



OUR CONNECTED WORLD

Research expands knowledge. Research explores new knowledge. Research solves problems, creates understanding, and provides rich connections between the academic world, the private sector, communities, and governments. Research is in the DNA of the University of Waterloo, both within and across its many Departments, Faculties, Centres, and Institutes.

Waterloo research spans the continuum from fundamental, curiosity-based inquiry to the practical applications of new knowledge. It is conducted in both a discipline-specific manner and by inter- and multidisciplinary teams. A strong spirit of entrepreneurship underpins this research, giving rise not only to the development of new technologies, but their application and commercialization.

Waterloo's research strengths are deliberately aligned with important global challenges. This is in recognition of the critical role that technology coupled with reflective scholarship will play in meeting these challenges and understanding their human dimensions. Discoveries heralding transformative disruption that benefits society are a hallmark of Waterloo research.

A. FUNDAMENTAL THEMATIC AREAS

DEVELOPING TECHNOLOGIES FOR THE FUTURE

Innovative technologies are transforming the way we work, live and play. Researchers at Waterloo are not only creating these new technologies, they are probing the nature of human interaction with technology, uncovering the benefits it heralds as well as exposing and mitigating the risks it poses.

SUB-THEMES

- Advancements in big and small manufacturing
- Autonomous systems for independence
- Cybersecurity, cryptography and privacy
- Intelligent systems and attendant paradigm shifts
- Light and sound for improved vision and imaging
- Technologies for connectedness
- The quantum-nano revolution

PUSHING THE FRONTIERS OF KNOWLEDGE

The very big and the very small shape humanity. Waterloo researchers are seeking to understand how. They are exploring the cosmos, probing the genetic code and the limits of complexity, discovering what shapes the interactions of humans with each other and the planet. They are searching for answers, for theoretical proof, for knowledge.

SUB-THEMES

- Abstraction, inference and proof
- Classical and quantum information
- Foundational principles and their application
- Genetics and the origins of life
- Knowledge discovery and representation
- Limits of complexity and emergent phenomena



Origin and composition of the universe
The building blocks of matter

UNDERSTANDING AND ENHANCING HUMAN EXPERIENCE

Waterloo researchers are exploring opportunities for social, artistic and cultural innovation in a rapidly changing world and the challenges this poses. They are looking for connection and commonality. They are exploring and promoting scholarship in the area of Indigenous culture. They are analyzing how technology and innovation can help knit humanity, with all its diversity, closer together.

SUB-THEMES

Communication, technology and culture
Creative and scholarly innovation
Design of and experience with interactive media
Ethics, governance and politics
Human-centered technology
Identity: inclusivity, diversity, and equity
Risks, crises and conflicts of our time
Social impact of science and technology

ACCELERATING SUSTAINABILITY

Through deliberate alignment of research strengths with global challenges, Waterloo is accelerating the development of technology and novel practices for enhancement of environmental sustainability. This research is guiding the formulation of principles, policies and paradigm shifts in global environmental governance for achieving local and regional sustainability outcomes.

SUB-THEMES

Integrated ecosystems approach to managing the natural environment
Clean and affordable energy
Clean technology and responsible production
Climate - resilient and low - carbon society
Sustainable cities, buildings and infrastructure
Sustainable water management

ADVANCING HEALTH AND WELLBEING

Waterloo is poised to make major advances at the interface between technology and health. For example, new technologies being developed by Waterloo researchers have the potential to revolutionize the collection and interpretation of health data. This is complemented by innovative research on the social determinants of health, including healthy aging, lifestyles, and substance-use, that is giving rise to new paradigms for population health.

SUB-THEMES

Biomedical/social determinants of health
Health care delivery
Health informatics and health technologies
Aging
Neuroscience



Mental health
Population health and health systems for communities
Vision science
Pharmaceutical science

B. ADVANCING RESEARCH FOR GLOBAL IMPACT

To maximize global impact, Waterloo has aligned its thematic research strengths with opportunities for new discoveries that are likely to shape approaches to global challenges. In doing so, the institution continues to build on established strengths in fundamental research, engage in applied research, and take a leadership role in commercializing new technology. That solutions to global challenges will be both technology-based and informed by an increased understanding of their human dimensions has prompted mobilization of complementary research strengths in several fields in the quest to develop and implement these solutions.

QUANTUM SCIENCE, NANOTECHNOLOGY, CONNECTIVITY AND TELECOMMUNICATIONS

Pioneering basic and applied research in: quantum and materials science, quantum computing and quantum simulation for understanding physics and materials, nanotechnology, digital media, and telecommunications, is pushing the frontiers of knowledge and giving rise to new technologies. Waterloo researchers are also examining human interaction with these technologies and their potential for transformative impact on industrial, social, artistic, environmental and cultural landscapes. Developments that are having a transformative impact include:

- new quantum sensors with enhanced sensitivity
- smart functional materials
- advances in quantum security
- new developments in photonics
- nano sensors and electronics for lab-on-a-chip
- advances in network and satellite communication enabling increased connectivity and future expansion of the Internet of Things
- emerging technologies for social innovation
- social and ethical impacts of connectivity

WATER, ENERGY AND CLIMATE: SUSTAINABILITY, SECURITY, INFRASTRUCTURE

Waterloo research is facilitating the transition to a climate-resilient, low – carbon sustainable society. A cornerstone objective is sustainable use and management of space, land, water, and energy on a global scale. Developments that are having a transformative impact include:

- nanotechnologies for the delivery of clean water



- environmental and resource economics and governance and the formulation of sustainable land and water-management policies
- next generation batteries, fuel cells and smart-grid infrastructure for the provision of clean, affordable, low - carbon energy
- digital and remote sensing technologies for environmental monitoring of air, land, water and the stratosphere, providing information that will shape pivotal environmental policies
- new paradigms of architectural and urban design for enhanced sustainability of cities, buildings and infrastructure

INFORMATION TECHNOLOGY AND ITS IMPACT, INCLUDING INTELLIGENT SYSTEMS, HUMAN-MACHINE INTERFACES, CYBERSECURITY, PRIVACY AND DATA SCIENCE

Artificial intelligence and machine learning are enabling Waterloo researchers to develop systems that are ushering in a new era of automated, intelligent transportation. The attendant challenges will test the mettle of human/machine interfaces. Social scientists are studying the impact of these intelligent systems on the transportation industry and on domestic and international job markets. Developments that are having a transformative impact include:

- autonomous scale cars with novel sensors enabling robust navigation without human inputs
- smart systems for hybrid and electric vehicles
- network and operational security for internet-connected systems and data
- quantum-safe cryptography
- blockchain technology for secure data storage, financial transactions and asset management
- societal implications of cyber risk, including cyber terrorism and global security
- ethical considerations of the applications of artificial intelligence

ROBOTICS AND ADVANCED MANUFACTURING

Through innovative research encompassing the use of advanced materials, advanced robotics and mechatronics, Waterloo is developing next-generation additive manufacturing. Robotics research at Waterloo is both fundamental and applied in nature and runs the gamut from designing robots for the service industry to those able to defuse land mines or perform surgery. New developments that are having a transformative impact include:

- human-robot interaction including its impact on cognitive function and development
- robot-assisted full cycle manufacturing in a factory setting
- custom-product development using next-generation additive manufacturing
- autonomous robots for detecting structural defects in bridges
- human-centered robotics and machine learning



HEALTH TECHNOLOGIES

New technologies with the potential to reshape aspects of medicine are being developed at Waterloo. Research on the social determinants of health including healthy aging, tobacco control and substance use is having population-scale impacts. Development and deployment of digital health systems for improving population health are enhancing health - care outcomes. Enhanced understanding of human response to technical and policy interventions is helping to stem viral spreads and mitigate their impact on the most vulnerable. New developments that are having a transformative impact include:

- wearable devices for monitoring indices of health
- next generation contact lenses with drug-delivery potential
- soft-robotics for ocular treatment and surgery
- nanoparticles for targeted drug delivery
- high resolution imaging technology