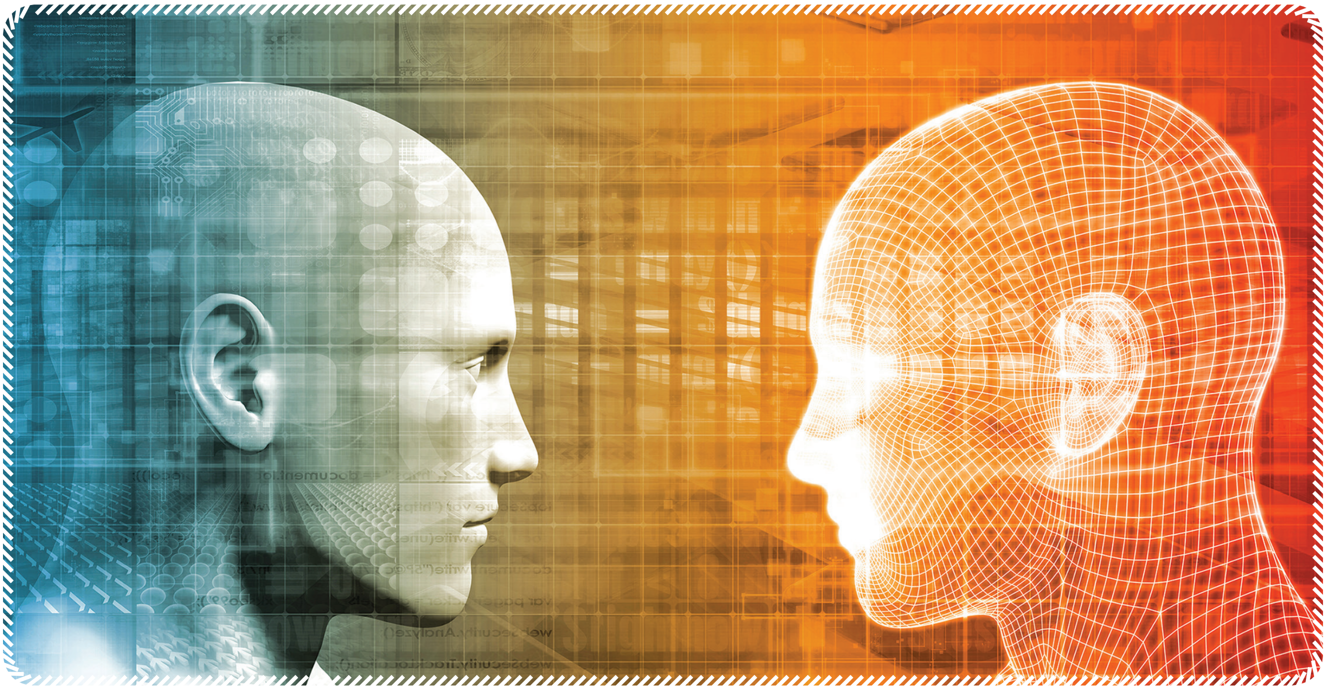
Also, I mentioned that the Josephson oscillation in a weak link occurs below T_λ and, for this, the gyroscope needs only a few mK below T_λ to work. But if the temperature is brought more below T_λ, the sinusoidal waveform in $I = I_c \sin(\theta)$ becomes a sawtooth one! This regime of whistling is due to an effect called *phase slip*. When and if it occurs depends on the temperature and geometry of the weak links (those nanometric holes).

In the discussion about the quantum whistle, we only talked about a constant pressure bias (ΔP) because of which the current oscillates with Josephson frequency ($\omega_J \propto \Delta P$). What if a sinusoidal

(Continued on p. 30)

The Quest for Ethical Artificial Intelligence

by Mehrdad Safaei



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Preamble: The Quest for Understanding and Connection

The quest to understand and interact with our surroundings is a fundamental drive that has led to the development of complex systems throughout history. It is a survival skill inherent in all creatures, manifesting in diverse communication methods. This drive propels us toward a future where we seek to create entities capable of understanding us beyond our individual perspectives. The vision of developing artificial intelligence (AI) that surpasses human intelligence and offers benevolent guidance is a reflection of our desire for an ethical entity, akin to a benevolent deity, rather than the capricious gods of ancient myths. This article explores the feasibility of ethical AI, examining its potential from chatbots to artificial general intelligence (AGI), and the challenges of embedding moral principles within these systems.

Ethical Dilemmas and Diverse Definitions

Ethics, as defined by the *Oxford Dictionary*, encompasses the study of concepts such as good, right, duty, and virtue in practical reasoning. It is important to recognize the subjective nature of ethics, which contributes to the rich diversity of our world. Throughout history, dominant societies have imposed their ethical standards, leading to universally accepted norms, such as the prohibition of murder. For AI systems, it is crucial to consider these universal ethics, ensuring they are embedded in their operations regardless of geographical location. However, the challenge arises when considering the diverse ethical standards across different societies around the globe. This diversity can lead to varying outcomes in AI-assisted decision making, such as in the justice system, where algorithms may inadvertently learn and perpetuate biases based on ethnicity or location [1]. The question, then, becomes how to address and rectify these biases in AI systems.

What Are "Garbage Data"?

The adage "garbage in, garbage out" underscores the critical role of data quality in algorithms and neural networks, illustrating how absolute errors, such as $1 + 1 = 3$, can compromise outputs. However, this concept does not fully address the issue of biases in datasets, which can significantly impact the performance of AI systems. Both our brains and AI systems form conclusions based on observed patterns (Figure 1), and, when these patterns reflect societal biases, the resulting connections and associations may exhibit "unwanted bias." This problem is often not rooted in the algorithmic decision-making process itself but in the biased nature of the input data. To tackle this, we can label biased data as "bias alert: proceed with caution" to highlight its nature. Despite this, the challenge remains in how to neutralize such data to ensure fair and unbiased decision making by AI systems, as the quality of the input data directly impacts the output.

The "pizza meter" phenomenon [2], where pizza orders from the White House were linked to potential military operations, and the "falafel metric," [3] used to monitor potential terrorist activities based on falafel purchases, illustrate the complexity of biased datasets. Altering such datasets for neutrality is fraught with risks of false or meaningless outcomes. (Is it ethical to use a biased algorithm with 80% accuracy or more for national security decisions?) These examples demonstrate that seemingly illogical biased data can still be relevant and useful, albeit controversially. The challenge, therefore, is not in dismissing biased data as garbage but in addressing biases (by leaning more toward our own biased beliefs?) while preserving the data's integrity to ensure the likelihood of correct decision making by AI systems. While new methods such as Machine Unlearning (MU) are gaining attention for their ability to remove or modify predictions made by machine learning (ML) models, it is crucial to address their downsides while preserving data integrity. This ensures accurate decision-making by AI systems (https://arxiv.org/abs/2305.06360).

The Black Box Conundrum

In the realm of AI, the concept of a "black box" often arises, referring to the opacity of AI algorithms and their decision-making processes. As AI systems become more complex, understanding the inner workings of these systems becomes increasingly challenging. This poses a significant dilemma for engineers and developers, as they must balance the benefits of AI automation with the need for transparency and accountability. It is crucial for engineers to consider how to make these algorithms more interpretable and explainable, especially in contexts where their decisions have significant impacts on individuals or society as a whole. Engineers must grapple with questions like, How can we ensure that AI systems make decisions that align with ethical standards and societal values? How can we build AI systems that are not only efficient but also transparent and accountable?

The Lesson for Engineers

Before implementing automated systems powered by AI, engineers must navigate the ethical complexities inherent in the black box nature of AI algorithms. It is imperative to develop AI systems that are not only efficient but also transparent and explainable, incorporating mechanisms that enable human understanding and interpretation of AI decisions. Additionally, engineers must be vigilant in identifying and mitigating potential biases within AI systems, acknowledging limitations where mitigation is not feasible.

As we stand on the cusp of a new era in AI, the role of engineers in shaping the future of ethical AI is critical. Key questions to consider include the following: How can we design AI systems that uphold human dignity and respect? How can we ensure the equitable distribution of AI benefits across society? How can we cultivate a culture of ethical responsibility within the AI community? The journey toward ethical AI is a collective endeavor, requiring the commitment and collaboration of all stakeholders involved in the development and deployment of AI technologies. By prioritizing transparency and accountability, engineers can help ensure that AI technologies are used ethically and responsibly, paving the way for a future where AI serves the greater good of humanity.

Creating a Framework

Creating ethical AI necessitates a holistic framework that tackles the complex challenges AI technologies present. This framework must integrate legal, social, and technical aspects to ensure AI systems uphold human rights and dignity. It is crucial to involve all stakeholders in this process, including engineers, companies, public representatives, and legal entities, to develop tailored frameworks for different AI applications, as one approach does not fit all. A key component of this framework is establishing ethical guidelines and standards for AI development, informed by a variety of perspectives, including ethicists, sociologists, psychologists, and representatives from diverse cultural and demographic groups.

The Importance of Diversity in AI Development

Diversity in AI development is crucial for mitigating biases and ensuring that AI systems are inclusive and equitable. A diverse team of developers and researchers can bring a wide range of experiences and viewpoints to the table, helping to identify and address potential biases in AI algorithms and datasets. Moreover, involving stakeholders from different backgrounds in the AI development process can foster a more holistic

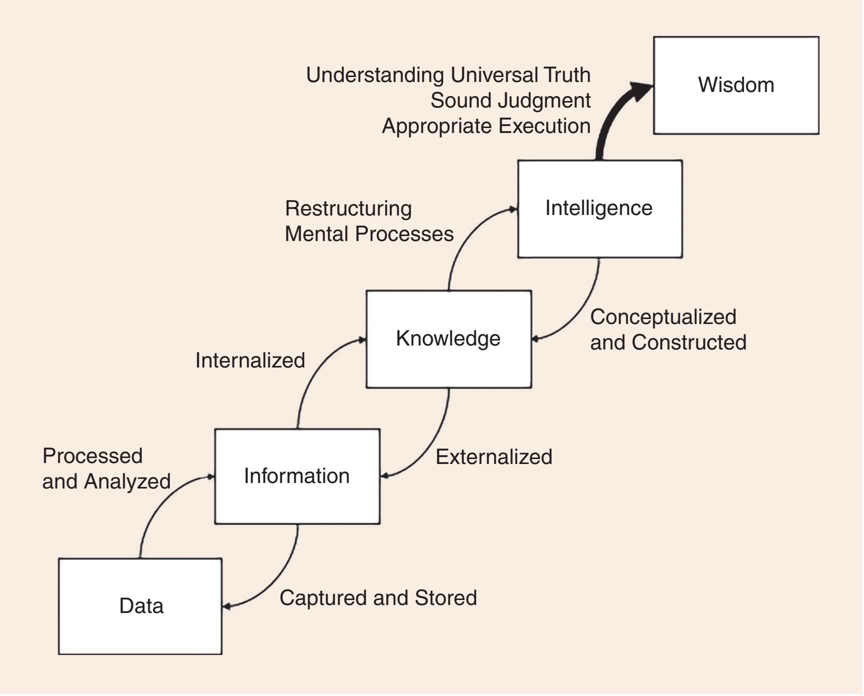

Figure 1: The DIKIW hierarchy. (Source: Liew, [4] p. 49.)

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understanding of the ethical implications of AI technologies.

The Role of Regulation and Oversight

Regulation and oversight play a crucial role in ensuring the ethical development and deployment of AI systems, within the limits of what can be measured and regulated. Governments and international organizations should establish regulatory frameworks that set clear standards for transparency, accountability, and fairness in AI. These frameworks should also include mechanisms for monitoring and auditing AI systems to ensure compliance with ethical and legal standards. Additionally, there should be avenues for redress and accountability when AI systems cause harm or violate ethical principles. The key to success lies not in silencing minority voices, as history has shown with dominant groups, but in creating common and mutually beneficial solutions that work for all in the digital age. The first international AI treaty created and adapted by the Council of Europe Framework Convention on artificial intelligence and human rights, democracy, and the rule of law could be a great example to learn from (May 2024, https://www.coe.int/en/web/portal/-/council-of-europe-adopts-first-international-treaty-on-artificial-intelligence).

The Future of Ethical AI

The journey toward ethical AI presents both challenges and opportunities for innovation and progress. As we explore advanced computational techniques, like quantum computing, and delve into the potential of complex systems, such as wetware computers, it is imperative to remain vigilant in ensuring that AI technologies are used for the betterment of humanity. These systems, initially created to interact with and understand our world, hold the promise of enhancing our collective understanding and addressing pressing global issues.

The prospect of creating an AGI that surpasses its creators raises intriguing questions about the nature of our technological aspirations. The idea of limited beings (humans) creating a limitless entity reflects a deep-seated desire to transcend our own limitations, suggesting the possibility of achieving such a feat.

In the current landscape of AI technology, it is crucial to foster ongoing dialogue among engineers, policymakers, ethicists, and the public to navigate the ethical complexities of AI. Embracing AI's potential to address challenges like climate change, health care, and social inequality requires a mindful approach to the ethical implications of these technologies. By considering AI as a tool for humanitarian purposes, we can enhance food security, education, and scientific discoveries, ensuring that AI serves as a catalyst for positive change in our society. ■

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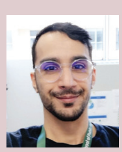
Disclaimer
The perspectives presented in this article are based on the author's personal views and do not necessarily reflect the opinions or positions of any affiliated organizations or institutions. The topic of ethical artificial intelligence is multifaceted and open to various interpretations. Readers are encouraged to consider a diverse range of viewpoints when exploring the ethical implications of AI.

About the Author



Mehrdad Safaei (mehrdadsafaei@ieee.org) is a policy analyst specialised in data and artificial intelligence at the Indigenous Services Canada, Government of Canada. They also work as a research assistant at Johnson Shoyama Graduate School of Public Policy and McGill University. Their recent research includes investigating the capability of artificial intelligence to generate plausible, persuasive, and useful policy analysis and performing Twitter sentiment analysis for "Attributions of Blame and Credit in Policy-Making." Mehrdad's areas of expertise are AI, ML, smart cities, evidence-based decision-making, data analysis, technology and innovation policy, open government, and digital government.

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Always Remember: D-Day—80th Anniversary 6 June

by Terrance Malkinson

Every 6 June, we honour the memory of the Allied troops who stormed the beaches of Normandy, France; an action that led to the liberation of Europe and the defeat of Nazism. Victory in the Normandy campaign came at a terrible cost. Canada suffered almost a thousand casualties. Commanded by the British Second Army, Canadians advanced to Juno Beach through stormy water, obstacles, wire, mines, and gunfire. They secured a beachhead. Many of the men who died on the beaches and in the following bridgehead battles are buried in Bény-sur-Mer Canadian War Cemetery. The cemetery contains 2,049 headstones. The Juno Beach Centre is an interactive educational facility that provides information about Canada's role in World War II. This year, Veterans Affairs Canada and our allied partners will commemorate the 80th anniversary of D-Day and the Battle of Normandy.

The world remembers and pays tribute to those who served from America, Great Britain, Canada, Belgium, Denmark, Holland, Norway, Poland, Australia, and France. We honour the many heroic men and women who lost their lives and are at rest in the cemeteries to be found throughout the area. We honour the many who returned home physically and mentally injured. Canadians must recognize and never forget this necessary action that provided them and their descendants the opportunity to develop and prosper in freedom. Young Canadian men and women played a major role in D-Day (also known as *Operation Overlord*), the greatest seaborne invasion of all time; the Allied assault on Normandy on 6 June 1944. Canadians also played an important role in the long struggle that followed in the Norman countryside and inland throughout Europe. Victory would only be achieved by driving the Nazi forces from the countries they occupied and finally by invading Germany.

On 1 September 1939, Germany, invaded Poland. Great Britain and France had pledged to protect Polish sovereignty and, after the demand for a German withdrawal went unanswered, they declared war on 3 September. In just two months, Norway, Denmark, and other European countries all the way to France were defeated. Thousands of British and French troops narrowly evaded capture because of a flotilla of naval vessels and pleasure craft that evacuated them to England from the port of Dunkirk.

With a growing realization of the threat that Nazism posed to freedom and democracy, the Canadian Parliament declared war on Germany on 10 September. Initially, Canada provided economic assistance in the form of foodstuffs, raw materials, and industrial production. From September 1940 through April 1945, the Provincial Institute of Technology and Art (currently SAIT) was taken over as part of the British Commonwealth Air Training Plan and renamed the No. 2 Wireless School (see Figure 1). Thousands of pilots and crew members from Commonwealth and Allied countries trained at this Calgary educational institution.

Following the surrender of France in June 1940, Canada was Great Britain's ranking ally. The best-equipped force facing Hitler was the 1st Canadian Infantry Division, then training in Great Britain. The Soviet Union (USSR) entered the conflict a year later following Hitler's attack on the USSR. Japan's raid on Pearl Harbor on 7 December 1941, and Germany's declaration of war against the United States a few days later solidified the Allied coalition.

This year, Veterans Affairs Canada and our allied partners will commemorate the 80th anniversary of D-Day and the Battle of Normandy.

Great Britain was all that stood against total victory by Nazi Germany. Canadians were among the group of pilots who, in their Spitfires and Hurricanes, held off the Luftwaffe in the Battle of Great Britain during the summer and autumn of 1940, stopping Hitler's plans to invade the British Isles. Canadian bomber crews then began nightly flights, encountering enemy antiaircraft fire to bomb German industrial sites. At the same time, Canadian sailors escorted the merchant navy convoys that kept open the supply line to Great Britain across the North Atlantic.

The Allies realized that it would take time to determine a strategy and to gather the manpower and materials need to invade Western Europe and defeat Germany. Amphibious operations had to be tested and German defences assessed. The Canadian military, politicians, and the public wanted significantly more involvement and action. Combined Operations Headquarters decided to launch a raid on France's Port of Dieppe on 19 August 1942, with the 2nd Canadian Infantry Division. Regrettably, this raid did not go well; the losses were huge. Five thousand Canadians formed the assault force, 3,367 became casualties, including 907 killed in action, and 1,946 were captured as prisoners of war. The battle, however, provided learnings that enabled the success of D-Day two years later. Canada again was an important contributor to final victory over Germany. Other battles in Europe followed, including the Battle of Stalingrad, which saw the defeat of the entire German Sixth Army, the battle of El Alamein, the Italian campaign, and the Battle of Little Stalingrad.

Planning for the invasion of France began in 1942. By spring 1944, all aspects for Operation Overlord, the invasion of France, were ready. Secrecy was paramount. The Supreme Allied Commander, American General Dwight D. Eisenhower, and his advisors decided that the attack should fall on the Cotentin Caen area of the Normandy coast and occur on 5 June. This site was a long and hazardous sea journey for the invasion fleet but had the important element of surprise. It was a risky undertaking. German defences in France were being strengthened. Concrete-reinforced steel pillboxes, barbed wire, mines, artillery, machine gun nests, mortar pits, and beach obstacles were constructed.

On 5 June, bad weather forced a postponement of the invasion. Allied meteorologists predicted a small and last best window of opportunity on 6 June. General Eisenhower gave the order for battle. Canadian airmen and sailors were among the first to act. The Royal Canadian Air Force (RCAF) had already been involved for several months in bombing key enemy targets in the invasion area: roads, bridges, railways, airfields, and command and communications centres. They now flew as part of the 171 Allied squadrons that attacked on D-Day. As the land invasion approached, RCAF Lancasters of the No. 6 Bomber Group dropped tons of explosives on German coastal defences.

Figure 1: Men and women of the No. 2 Wireless School outside the main building of the Provincial Institute of Technology and Art in Calgary. 14 March 1945. (Source: SAIT Archives.)

Figure 2: Troops of the Canadian 3rd Division and the 2nd Canadian Armoured Brigade land on Juno Beach. (Source: Wikimedia Commons; Public Domain).

Canadian fighter pilots protected the soldiers on the beach and attacked German formations on the ground.

The Royal Canadian Navy provided 109 vessels and 10,000 sailors as its contribution to the massive armada totalling 7,000 Allied vessels that went to sea on D-Day. Canadian minesweepers assisted in the important job of clearing a safe path across the English Channel for the invasion fleet. Canadian destroyers like Algonquin and Sioux attacked enemy shore fortified gun sites and continued to fire supporting the ground attackers. In the early hours of 6 June, Allied paratroopers, including 450 Canadians, jumped from aircraft or landed in gliders behind the German coastal defences. Outnumbered, they captured German military buildings, destroyed key bridges, and seized important roads.

The Canadian soldiers scheduled to land at Juno Beach approached the coastline in their landing craft (see Figure 2). An estimated 15,000 Canadians participated in the landing force; wet, cold, seasick, and determined. Many men were killed the instant they waded into the chest-high water. There was a tremendous loss of life. Toronto's Queen's Own Rifles received the worst battering of any Canadian unit on D-Day. Landing craft carrying the Queen's Own reached the beach. Men rushed from the shoreline to a seawall 183 m away with no cover. Hidden German guns killed two-thirds of the lead platoon. Few survived to get off the beach. A second Queen's Own company landed directly in front of an enemy strongpoint and very quickly lost half of its men. Surviving infantry succeeded in fighting their way off the beach and into the nearby town of Courseulles-sur-Mer, where they became engaged in house-to-house combat. They were moving inland by late afternoon.

With courage and a massive loss of life, the D-Day objective, defeating this, the first line of German defences, was accomplished. Canadian troops had progressed farther inland than any of their Allies. It was a necessary and incredible achievement. Dead German soldiers were scattered over the dunes. Beside them lay Canadians in the sand and in the grass, on the wire and beside the concrete fortresses. Three hundred forty Canadians lost their lives, 574 were wounded, and 47 taken prisoner. The British and Americans advanced inland, forming an Allied continuous front. By the end of D-Day, the Allies had landed 155,000 troops in France by sea and air, 5,000 vehicles, 900 tanks, 600 guns, and 4,000 tons of supplies. Securing the bridgehead prevented the Germans from forcing the Allies back into the sea.

The Battle of Normandy (D-Day) ended, but the war continued for almost another year. The Canadian Army subdued any remaining isolated German garrisons. The Canadian troops joined their compatriots in northwest Europe and were now reunited under one command. They advanced north, liberating The Netherlands in April. Nazi Germany's defeat was now imminent. Adolf Hitler committed suicide on 30 April. German forces in Italy surrendered on 2 May. Those in northwest Europe surrendered five days later. Almost six years after it had begun, the war in Europe was over.

The backbone of the German Army in the west was broken in Normandy. Canadians contributed immensely to the defeat of Hitlerism. There is much more to this story than is provided in this account. A plethora of authoritative written, photographic, and video information is available to those who are interested in learning more.

The Longest Day is a 1962 American epic war film based on Cornelius Ryan's 1959 nonfiction book of the same name about the D-Day landings at Normandy on 6 June 1944. The film was produced by Darryl F. Zanuck for 20th Century Fox and consultants included Allied and Axis D-Day participants. Additionally, military collaboration was achieved with many Allied governments.

The year 2024 marks the 80th anniversary of this historic event, and with it an occasion to celebrate peace, liberty, and reconciliation. The official international ceremony will take place on Thursday, 6 June 2024 on Omaha Beach. Many heads of state, veterans, and officials will attend.

The accomplishments of the Canadians who landed in Normandy and of the Canadians who fought through WWII battles deserve to be remembered by their country and the world.

The accomplishments of the Canadians who landed in Normandy and of the Canadians who fought through WWII battles deserve to be remembered by their country and the world. Veterans want Canadians to understand the price of freedom. They are passing the torch to all the people of Canada so that the memory of their sacrifices will continue and the values they fought for will live on in all of us. Remember them and remember the importance of their necessary achievement. ■

About the Author

Terrance Malkinson, the author of more than 580 peer- and editorial reviewed earned publications, is now retired. His diverse career path included 26 years in medical research as a founding member of the Faculty of Medicine at the University of Calgary, a three-year appointment as a business manager with the General Electric Company, followed by a one-year applied research appointment with SAIT Polytechnic. He is an alumnus of continuing professional education programs with Outward Bound International, the Banff Centre for Management, the Massachusetts Institute of Technology, and the University of Colorado. During his long career, he has advanced both basic and applied medical, health and wellness, scientific, and engineering knowledge. He has trained and mentored undergraduate, graduate, and postdoctoral students as well as professional staff in the business sector and government. He is a 45-year Life Senior Member of IEEE. He has served in many professional public and private governance and publication roles. He is the recipient of several peer-selected earned awards, including induction into the Order of the University of Calgary, IEEE achievement medals, and APEX awards for publication excellence. In retirement, he vigorously continues basic and applied research, with an extensive portfolio of basic and applied research projects. Other passions include communicating emerging technologies to the public, investigative journalism, philanthropy, and mentorship. His current research interests in emerging technologies and health and wellness extend to being an accomplished multisport triathlete, including, among other events, the completion of 10 full-distance Ironman Triathlons.

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History Matters

Cavity Magnetron No. 12

by David G. Michelson
IEEE Canada Historian

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 us and define us.

Although historical fact is immutable, historical evidence is inherently fragile and often irreplaceable. Accordingly, efforts to preserve and interpret the past are among the most valuable of legacies. In this column, we consider the story of cavity magnetron no. 12, which some consider to be the most valuable of the items that the Tizard Mission brought to North America in fall 1940.

Among the collection of the Canada Science and Technology Museum is artifact 1969.0482.001, a model E1189 cavity magnetron, serial number 12, shown in Figure 1. According to James Phinney Baxter III, official historian of the U.S. Office of Scientific Research and Development, "When the members of the Tizard Mission brought [cavity magnetron no. 12] to America in [late] 1940, they carried the most valuable cargo ever brought to [American] shores." The dramatic performance improvements offered by the new device were the motivation and justification for developing the enabling technologies and infrastructure required to make the transition from radio frequency to microwave radar. This led to expansion of existing labs, including those at the National Research Council (NRC) and Bell Telephone Laboratories, and formation of new labs, such as the McGill Stormy Weather Group and the MIT Radiation Laboratory.

Cavity magnetron no. 12 astonished U.S. officials when it was demonstrated to them in fall 1940. Compared to the devices used in radar transmitters then under development in the United States and Canada, it generated significantly greater power at a higher frequency while occupying a much smaller volume and being much lighter. In one fell swoop, the new device made it possible to develop radars with greater range and higher resolution than previous systems, and which could be more easily carried by mobile forces, including aircraft.

Cavity magnetron no. 12 was one of several fabricated by Eric Megaw and his collaborators at GEC Laboratories in Wembley, United Kingdom, in summer 1940 following the breakthrough work of John Randall and Harry Boot at the University of Birmingham earlier that year. These units incorporated several improvements and innovations that increased both the output power and longevity of the device compared to previous devices. Details of the internal construction of the eight-cavity version are shown in Figure 2. In a letter to Megaw's secretary shortly after his death in 1956, Sir Edward Appleton wrote, "Those who were in the business know how much the practical development of the cavity magnetron—the development that made it something that could go into operational use—was due to Dr. Megaw."

Cavity magnetron no. 12 served as the template for the more than 1 million cavity magnetrons that were manufactured in North America by Westinghouse, Sylvania, Northern Electric, and others during the remainder of the war. Microwave radars based on these devices, and especially those carried by aircraft, provided the Allies with a powerful advantage on many fronts.

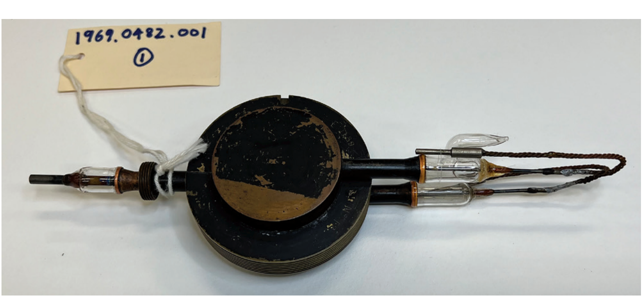

Figure 1: Artifact 1969.0482.001. (Source: Ingenium.)

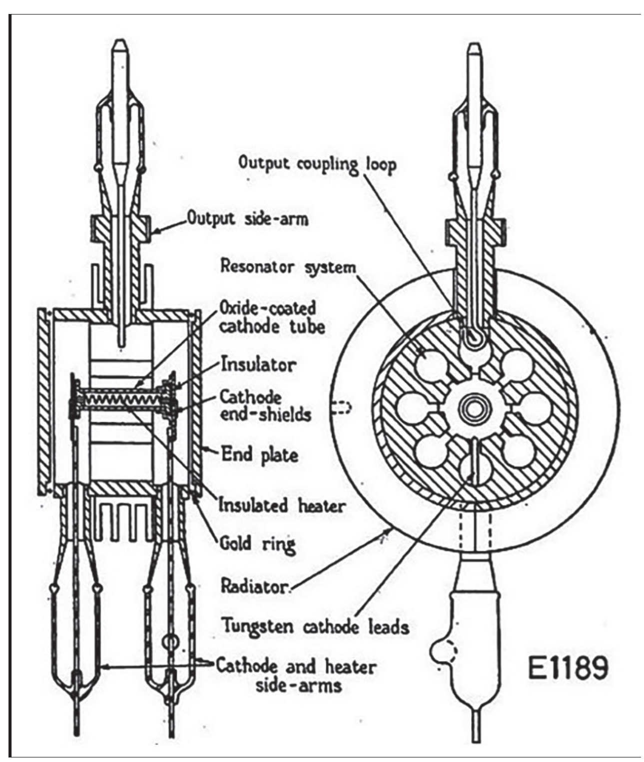

Figure 2: Internal details of an eight-cavity model E1189 magnetron.

They also set the stage for a postwar microwave electronics revolution that would transform both telecommunications and industrial heating.

Once magnetrons were being manufactured on an industrial scale and began to incorporate further improvements, such as the cavity strapping rings introduced by James Sayers, cavity magnetron no. 12 was retired. It remained with the NRC in Ottawa where, in 1963, it eventually entered the collection of the NRC Museum. In 1969, it was transferred to the collection of the newly formed National Museum of Science and Technology (renamed the *Canada Science and Technology Museum* in 2000) where it remains today.

Cavity magnetron no. 12 has been loaned for exhibition at special events several times, including an IEEE seminar in 1985 on the development of radar up until the end of the Second World War and an event in 2015 that commemorated the 75th anniversary of the Tizard Mission that was jointly organized by the U.S., British, and Canadian governments. In November 2018, the device was featured in the Past Forward column in *IEEE Spectrum*.

Those involved in the microwave radar effort on both sides of the Atlantic recognized the significance of their work. A first wave of publications from the 1940s and 1950s was an effort by those involved directly in the microwave radar development effort to share their own technical contributions. A second wave from the 1980s and 1990s represents an effort by both participants and historians to capture the accomplishments of the era from a broader organizational perspective. A third wave since the early 2000s, both formal and informal, has focused on identifying and resolving missing details or apparent contradictions in the historical record.

The story of cavity magnetron no. 12 continues to attract interest because it 1) significantly contributed to the success of the Allied war effort during the Second World War; 2) represents a disruptive technology that surpassed the capabilities of contemporary technologies in multiple ways with few, if any, weaknesses or shortcomings; 3) can serve as a case study of the impact of disruptive technologies on technical innovation; and 4) is well documented, at least compared to most technical innovations, with an abundance of both primary and secondary sources spanning several decades. However, the documentation concerning cavity magnetron no. 12 is quite dispersed, with many elements either unpublished or only informally published.

Cavity magnetron no. 12 astonished U.S. officials when it was demonstrated to them in fall 1940.

The lack of a guide to, or review of, the literature concerning cavity magnetron no. 12 is a major obstacle to those who wish to learn more about or contribute to its story, or who wish to use it as a case study of the impact of disruptive technologies on technical innovation. IEEE Canada is working with the Canada Science and Technology Museum to prepare a monograph that will bring this material together in one place for the benefit of both researchers and the general public. I will present a preview of the monograph as an invited speaker at the IEEE Radar Conference in Denver, Colorado, in May 2024. ■

About the Author

David G. Michelson is the IEEE Canada historian and chair of the IEEE Canada History Committee. An active contributor to the history of technology for two decades, he has been a member or corresponding member of the IEEE History Committee since 2012 and is responsible for more than one quarter of the 17 IEEE Milestones that recognize Canadian technology achievements. He was appointed as 2024–25 chair of the IEEE History Committee by the IEEE Board of Directors. He is also a member of the Society for the History of Technology (and its Special Interest Group on Telecommunications History), and a member of the History and Archives Committee of the Engineering Institute of Canada. His research interests in this area include the historiography of contemporary science and technology, the development and impact of Canadian science and technology since the Second World War, and the development and impact of both wireless technology and space technology since the Second World War. He can be contacted at dmichelson@ieee.org or historian@ieee.ca.

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Simple Steps in Organizing a Student Project

GROUP PROJECTS. They are a waking nightmare for every student, regardless of their level of education. Group projects are a harsh reflection of the professional working world. Of course, there remain differences, like compensation and responsibility to employers or stakeholders in a professional environment, yet the fundamental remains unchanged: learning how to manage complex group dynamics. A hypothetical scenario that rings true for too many postsecondary students:

Your professor assigns you to a team for your software capstone project. You have a productive first meeting where you discuss ideas and divvy up responsibilities: you will code and lead the team, Sarah will design the user interface, Raj will handle testing, and Fatima will create the presentation. Your team has a few more members with similar tasks and deliverables. You exchange contact information and form a WhatsApp group. But as the weeks pass, group communication grinds to a halt, with conversations becoming increasingly disorganized.

You continually have to remind others of deadlines and tasks needing completion. Sarah keeps altering her design concepts without consulting the team, leading to prolonged delays in progress. Tom skips multiple meetings without providing updates about his progress. Emily slips off the grid for days at a time, leaving the others unsure if she has even started on her part of the project since her phone is broken. On top of that, your college classes and other responsibilities have piled up, making it almost impossible for you to manage so many unknowns simultaneously.

As the deadline looms, the air grows thick with tension as none of the group members listen to one another, yet no one is willing to admit that progress has stalled. When you finally come together on the day of the presentation, it soon becomes apparent that everything clashes and nothing is compatible. The presentation is a disaster; if you get a D–, count yourself lucky.

As the deadline looms, the air grows thick with tension as none of the group members listen to one another, yet no one is willing to admit that progress has stalled.

So, was this avoidable? Maybe. Probably.

It did not have to be this way. With better management, this may not have happened. Projects can take short or long timespan and be small or large scale, but some form of governance is required for success. Allotted resources must be managed, including time, and communication among team members is vital. Chatrooms are inadequate for managing processes; an organized system with tangible action items is needed for collaboration and progress tracking.

Cue in: Kanban System. Developed by Taiichi Ohno of Toyota to streamline production processes and reduce inventory pileup, Kanban can quickly be adopted for student projects (Figure 1). This visual system helps teams identify and prioritize tasks appropriately, allowing everyone to see the big picture and focus on advancing relevant action items.

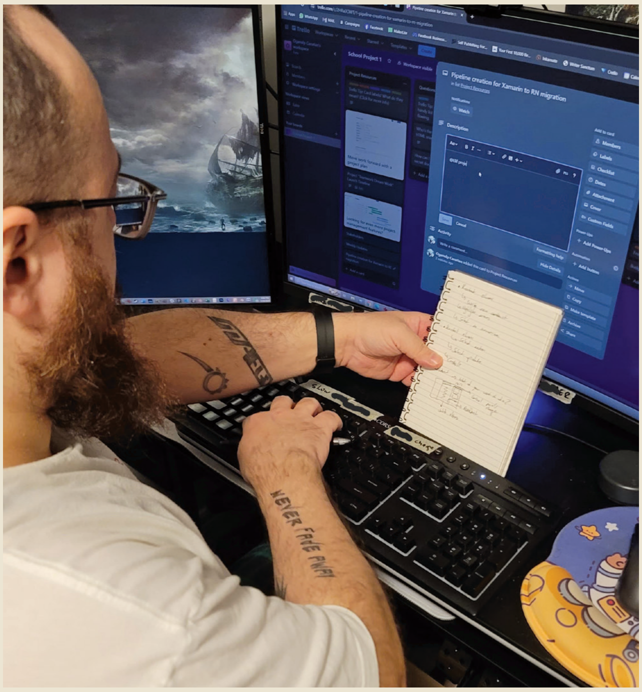

Figure 1: A Centennial College student working with the Trello implementation of Kanban.

Kanban offers an elegant and simple solution for effective task management. From a starting point of writing tasks onto pieces of paper or Post-it notes, users can easily manage their workflow with columnar organization. Track the progress of each individual assignment as it moves through groupings labeled "to do," "in progress," and "done." But do not limit yourself to pen and paper! Modern software, such as Trello, offers unbeatable convenience and improved functionality to teams working remotely. Connect different tasks based on dependencies, prioritize tasks, and identify problems and blocked cards before they become disastrous delays, all while enjoying a comprehensive project overview from a management perspective.

Setting up Trello is simple and easy:

- You start by creating a free account—do not forget to have your team members do the same!
- Once you have completed your registration, click the "+" sign and select "Create Board." If you feel creative, give it a name and spice it up with colors and images.
- Now that the board is ready, invite all your teammates to join the project.
- Time to add lists! These are different stages of your workflow or project. It is totally up to you how many columns you need; just make sure not to under- or overdo it. Too many columns can cause confusion, and too few will be vague.

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- Next comes adding cards—each card represents a task or information. Fill out the card with details, checklists, labels, or attachments as needed. Make sure there is enough info that everyone who looks at the card understands what it is about.
- Then, move the cards around according to their status.

And you have got yourself a fully functional environment for managing projects! You can now see who is doing which tasks, how they affect the overall project, and if any assignments need to be adjusted or changed—all with one glance! Plus, take advantage of Trello integrations to expand this system even further.

Group projects can seem insurmountable at times, but it is vital to remember that many objectives require a joint effort to be achieved. We cannot do everything independently; the most valuable commodity we lack is time. All too often, when projects fail, it is not because of a single person's inadequate contribution but, rather, due to an absence of constructive organization and process.

For those in the engineering or sciences field with an insatiable thirst for knowledge, IEEE offers a window into a world of unlimited possibilities. From the latest advancements to intricate technical details, from project management frameworks like Kanban to unparalleled resources, IEEE is your one-stop shop for all things cutting-edge and game-changing. Equip yourself with the tools you need to tackle any challenge that comes your way and emerge victorious in your career.

Group projects can seem insurmountable at times, but it is vital to remember that many objectives require a joint effort to be achieved.

So what are you waiting for? Join the rest of us on this thrilling journey of perpetual learning and growth, and unlock your full potential today. ■

Elif Bilge Canatan
IEEE Student Member
Health Informatics Technology, Centennial College
2023 IEEE Canadian Foundation Dr. Robert T. H. Alden Scholarship Recipient

About the Dr. Robert T. H. Alden Scholarship

This scholarship honours the memory of Robert T. H. (Bob) Alden, Ph.D., P.Eng., F-EIC, LF-IEEE, professor emeritus (McMaster University), 1937–2016.

Bob's enthusiasm and perseverance lead to the creation of the Power Research Lab at McMaster University, Hamilton.

In 2002 Bob was honoured with The Haraden Pratt Award, the top service award for all of IEEE. The citation referenced his "outstanding and sustained leadership in many areas of the IEEE especially in the use of electronic communication."

Bob is remembered for many contributions to IEEE, including his series *Travelling the Information Highway*, published in "The Institute" from 1992 to 2002. His articles helped individual members and IEEE operations realize the benefits of new communications and computing technology. For nostalgia buffs, they can be found here: www.ieeecanadianfoundation.org/EN/alden_institute_columns.pdf.

The scholarship recipient is asked to prepare an article in the same line as that series. The accompanying article is from the 2023 recipient Elif Bilge Canatan of Centennial College, Toronto.

This scholarship may evolve to recognize student achievements in power engineering, Bob's academic and professional field.

A full tribute to Dr. Alden is found in the fall 2016 *IEEE Canadian Review*, no. 76.

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Radio Science in Canada

by **David G. Michelson**

The International Union of Radio Science (abbreviated URSI, after its French name, Union Radio-Scientifique Internationale) has a long history of cooperating with IEEE to advance international cooperation in the study of electromagnetic fields and waves. This month's column focuses on the IEEE AP-S International Symposium and North American Radio Science Meeting to be held in Ottawa in 2025. It will be the largest radio science meeting to be held in Canada in nearly a decade.

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IEEE ANTENNAS AND PROPAGATION SOCIETY/ URSI 2025: 13–18 JULY 2025, OTTAWA

As reported in the fall 2023 issue, Canada will host the IEEE Antennas and Propagation Society International Symposium and North American Radio Science Meeting (IEEE AP-S/URSI) at the Shaw Centre in Ottawa from 13 to 18 July 2025. The conference will bring together as many as 2,000 researchers from around the world to share their latest work in antennas, propagation, and radio science.

The Canadian National Committee of URSI is taking the lead in organizing the conference. The following individuals are on the organizing committee:

General chair

- Prof. David Michelson, *University of British Columbia*

Finance cochairs

- Prof. Vladimir Okhmatovski, University of Manitoba
- Prof. Zhizhang David Chen, *Dalhousie University*

TPC cochairs

- Prof. Natalia Nikolova, *McMaster University*
- Prof. Marco Antoniades, *Toronto Metropolitan University*
- Prof. Loïc Markley, *University of British Columbia-Okanagan*

Publication cochairs

- Dr. Michel Clénet, *Defence Research and Development Canada, Ottawa*
- Prof. Tarek Djerafi, *Institut national de la recherche scientifique (INRS)*

Patronage and exhibits cochairs

- Lars Foged, *Microwave Vision Group*
- Charlotte Blair, *Ansys*

Local arrangement cochairs

- Prof. Shulabh Gupta, *Carleton University*
- Prof. Atif Shamim, *King Abdullah University of Science and Technology (KAUST)*

General vice-chairs

- Prof. Yahia Antar, *Royal Military College of Canada*
- Prof. George Eleftheriades, *University of Toronto*
- Prof. Ke Wu, *Ecole Polytechnique*

Figure 1: The Shaw Centre in the foreground with the Westin Ottawa in the background.

Conference Management Services Worldwide will provide planning, finance, registration, and paper management services to the conference, with Tourism Ottawa assisting with local arrangements. A view of the conference venue is shown in Figure 1.

A major goal of this edition of the conference is to create opportunities for attendees to interact with the local tech community and vice versa. The IEEE Antennas and Propagation Society/Microwave Theory and Technology Society Joint Chapter of the IEEE Ottawa Section is organizing a local support team that will assist with industry and community outreach before the conference and onsite support during the conference. It will also coordinate the open plenary talks to which members of the local community will be invited to attend alongside conference attendees and assist local tech firms in arranging to participate in the commercial exhibits section of the event.

Because it will be held in Ottawa, IEEE AP-S/URSI 2025 offers a significant opportunity for both Canadian government entities and industry firms to share success stories, increase visibility and recognition, engage with potential collaborators, and recruit new talent. Visibility and recognition can be enhanced by hosting a booth and possibly giving a presentation or demonstration in the exhibits area, hosting a workshop (onsite) or corporate tour (offsite), and becoming a conference patron and possibly giving a plenary presentation. During the next few months, the organizing committee will be reaching out to potential industry and government participants and encouraging them to sign on.

IEEE AP-S/URSI 2025 will be the largest radio science meeting to be held in Canada since the URSI General Assembly and Scientific Symposium was held in Montréal in 2017. We're looking forward to another very successful event. Additional details can be found at https://2025.apsursi.org/. ■

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

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

About the Author

David G. Michelson is president of the Canadian National Committee of the International Union of Radio Science (2018–2026). He has led the Radio Science Lab at the University of British Columbia, Department of Electrical and Computer Engineering, since 2003. His current research focuses on short-range/low-power wireless networks for industrial vertical and transportation applications, millimetre-wave channels and systems, and satellite networks for communications and remote sensing. Prof. Michelson currently serves as a member of the Board of Governors of the IEEE Vehicular Technology Society, as a member of the Steering Committee of the National Institute of Standards and Technology-sponsored NextG Channel Model Alliance, as director of the AURORA Smart Transportation Testbed, and as principal investigator of the Campus as a Wireless Living Lab project at UBC. He is licensed in Canada (basic, advanced, and digital) as VA7DM and in the United States as NC7V (extra class). He is an ISED-accredited amateur radio examiner.

Engineering Institute of Canada's Selection for 2024 Medalists and Fellows

The Engineering Institute of Canada (EIC), founded in 1887, announced the winning recipients of its 2024 medalists and fellows. The following IEEE Canada members received a distinction.

Julian C. Smith Medal

(For exceptional achievement in the development of Canada)

Samuel Pierre, Montréal

EIC Fellowships

(For excellence in engineering and their services to the profession and to society)

Naser El-Sheimy, Southern Alberta

Medhat Moussa, Kitchener-Waterloo

Vincent Wong, Vancouver

Elise Fear, Southern Alberta

Thamir (Tom) Murad, Toronto

David Anthony Clausi, Kitchener-Waterloo

Baochun Li, Toronto

Zhenguo Lu, Ottawa

Svetlana Yanushkevich, Southern Alberta

Biz Tech Report

by Terrance Malkinson

A group of engineering students at Memorial University have designed and built a satellite (www.cbc.ca/news/canada/newfoundland-labrador/mun-cube-satellite-launch-1.7083920). The satellite will be sent into space as part of SpaceX's mission to the International Space Station this spring. The 10-cm cubic satellite is made of aluminum and weighs about 1 kg. The project began in 2018, when students from across the country were invited to compete for the opportunity by the Canadian Space Agency. Since then, Memorial University professors and students as well as engineers at St. John's-based research and development company C-CORE came together to build the cube satellite. It will receive the GPS signals that reflect from Earth for sea ice, ocean waves, and other important features. Only a few Canadian universities offer space engineering programs. Cube satellites are envisioned to be a growing industry. Canada is a respected international partner in space exploration. Many rewarding career paths are emerging.

NASA's James Webb Space Telescope has been an extraordinary success. Details of the telescope and Canadian involvement in this engineering marvel are provided in the spring 2022 issue of *IEEE Canadian Review* (no. 89, pp. 6–12). In its first year, the telescope has transformed our view of the cosmos, seeing light from the edges of the universe and producing the deepest and sharpest infrared images of the distant universe to date. New information emerges daily, improving our understanding of the origins of the universe and of galaxies, stars, and planets outside of our solar system. Information provided by the telescope is much greater than what was expected. Future discoveries will likely be even more amazing. Beyond the stunning infrared images, most important are Webb's spectra—detailed information from distant light by the telescope's spectroscopic instruments. Webb's spectra have confirmed the distances of some of the farthest galaxies ever observed and have discovered the earliest, most distant supermassive black holes. They have identified the composition of planet atmospheres, including exoplanets, for the first time. Recently (5 February 2024), a new dwarf galaxy was seen by astronomers in an area of space where scientists were not expecting to see anything. This information improves our understanding of galaxy formation. Earlier in February, NASA discovered a "super-Earth" 137 light-years away in the habitable zone that could be a promising candidate for life. This exoplanet located outside of our solar system is 1.5 times larger than Earth and orbits a small, reddish star every 19 days. NASA has discovered more than 5,000 exoplanets since the first was discovered three decades ago and predicts that there are more than a trillion exoplanets in the Milky Way, some of which may also be candidates for life.

Webb's spectra have confirmed the distances of some of the farthest galaxies ever observed and have discovered the earliest, most distant supermassive black holes.

NASA's OSIRIS-REx is the first U.S. mission to deliver a sample of an asteroid to Earth. Launched on 8 September 2016, it reached the asteroid Bennu and collected a sample of rocks and dust from the surface. On 24 September 2023, the spacecraft returned to Earth orbit and released its capsule containing the samples from Bennu, which then parachuted to Earth at the U.S. Department of Defense's Utah Test and Training Range near Salt Lake City for retrieval (https://science.nasa.gov/mission/osiris-rex/). This mission will help scientists investigate how planets formed and how life began as well as improve our understanding of asteroids. Initially, the canister containing the material could not be opened. After months of work, the NASA team at the Johnson Space Center was able to remove two stuck fasteners on the canister on 11 January 2024 using newly developed tools. Protocols for opening and handling the samples are very elaborate to avoid any contamination of the material. It will take many years to fully analyse the material collected. Early impressions suggest the evidence of carbon and water. Portions of the asteroid sample will be sent to scientists around the world for study.

NASA's retired space shuttle *Endeavour* was hoisted and attached to its external fuel tank and two solid rocket boosters, where it will be displayed at the Air and Space Center at the California Science Center in Los Angeles. The 20-story-tall shuttle stands on a concrete slab supported by six base isolators to protect it from earthquakes. All parts of the launch configuration are authentic components of the shuttle system. *Endeavour* flew 25 missions between 1992 and 2011. In addition to *Endeavour*, other aircraft and spacecraft will be displayed. NASA operated five shuttles in space. *Challenger* was destroyed, and its crew of seven died in a launch accident on 28 January 1986. *Columbia* broke apart during re-entry on 1 February 2003, killing all seven on board. *Atlantis* is at the Kennedy Space Center in Florida. *Discovery* rests at the National Air and Space Museum in Chantilly, Virginia. *Enterprise* is displayed at the Intrepid Museum in New York. These displays are a tribute to the engineers, scientists, and crews of the shuttle program.

A report, "Unlocking Health Care: How to Free the Flow of Life-Saving Health Data in Canada" by the Public Policy Forum, a nonprofit group that brings together experts to tackle and advise on significant public issues, was published in January 2024 (www.ppforum.ca/wp-content/uploads/2024/01/UnlockingHealthcare-LifeSavingDataInCanada-PPF

-Jan2024-EN-2.pdf). The report describes Canada's failure to harness digital technology to ensure that a patient's complete health data are available to all members of their care team. It calls for all health records to be paperless and digitally accessible across provincial and territorial boundaries to all members of a patient's care team by 2028. The objective is a secure and comprehensive database that includes all health information and test results. The Forum report also recommends that federal legislation be enacted to give patients ownership and access to their own health data. A digital-based system would permit patients to be proactive in their health and be cost-effective, providing a historical archival record of all test results, revealing trends and eliminating the need for repetitive testing by each member of the patient's medical care team. The Forum recognized that patients may be concerned about the security of their health data in a digital system.

The objective is a secure and comprehensive database that includes all health information and test results.

Dr. Ed McCauley, president and vice chancellor of the University of Calgary, provides his perspectives on "Why Is Canada So Miserly In Funding Academic Research?" in a 29 December 2023 *The Globe and Mail* opinion article (www.theglobeandmail.com/business/commentary/article-canada-academic-research-funding). University education is important and can be measured in a number of different ways, including increased earnings potential; qualification for new employment opportunities as they emerge; a network of fellow alumni; expertise; tenacity; and a well-rounded, informed, innovative, critical thinking, socially responsible, and globally aware citizen who has a diversity of learnings that facilitate a successful personal and career journey. Perspectives emerging from his article are important. Research done on university campuses fosters innovation that drives the economy. Federal spending on university science and research has declined by 19% in real terms since 2020. Universities are unable to retain their best faculty and graduate students because they are lured away by better opportunities abroad. Without talented researchers, we cannot compete in the high-growth sectors of the economy now and in the future. As he describes, other countries are committing to massive increases in postsecondary and academic and research funding. Regrettably, Canada is not.

Artificial intelligence has understandably led to concerns about the potential for unemployment and societal change. AI is a generic term describing many different technologies that have the ability to learn and improve on their own. The major difference between AI and traditional technology is that AI has the capacity to make predictions and learn on its own. It analyzes data and then uses those data to make accurate predictions. It learns from every prediction it makes and optimizes its approach to use in the future. The far-reaching nature of AI and the speed of recent progress means that career-savvy individuals need to understand fully its impact. History shows that new technologies can have positive effects that are hard to foresee. Canada has some of the best AI researchers in the world, has attracted private investment in AI, and is seeing many AI-related business start-ups, and this is an opportunity for rewarding career opportunities. The regulation of AI is of critical importance because of the danger if misused. It is possible that AI could defeat our current cyberdefences, spread disinformation, and be used in many other ways that harm our society. AI has the benefits of automating repetitive tasks, making us more productive, reducing human error, solving problems in new ways, and helping us make better decisions. We must recognize that it can make errors—the more data it has, the better the decision. AI experts all agree on one thing: AI technology is going to have significant effects on society and business. AI can have a positive net impact on the world, but we also must have an understanding of and mitigate its risks and problems. ■

About the Author

Terrance Malkinson (malkinst@telus.net), the author of more than 600 peer- and editorial-reviewed earned publications is now retired. His diverse career path includes 26 years in medical research as a founding member of the Faculty of Medicine at the University of Calgary and a three-year appointment as a business manager with the General Electric Company, followed by a one-year applied research appointment with SAIT Polytechnic. He is an alumnus of continuing professional education programs with Outward Bound International, Banff Centre for Management, the Massachusetts Institute of Technology, and the University of Colorado. During his long career, he has advanced both basic and applied medical, health and wellness, scientific, and engineering knowledge. He has trained and mentored undergraduate, graduate, and postdoctoral students as well as staff in the business sector and government. He is a 45-year Life Senior Member of IEEE. He has served in many professional public and private governance and publication roles. He is the recipient of several peer-selected earned awards, including induction into the Order of the University of Calgary, IEEE achievement medals, and APEX awards for publication excellence. In retirement, he vigorously continues basic and applied research with an extensive portfolio of projects. He is a manuscript reviewer and a special topic editor for several journals. Other passions include communicating emerging technologies to the public, investigative journalism, philanthropy, and mentorship. His current research interest in emerging technologies and health and wellness extends to being an accomplished multisports triathlete, including, among other events, completion of 11 full-distance Ironman Triathlons. His profile can be found on Academia.

Superfluidity for Engineers, Part 3: Applications

(Continued from p. 15)

pressure bias is applied to the Josephson cell, i.e., $\Delta P = P_o \sin(\omega_p t)$ instead of a constant one? What would be the shape of the current? Does it have any application?

What if instead of two parallel Josephson cells in a loop [Figure 3(a)], three or more cells are connected in parallel? Do they resemble a phased-array antenna [7]? ■

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About the Author

Daryoush Shiri received his Ph.D. degree in electrical and computer engineering in 2013 from the University of Waterloo, Canada. Prior to this, he worked at a few start-up companies as a radio-frequency/analog CMOS design engineer and team leader. His thesis was devoted to the computational study of electron transport in silicon nanowires. As a postdoctoral fellow at the Institute for Quantum Computing, Waterloo (2013–2015), he collaborated in developing a scalable package for quantum-computing circuits. He came to Sweden in 2016 as a postdoctoral fellow at the Department of Physics, Chalmers University of Technology, to work on heat transport in 2D materials. Currently, he is a researcher at the Quantum Technology Laboratory in the same university, working on the simulation of superconducting microwave circuits for quantum computing. He cosupervised several Ph.D. and master's degree students during these years. He loves teaching and always quotes John Archibald Wheeler: "If you would learn, teach."


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