ALBERTA INNOVATES

NSERC Alliance-AI Advance program

July 26, 2024

About Alberta Innovates

Innovation is the catalyst for sustainable jobs, economic and community strength, improved health and environmental benefits. Alberta Innovates leads and accelerates innovation from discovery to use across all sectors in all parts of the province. As Alberta's largest research and innovation agency, we are uniquely positioned to propel great ideas forward to improve the lives of Albertans today and for generations to come.

Alberta Innovates believes the research and innovation (R&I) ecosystem is stronger and more sustainable when it is broadly representative of the overall diversity of our community. We strive to ensure that all interested and qualified parties have an equitable opportunity to participate and contribute to the ecosystem and that our processes are inclusive.

The projects that our programs invest in are critical to how Alberta Innovates achieves positive impact for Albertans in alignment with the Government of Alberta's R&I priorities, as expressed in our corporate Business Plan. (See the most recent Business Plan on our Publications page on our website.) Accordingly, it is essential for project outcomes to align with those of the program.

The NSERC Alliance-Alberta Innovates Advance Program is managed through the Post-Secondary Investments and Emerging Technologies (PSIET) within Alberta Innovates. The PSIET team provides funding, enabling and matchmaking to emerging technology inventors to increase the volume of commercial outcomes for Alberta's future prosperity. Please visit https://albertainnovates.ca/focus-areas/post-secondary-investments/.

Program Overview

In partnership with Natural Sciences and Engineering Research Council of Canada (NSERC), the **NSERC Alliance-Alberta Innovates Advance Program** invests in projects that, in alignment with Alberta's technology and innovation strategies, advance discoveries to develop and/or use emerging technologies that can generate economic, environmental, health and social benefits for Albertans and Canadians.

The **NSERC Alliance-Alberta Innovates Advance Program** has two streams:

Stream I (NSERC Discovery Grants (Individual)): During 2024-25, Alberta Innovates will offer supplemental funding opportunities to NSERC Discovery Grants (Individual) researchers who hold active NSERC Discovery Grants (Individual) in Alberta, awarded in **Competition Year (CY) 2023,** and have R&D activities focusing on one or more **emerging technology subject areas** as outlined in **Appendix A** of this Guide.

Stream II (General stream): This stream is the general Advance program stream. Funding is available to NSERC eligible researchers at Alberta-based universities to help those who have made promising discoveries to conduct the research needed to advance to the development stage, which could eventually lead to commercialization.

In 2024-25, the following four targeted emerging technology research topics under the Information and Communications Technologies (ICT) category, as described in **Appendix B** of this Guide, will be in-scope for Stream II:

i) Internet of Things (IoT)/Machine-to-machine systems,

ii) Advanced data management and analytics (Artificial intelligence and machine learning),

iii) Cybersecurity,

iv) Quantum computing.

The objectives of the **NSERC Alliance-Alberta Innovates Advance Program** are to:

- Improve the direction of research efforts that could lead to technology transfer and commercialization in Alberta and Canada
- Advance emerging technologies' readiness level toward future market potential
- Augment the Alberta academic researcher's capacity to accelerate and advance research excellence in Alberta's emerging technology areas
- Develop an enhanced skill and knowledge base [Highly Qualified Personnel (HQP)] for Alberta companies

The emerging technology research topics and subject areas in the NSERC Alliance-Alberta Innovates Advance Program offer transformational promise for challenges across Alberta's existing sectors and entry into wider global markets. Their development provides the foundation for job creation and economic diversification into nascent industries in Alberta.

The key outcomes (i.e., measurable effects) the program will accomplish for the benefit of Albertans and Canadians are:

- Increased R&D activity in Alberta's emerging technology areas
- Create new HQPs with enhanced technical skills and knowledge base in Alberta's emerging technology areas
- Increased HQP career opportunities
- Advanced products and/or services

Funding

Stream I (NSERC Discovery Grants (Individual))

Successful applicants can receive 2/3rd of NSERC's annual Discovery Grants (Individual) award value from Alberta Innovates to a maximum of $20,000 per year per award for a maximum of two (2) years.

Stream II (General stream)

Individual proposals can request up to $150,000 per year and can be for up to two years in duration. Alberta Innovates will provide a maximum of $100,000 per year and NSERC will match the Alberta Innovates contribution by a ratio of 50% up to a maximum of $50,000 per year.

For Stream II, project funding is intended to help bridge the gap between academic research and technology validation [within Technology Readiness Levels (TRL) 2-4]. Projects will advance an idea toward developing a technological solution with an envisioned future market opportunity. Projects could later lead to technology transfer activities and commercialization post-grant. Eligible technology development within this program can begin as early as the conceptual research stage (starting at TRL 2), up to testing/validation of ad-hoc component integration in a laboratory setting (TRL 4). Projects developing technologies at later stages are not eligible for this program. Industry participation in the Advance program is not permitted; projects with industry partners could apply to the NSERC Alliance mainstream program or other AI/NSERC supports.

Alberta Innovates only funds reasonable costs incurred after an Investment Agreement is signed by Alberta Innovates and the Applicant. Any costs incurred before signing the Investment Agreement, and costs greater than market prices, are ineligible. Costs must be incurred between -arm's length entities. Please refer to Schedule C in the Investment Agreement posted on the Advance web page https://albertainnovates.ca/programs/advance/ for detailed information, including eligible and ineligible expenses.

Key Dates

Stream I (NSERC Discovery Grants (Individual))

- **Intake form submission:** Eligible applicants may submit the PSIET Intake Form. The deadline for submission is **September 25, 2024**.
- **Full application submission:** Applicants receiving approval of the PSIET Intake Form will be notified by **October 8, 2024,** and must submit the full application by **November 1, 2024**.

Stream II (General stream)

Stream II application inquiries (pre-intake stage) will be received on a continuous intake basis until application capacity for the current fiscal year has been reached.

Eligibility

Please see the Applicant and Project eligibility requirements below, including **Appendices A and B** for the list of emerging technologies targeted under Stream I and Stream II, respectively, in 2024-25.

Applicant Eligibility

Stream I (NSERC Discovery Grants (Individual)

Advance program (Stream I) is open to:

- Researchers with active NSERC Discovery Grants (Individual), currently holding at a post-secondary institution in Alberta for **Competition Year 2023** with **research focusing on one or more of the emerging technology subject areas** as outlined in **Appendix A** in this Guide.
- Applicants cannot hold more than one Advance Stream I grant simultaneously.

Stream II (General stream)

Advance program (Stream II) is open to:

- Researchers from post-secondary institutions that are on NSERC's list of Alberta-based universities.

  (Researchers from Alberta universities are the Applicant Representatives for applications to this program. To be eligible for the program, ***the Applicant Representative (NSERC primary applicant) must hold an NSERC peer-reviewed grant*** *when they apply and meet NSERC eligibility criteria when applying and when funding is released)*

- Only one application per Primary Applicant (Principal Investigator) per fiscal year (April 1 to March 31) is permitted. There is no limit on the number of applications submitted as co-applicants.
- Applicants cannot hold more than one Advance Stream II grant simultaneously; current Advance Stream II grant holders, however, may be eligible to apply for Stream I funding, meeting the eligibility requirements of Stream I.

All Applicants (in Stream I and Stream II) must also:

- Be authorized to undertake the proposed project, and execute a grant agreement with Alberta Innovates on our standard terms;
- Not otherwise be prohibited from receiving Alberta Innovates funding, for instance, due to a past bad debt or otherwise not in good financial standing with Alberta Innovates or its subsidiaries, InnoTech Alberta and C-FER Technologies;
- Have a physical presence in Alberta.

Project Eligibility

To qualify for funding, all Projects must:

- Align with the objectives of the Advance Program;
- Meet NSERC's eligibility criteria;
- Align with at least one of the emerging technology subject areas outlined in **Appendix A (for Stream I)**; or at least one of the four emerging technology research topics outlined in **Appendix B (for Stream II)** in this Program Guide;
- Start by **February 3, 2025**;
- Be completed within the two-year term;
- Technology being developed by the Project in Stream II must be within TRL levels 2 to 4; and
- Comply with other criteria that Alberta Innovates may develop from time to time.

How to Apply?

Stream I (NSERC Discovery Grants (Individual))

The Advance Program (Stream I) application process involves the following steps:

i. Researchers currently holding active NSERC Discovery Grants (Individual) in Alberta for Competition Year 2023 and interested in applying for Alberta Innovates supplemental funding, should start by submitting the Post-Secondary Investments & Emerging Technologies (PSIET) Intake Form within the *Funding Opportunities* tab on the AI online portal (also known as the SmartSimple application portal).

   Alberta Innovates will process intake applications in the order they are received, until the budget for this year's Discovery Grant (DG) stream is fully allocated. Applications received before September 25, 2024, that meet requirements may be queued for future funding consideration if additional budget becomes available after the 2024/25 budget has been fully allocated. However, there is no guarantee or expectation that queued applications will receive funding from Alberta Innovates.

   It is highly recommended that you complete your Intake Form to avoid mistakes that could result in your application being removed from the queue. Due to the potentially high volume of DG stream applications, Alberta Innovates aims to respond to applications within two months of receipt.

ii. Researchers intending to submit the PSIET Intake Form, must select "NSERC – AI Advance Stream I (Discovery Grants)" from the dropdown list provided on the intake form.

   a. Under the 'non-confidential summary' section of the PSIET Intake Form, in regards to

      i) Project Title: Include the title of your approved NSERC Discovery Grants program/project, followed by adding "(supplement)" in parentheses at the end of the project title;

      ii) Project Summary: Provide the summary of your NSERC Discovery Grants proposal (i.e., non-confidential and can be publicly available through the NSERC Awards Database).

   b. Under the 'project overview' section of the PSIET Intake Form, please ensure to include

      i) Applicable Emerging Technology Subject Area(s); and how your project aligns (research topic and relevance).

      ii) Description of the activities/methodology that are proposed to be carried out by the Alberta Innovates supplemental funding, including associated objectives, deliverables and anticipated outcomes (R&D capacity for Alberta while creating new HQP in the identified ET subject area(s)). These activities should be new (additional) activities not covered by the approved NSERC Discovery Grants (Individual) but should be relevant and complementary to the approved NSERC Discovery Grants project/program.

iii. Once the PSIET Intake Form has been approved, the applicant will receive a link to complete the full proposal by uploading the following essential documents under the 'attachments' section in SmartSimple:

      i) Approved NSERC Discovery Grants (Individual) full application,

ii) NSERC's Notice of Decision including Terms and Conditions,

iii) Message from the evaluation group, and

iv) Alberta Innovates supplemental budget expenses.

Stream II (General stream)

The Advance Program (Stream II) application process involves the following steps:

i. Researchers contact the Alberta Innovates Advance Program manager to determine initial alignment with the program requirements including one of the emerging technology research topics (see Appendix B).

ii. Upon confirming preliminary alignment, applicants complete and submit the Post-Secondary Investments & Emerging Technologies (PSIET) Intake Form within the *Funding Opportunities* tab on the AI online portal (also known as the SmartSimple application portal). On the Intake Form, select "Advance Stream II (General stream)".

iii. If the PSIET Intake Form is approved, the applicant receives an invitation to submit a full proposal. All applications are reviewed until the annual budget is allocated.

iv. Once invited to apply for a full proposal, the applicant must

   a. First, complete the NSERC application (without submitting it) and generate the PDF version of it using NSERC's online portal.

   b. The applicant then completes the Alberta Innovates application form in the AI online portal (SmartSimple). The applicant must attach a PDF of the NSERC application as part of the Alberta Innovates application.

   c. If conditionally approved, Alberta Innovates will sign the NSERC 'joint call funding partner' form in the NSERC application portal.

   d. Once Alberta Innovates has signed the Partner Form, the applicant can proceed to submit the application to NSERC through the appropriate NSERC application portal (NSERC online system).

By submitting the Advance application to Alberta Innovates and the related NSERC application to NSERC, applicants and co-applicants consent to the sharing of all information, including personal information, between Alberta Innovates and NSERC for the purpose of application adjudication and awards.

Evaluation Process

Stream I (NSERC Discovery Grants (Individual))

Alberta Innovates evaluation

After submitting the full proposal as outlined in the guide for Stream I under the 'How to Apply' section, the application undergoes internal review. Comments from the NSERC evaluation group are taken into consideration during this process.

Decision

Applicants will be notified through SmartSimple once a decision has been made. Approved applications will receive funding from Alberta Innovates. Successful Applicants will execute an Investment Agreement with Alberta Innovates to proceed with the activities of the Project.

Stream II (General Stream)

Applications under Steam II are reviewed jointly by Alberta Innovates and NSERC. Meeting all evaluation criteria does not guarantee funding as awards are competitive.

Alberta Innovates evaluation

All applications are assessed by Alberta Innovates to determine alignment with the Advance Program objectives and intended outcomes. Applicants are encouraged to demonstrate research collaboration at both the intake and full proposal stages. Alberta Innovates evaluates submitted applications based on the

- Eligibility criteria for the Applicant and the proposed project, as outlined in the guideline,
- NSERC Merit indicators: a) Quality of the proposal, b) Project Team and Training Opportunities, c) Relevance and Outcomes, and d) Future Market Opportunity

Decision

Upon receiving a recommendation from Alberta Innovates to proceed to NSERC, NSERC will review and evaluate applications under the NSERC Alliance-Alberta Innovates Advance Program (Stream II). Applications approved by both NSERC and Alberta Innovates will receive funding from Alberta Innovates. Separate agreements will be executed by NSERC and Alberta Innovates with the Applicant. Successful applicants will execute an Investment Agreement with Alberta Innovates to commence project activities.

For both streams, It is strongly recommended that applicants demonstrate the practice of Equity, Diversity, and Inclusion (EDI) adequately in their proposed project.

Alberta Innovates retains the sole right to determine the evaluation process and assessment criteria and does not disclose the names of its reviewers to ensure their objectivity and impartiality. Internal and external parties involved in the evaluation are subject to confidentiality and conflict-of-interest policies set by Alberta Innovates.

Performance Measurement

Alberta Innovates invests in research and innovation activities on behalf of Albertans to help build a healthier, more sustainable and prosperous future for the province.

To maximize the impact of these investments, our funding is tied to the achievement of results and outcomes. For this reason, Alberta Innovates funds on a milestone completion basis. This means the Applicant must submit a Progress and/or Final Report and demonstrate sufficient progress before Alberta Innovates advances the next milestone payment.

The Investment Agreement outlines the responsibilities the Applicant has in reporting Project outcomes to Alberta Innovates over the course of the Project and following completion of the Project. Outcomes of the Project may be monitored for up to five years after Project completion, so Alberta Innovates can evaluate the economic, social, health and/or environmental benefits to Alberta resulting from our investments.

Alberta Innovates has a common set of performance metrics it monitors, both at the individual Project level and for the aggregate Program. These metrics may evolve over time.

Terms and Conditions

Once we have evaluated and approved an application for funding, Alberta Innovates will require the Applicant to sign our standard-form Investment Agreement. A copy of the Investment Agreement is available on the Alberta Innovates website https://albertainnovates.ca/programs/advance/ for your reference.

The Investment Agreement sets out in detail the roles, responsibilities, and obligations of the various Parties to ensure a successful Project. Alberta Innovate will not provide any funding until the Investment Agreement has been signed by all Parties.

Alberta Innovates will only fund Applicants who have satisfied all eligibility criteria. Meeting the eligibility criteria does not guarantee access to funding, and all funding decisions will be made by Alberta Innovates at its sole discretion.

Alberta Innovates will only correspond in writing and provide copies of the Application to the person named in the Application form as the one authorized to speak for the Applicant.

Should you have any questions about this guide or what is expected, please contact Alberta Innovates (see contact information below). Please note that Alberta Innovates may modify this guide from time to time in keeping with any changes to the program.

Contact Information

ADVANCE PROGRAM (STREAM I AND II)
Susie Li PhD
Senior Business Partner
Post-Secondary Investments and Emerging Technologies (PSIET)
Alberta Innovates
Tel : 780-632-8229
Email : susie.li@albertainnovates.ca

NSERC (STREAM I – DISCOVERY GRANTS)
Kate Henbest
Manager | Gestionnaire
Research Grants and Scholarships | Subventions de recherche et bourses
Natural Sciences and Engineering Research Council of Canada | Conseil de recherches en sciences naturelles et en génie du Canada
Telephone | Téléphone 343-576-1731
Kate.Henbest@nserc-crsng.gc.ca

NSERC (STREAM II)
Irene R. Mikawoz, P. Eng. FEC
Deputy Director | Directrice adjointe
Pacific and Prairies Regional Office | Bureau régional du Pacifique et des Prairies
Natural Sciences and Engineering Research Council of Canada | Conseil de recherches en sciences naturelles et en génie du Canada
Telephone | Téléphone 204-290-7738
Toll Free | Sans frais 1-877-767-1767
irene.mikawoz@nserc-crsng.gc.ca

Appendix A.

NSERC Alliance-Alberta Innovates Advance Program (Stream I - NSERC Discovery Grants (Individual)) specific emerging technology subject areas

• Advanced or Additive Manufacturing	• Interactive Digital Media or Augmented, Virtual, Extended or Mixed Reality
• Artificial Intelligence	• Internet of Things (IOT)
• Autonomous Vehicle	• Machine Learning
• Automation	• Materials Informatics
• Blockchain	• Quantum
• Communications Networks and Services	• Remotely Piloted Aircraft System (RPAS) or Unmanned Aerial Vehicle (UAV)
• Cyber Security	• Robotics
• Geomatics or Geospatial	

Appendix B.

NSERC Alliance-Alberta Innovates Advance Program (Stream II – General stream):

During 2024-25, proposed projects must fall within one of the **following four (4) emerging technology targeted research topics** (**in-scope**) under the **Information and communications technologies (ICT)** category:

- **Information and communications technologies (ICT)**
  - ***Internet of Things (IoT)/Machine-to-machine systems*** (see research topic #2 in the section below for detailed scope)
  - ***Advanced data management and analytics*** (see research topic #3: **Artificial intelligence and machine learning,** in the section below for detailed scope)
  - ***Cybersecurity*** (see research topic #4 in the section below for detailed scope)
  - ***Quantum computing*** (see research topic #6 in the section below for detailed scope)

- **Advanced materials & manufacturing technologies (AMM)**
  - **During 2024-25,** research topics described under the Advanced materials & manufacturing technologies category will be **out-of-scope.**

NSERC ALLIANCE – ALBERTA INNOVATES ADVANCE PROGRAM EMERGING TECHNOLOGY AREAS

Information and communications technologies (ICT)

Context

The overall objective for proposals in the information and communications technologies (ICT) target area is to empower and protect individuals, organizations and society by leveraging ICT at scale. Indeed, many research challenges in the ICT area are focused on enabling humans to access the benefits latent in systems and data at scale while ensuring privacy and data security. Individuals can be empowered by utilizing data to improve their health, reduce environmental impact, increase personal productivity and enhance social interactions. Private and public organizations can use data analytics to enhance context awareness, leading to better decision-making. Innovative ICT helps societies to create successful economies while minimizing environmental impacts. Information is at the heart of these opportunities; however, information needs to be protected as well as responsibly and securely shared to gain the anticipated societal benefits.

Systems and data at scale require dealing with increasing data volume and velocity, data validity and veracity, and network and system diversity and complexity. Six research topics in ICT have been identified in support of this common thrust. Transformative research on communication networks and services is required to satisfy future bandwidth, energy and service needs. The Internet of Things (IoT) will allow unprecedented and fine-grained awareness of the surroundings, but will require overcoming communications and data-fusion challenges. Advanced data management, artificial intelligence and analysis techniques will allow humans and organizations to make better decisions on crucial social and/or economic issues. Cybersecurity is required to protect the confidentiality, privacy, integrity and availability of data and the systems over which it travels. Rethinking human interactions with digital media will improve the usability and usefulness of access to overwhelming amounts of information. Quantum computing is the next frontier of ICT, enabling improvements in sensor sensitivity and computational power by many orders of magnitude.

A strategic investment in ICT will allow Alberta's researchers to position at the forefront of innovation, leading to economic opportunities for Alberta companies as well as social benefits for Albertans. Research in this target area must specifically address one of the ICT research topics below.

Research topics

1. *Communications networks and services*

Transformative research on software-defined networks: Future communication networks need to be scalable, flexible, agile, secure, and cost-effective to offer an array of end-to-end communication services and applications that meet the requirements of big data, cloud computing, mobility and IoT.

Software-defined networks will scale by control and adaptive management and will handle changing demand and resources to achieve energy and resource efficiency and sustainability. Orchestration of services built on cloud computing and virtualized resources will support a dynamic applications environment. Architectures and methods will scale by enabling end-to-end connectivity spanning heterogeneous networks, including wired and wireless segments. They will deliver quality of experience and real-time and bandwidth-intensive applications, and also tolerate transient disconnection. Wireless networks will scale by exploiting dynamic spectrum to provide higher bandwidth, with reliability and low power, leveraging future radiofrequency and millimetre wave. Heterogeneous radio networks will interoperate to support services in IoT and 5G networks and to replace existing wired access, as well as new satellite and airborne networks. Wireline networks will be transformed by software-defined network elements (switches, routers, appliances) and virtualized network functions that will leverage scalable photonic and electronic technologies.

2. *Internet of Things (IoT)/Machine-to-machine systems*

Scaling IoT infrastructure: The next-generation IoT has the potential to change the way people and systems live in a world of massive and disparate data sources, and to provide opportunities for connectivity at different scales. It needs to include advanced communications with a wide range of low-power, low-cost, software-enabled devices. It should accommodate stationary, autonomous and wearable elements, in robust self-reconfiguring arrangements.

Integration, analysis and consumption of sensor data: Next-generation IoT systems need to operate in real or near-real time in a context of extreme data diversity and volumes. Information architectures and standards are needed to enable the reliable fusion of sensor data of disparate types from the full spectrum of data sources. The resulting systems must support the efficient extraction and rendering of relevant information to allow timely decisions and actions by users and systems, while enforcing appropriate requirements for data authentication and verification.

3. *Advanced data management and analytics*

Management, analytics and information extraction of data at scale: The volume, velocity, variety and veracity of data demand new approaches to the management of that data. New analytical methods, including the ability to predict, optimize and anonymize at scale—in real or near-real

time—are required to derive useful information from the data. Information needs to be extracted from a spectrum of data sources, such as numeric, textual, image, audio and video data, as well as social interactions and personal data.

Analytics for decision-making: Data at scale need to be analyzed to enable decision-making by people, applications, machines and systems. This includes interactive visualizations, query systems and other analytics that allow decision participants (human or software) to dialogue with the data and the analytics to arrive at a decision that is accurate and effective.

Artificial intelligence and machine learning: There is a need to develop artificial intelligence/machine learning capacity and develop opportunities to optimize artificial intelligence/machine learning use for application and digital transformation across one or multiple sectors.

4. *Cybersecurity*

Secure authentication and authorization at scale: New and improved methods to authenticate the identities of people, sensors, processes and systems, and to authorize access to services and information, will mitigate a fundamental weakness exploited by many cyber attacks. Useable, effective and scalable security interfaces and protocols are required. With increasing amounts of data, progress in this area will aid data security and privacy.

Quantitative approaches to cybersecurity: Quantitative approaches to cybersecurity will facilitate the application of data analytics and other metric-based approaches to protecting information and systems. The development of ontologies, behavioural and mathematical models, analytics, metrics, patterns, use cases and datasets will further the understanding, detection and prevention of both existing and new cyber threats—such as those being driven through the emergence of personal informatics, the IoT and quantum computing.

Advanced threat detection and defence systems: Advanced threats that are difficult to detect and defend against include moving and polymorphic targets that change over time, “low and slow” attacks and targeted attacks, which avoid detection by simple alert-based systems, in an ever-increasingly complex network of participants and targets. Advanced threat detection and defence systems will require coordination and correlation across different points in time and data sources and will leverage analytics and other approaches such as polymorphic defence.

5. *Human interaction with digital media*

Designing effortless interactions: Interactions must become invisible and engaging, as well as transparently indicate data quality. *Invisibility:* Sensors and intelligence that make the interface

disappear can address challenges of wear ability, minimization of mental load and actionable feedback. *Engagement*: Gamification, for example, can sustain motivation for challenges such as health, sustainable practices and people-centric security. *Transparency of data quality:* In the face of noisy data, information display should convey data uncertainty at a cognitively acceptable level. Application examples include novel interaction techniques; interactions for special groups, places and contexts; collection and collation of personal data for personal use; living in information spaces; and augmented reality and virtual environments.

Effective tools for creating and populating physical and virtual objects and spaces: For designers ranging from professionals to hobbyists, software tools are needed to support maker and do-it-yourself cultures, to facilitate seamless transition between physical and virtual worlds and objects, and to leverage interactive modelling and animation. Design tools must support practices including sharing and collaboration, iterative prototyping, and stages of creative inception, refinement and deployment. Individuals and groups require tools for customization of interfaces to specific use cases, demographics, context and individual preferences, with as little training as possible. Individuals need tools to deploy their own approaches to information management. Designers of varying expertise need tools to create virtual and augmented environments, and to build social information spaces.

6. *Quantum computing*

Exploitation of quantum devices: The challenge involves exploiting quantum engineering for improved performance and efficiency of useful devices. In particular, it includes development of quantum devices and applications that use multiple qubits, entanglement and quantum algorithms for sensors, actuators and communication systems that outperform their classical counterparts. Examples include deploying and improving navigation tools; quantum sensors for chemistry, magnetic fields, electron transport and photon detection; quantum actuators for interconversion of information (spin/charge/photon/phonon); and quantum communication for physics-based information security. The challenge is to develop devices and applications that can be deployed with near-term impact to areas such as medicine, environmental monitoring, materials and chemical characterization, security, improved nanofabrication and metrology.

Special-purpose quantum processors: A quantum computer is the ultimate quantum device and has broad applications, from breaking classical security protocols to machine learning. The challenge is to realize special-purpose quantum computers and in particular to deliver a well-working processor of 100 qubits. Examples include one optimized for running quantum simulations of materials and another for testing the robustness of quantum error correcting methods. These two building blocks are essential to the continued development of yet more complex and capable quantum processors. In addition to new hardware devices, the challenge includes new algorithms for quantum computing, particularly for small, noisy processors.

Advanced materials and manufacturing technologies (AMM)

Context

The overall objective for proposals in the Advanced materials & manufacturing technologies (AMM) target area is to lead to innovations and improvements in both the manufacturing process and the products produced. The overarching research thrust for all proposals must be to expand knowledge of the interactions between the material/part behaviour, machines and the final product performance. Proposals in this area must address these through a combination of science-based modelling and experimentation. This involves the integration of mathematical models of processes, materials, products and machines across manufacturing operations.

Research topics

1. *Automation (including robotics)*

The goal of research proposed under this topic is to design innovative machines and their efficient utilization to improve quality and productivity in manufacturing, transportation or farms through experimentally proven science-based digital models.

Design: Projects under this research topic should focus on design and digitally model intelligent, modular, reconfigurable and multi-functional machines that are easy to adapt to products. The following areas are specifically targeted: development and modelling of modular kinematic arrangements of the multi-axis machines, robots and material- handling devices; development and integration of novel smart sensors, actuators, robots and devices; multi-body dynamics and vibration modelling of machines; computer control modelling of multi-axis, multi-functional machines; digital modelling of physical interaction between machine structure, computer controller and processes.

Utilization of machines: Projects under this research topic should focus on developing methods and instruments to improve the productivity, accuracy, operation and safety of manufacturing, transportation or farms with the following target areas: integration of smart devices to machines, robots and assembly systems; human-machine/robot interaction; digital modelling of the manufacturing process physics for predictive process planning; on-line calibration and adaptive adjustment of digital models with sensory feedback; sensor-fused monitoring and adaptive control of processes; on-line and off-line part and machine metrology; energy-efficient and/or environmentally friendly manufacturing, transportation or farm processes; development of methods to improve safety in the manufacturing, transportation or farm environment.

2. *Lightweight materials and technologies*

Lightweight product design, assembly and use: Projects should focus on the development of innovative materials, material structures, designs and manufacturing methods, including fabrication technologies, that are needed to create lightweight multi-material products and assemblies of equivalent or superior performance in use and for maximum life- cycle energy efficiency. Projects that address component- level product development or system-level approaches will be considered. Specifically, projects are to address optimization for manufacturing (material and machine) built on a framework of integrated computational materials engineering (ICME), linking structure/process/property relationships to accelerate and enhance future product and process design. In the development of lightweight products and assemblies, care should be given to identify potential integration issues and formulate possible mitigation strategies.

3. *Additive manufacturing*

Projects in this area must integrate innovative solutions from more than one of the described research topics.

Process stability, monitoring and control: This research topic focuses on the development of the next generation of additive manufacturing technologies, integrating in-process monitoring, sensing and close-loop control strategies that allow for simultaneous improvement in manufacturing speed, repeatability and product consistency. Included in this challenge are hardware and algorithms adapted to process dynamics encountered during additive manufacturing processing and the response of the deposited material.

Development of tailored materials for additive manufacturing: This research topic focuses on the improvement and development of new additive manufacturing-specific categories of materials with adapted printability, allowing for new additive manufacturing opportunities, improved deposition quality/utilization (including recyclability and re-use) and response to post-processing operations. These will lead to superior process sustainability, part quality and performance.

Design for additive manufacturing: This Research Topic focuses on the development of integrated computation and design methodologies linking additive manufacturing process characteristics, part functionality, component and feature geometries, topology and internal structure optimization, and adaptive slicing strategies, to fully capture the novel disruptive potential of additive manufacturing.

4. *Nanotechnology*

Design and synthesis of nanomaterials: Projects should focus on the understanding of structural/functional properties and self-assembly characteristics that enable the synthesis of functional hierarchical 3D systems. Advantages of the material at the nanoscale and the impact of dimensionality on product properties of interest must be demonstrated. Emerging nanomaterials of interest include hybrid materials such as graphene, quantum dots, metal oxides, polymer-nanocomposites and their assemblies, based on Earth-abundant and Earth-friendly materials. A theoretical understanding, based on science-based modelling, of how these materials can be designed and integrated into manufactured products must be provided.

Scalability of synthesis and deposition/manufacturing processes: Projects in this research topic must focus on novel, efficient and sustainable manufacturing techniques for mass production of nanomaterials. Techniques to realize mass production on scales required for their integration into manufacturing processes or products, using either top-down or bottom-up processes, must be demonstrated. Clean manufacturing techniques, such as those using Earth-abundant and Earth-friendly materials, green solvents or solvent-free techniques, are encouraged. Reproducibility of the production process and engineering scale-up is required to produce high-quality nanomaterials, addressing safety aspects in handling and use. Modelling of the process and key parameters are required to demonstrate scalability.

5. *Quantum materials*

Scalability and manufacturing of graphene or graphene-like materials: Projects in this area must address the mass production of graphene or graphene-like materials. Graphene, the two-dimensional atomic crystal, possesses superior physical properties that include extreme mechanical strength, exceptionally high electronic and thermal conductivities and impermeability to any gas. The laboratory process of mechanical exfoliation of graphene is simple and cheap for small graphene sheets; however, a major challenge is to mass-produce graphene sheets (both small and large) with the same outstanding performance as those created in laboratories. Manufacturing of several new two-dimensional materials that have many of the properties of graphene is also important for future applications. These include a single layer of silicon (silicene), germanium (germanene) and black phosphorus (phosphorene) or other similarly structured materials.

Integration of graphene or graphene-like materials into devices: Projects should address the possible applications of small and large graphene (or similar materials) sheets and projects in the area of integration into future devices. For example, the small sheets of these materials could be used in composites, functional coatings, batteries and supercapacitors. Large graphene films could be used in touch panels; low-cost photovoltaic devices; next-generation flexible, wearable electronics and optoelectronics; high-frequency transistors; photodetectors; optical modulators;

energy generation and storage; sensors; and bioapplications. The films of silicene and germanene could be directly integrated into the current electronics industry, once the hurdles of manufacturing these materials on a large scale are resolved. A single layer of black phosphorus is promising for novel applications in nanoelectronics and nanophotonics.