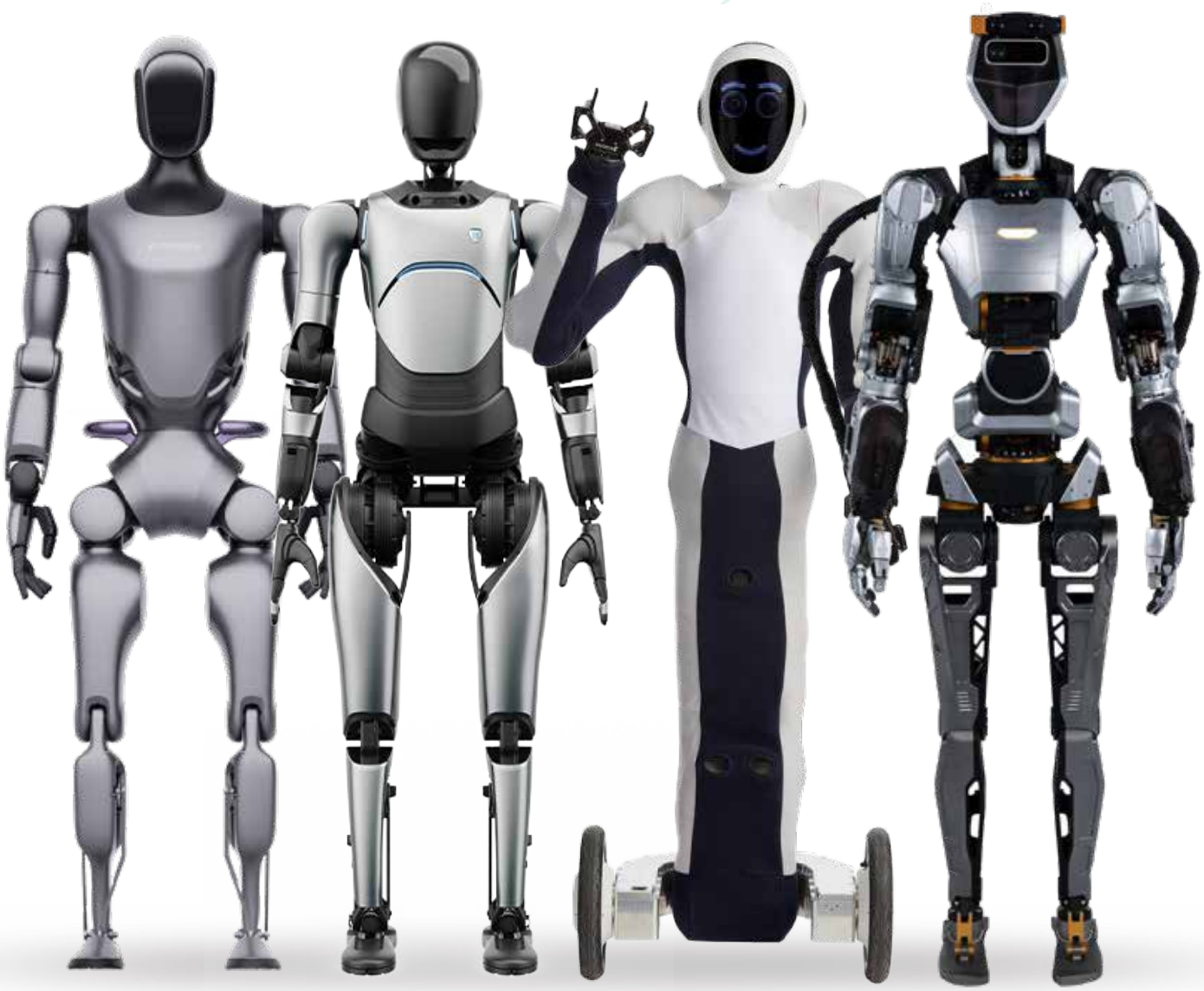
HUMANOIDS ARE HERE!

Why Canada Needs a Humanoid Robotics Strategy Now



Center for Designing Change

UNIVERSITY OF WATERLOO | ROBOHUB

CONESTOGA Connect Life and Learning

NGen Next Generation Manufacturing Canada

Cover Image (Left to Right):

https://ifdesign.com/en/winner-ranking/project/fourier-gr-2-robot/697768
https://www.agibot.com/products/A2
https://robotsguide.com/robots/optimus
https://www.sanctuary.ai/

Report brought to you by:

Three key organizations will play a pivotal role in shaping Canada's humanoid robotics sector:

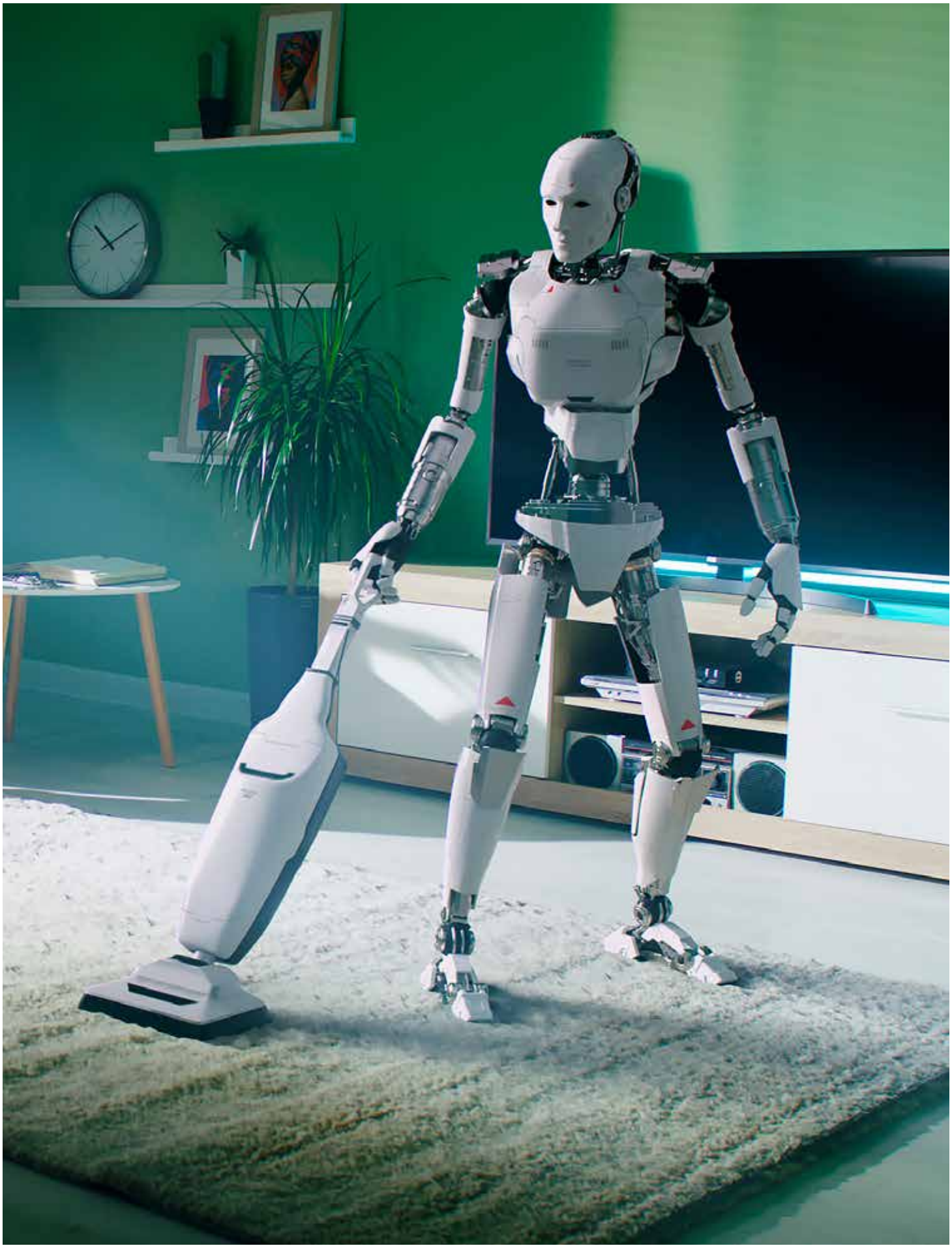
Centre for Designing Change (CDC)
A strategic not-for-profit innovation agency focusing on AI ethics, policy design, and robotics integration across sectors.

Waterloo RoboHub and the Region of Waterloo Robotics and Automation Cluster
The RoboHub is a research, education, and development unit within Waterloo Engineering with a state-of-the-art robotics facility and a globally unique fleet of robots, located within Canada's largest robotics and automation cluster.

Conestoga
Conestoga's SMART Centre is a hub for applied research and technical services with a focus on advanced manufacturing, automation, artificial intelligence, machine learning, and cybersecurity.

Next Generation Manufacturing Canada (NGen)
The Advanced Manufacturing Supercluster leading the development and funding of industrial AI and robotics projects.

By leveraging NGen's expertise in robotics manufacturing, CDC's leadership in AI governance, and Waterloo's experience with human-centred robotics education, research, and industry collaboration, Canada can build a world-class humanoid robotics ecosystem.



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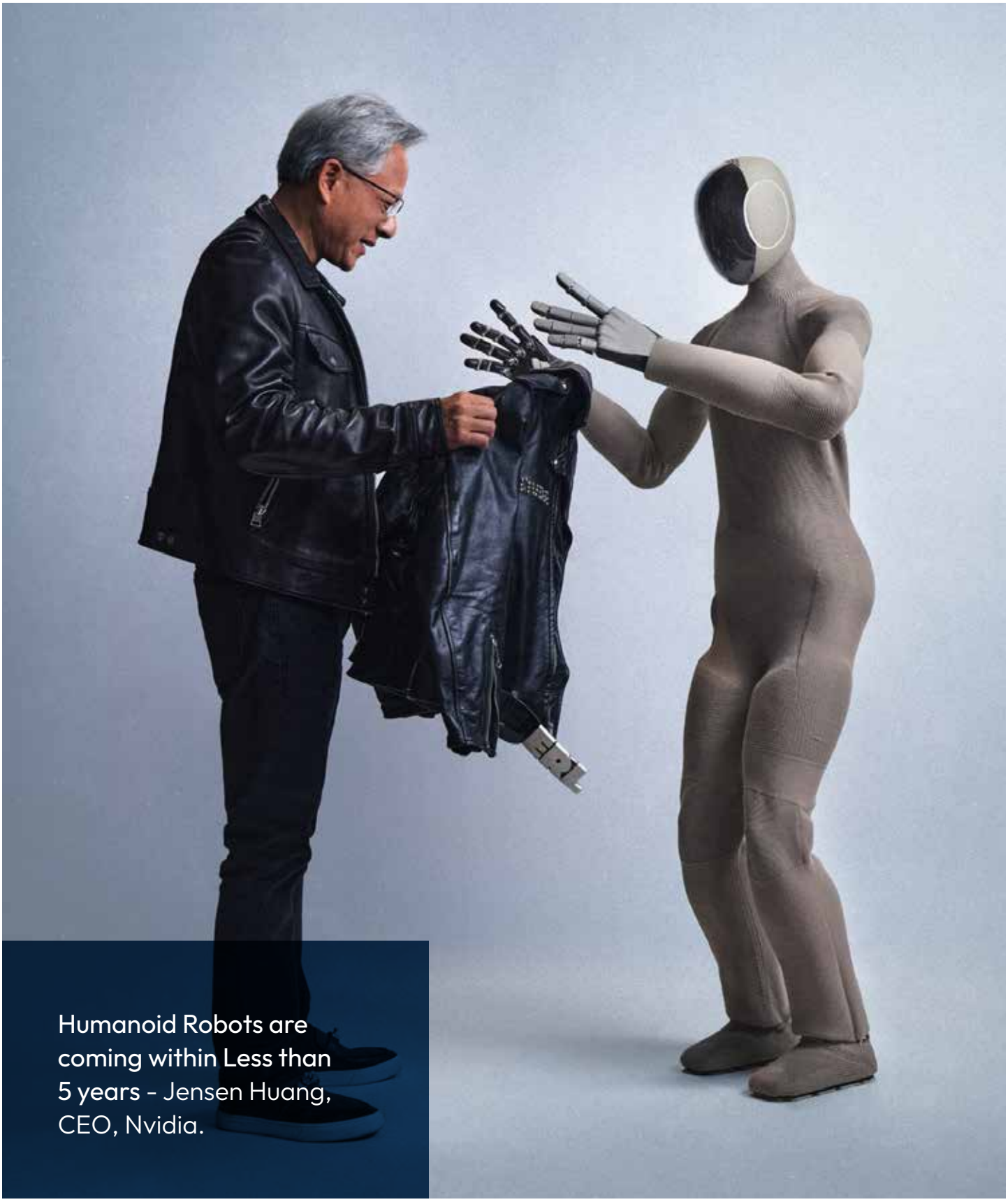
Executive Summary



Humanoid Robots are coming within Less than 5 years - Jensen Huang, CEO, Nvidia.

Humanoid robotics represents the next major industrial transformation, with leading nations shaping the future of automation, manufacturing, and ethical AI. For Canada, this is a generational opportunity to turn global leadership in AI into a sovereign, export-driven robotics sector.

This report proposes a national strategy anchored by the creation of Canada's first open-source bipedal humanoid robot—a reference platform designed to accelerate commercialization, attract talent, and establish a competitive robotics ecosystem. More than a prototype, it would serve as strategic infrastructure for research, industry collaboration, and policy development.

Canada's advantages include world-class AI expertise, strong manufacturing capabilities, and scalable clean energy. Yet, without a coordinated strategy, it risks losing ground to global competitors. Strategic investment could deliver billions in GDP growth, tens of thousands of skilled jobs, and significant export potential, positioning Canada as a trusted global leader in robotics.

Key Actions:

To establish itself as a global leader in humanoid robotics, Canada must:

1

Develop a National Humanoid Robotics Strategy
Align funding, policy, and research efforts under a cohesive federal strategy that can be adopted at provincial levels.

2

Expand Robotics R&D and Manufacturing
Invest in robotics prototyping facilities, AI compute centers, and talent development programs.

3

Secure Government & Private Sector Buy-In
Offer grants, tax incentives, and regulatory support to accelerate commercialization.

4

Promote Sustainable Robotics Innovation
Integrate clean energy solutions (SMRs, hydrogen-powered AI compute) into robotics development.

5

Position Canada as a global leader in robotics governance
Shape global standards for humanoid robotics - develop certification standards, safety frameworks, and ethical use cases in public settings.development programs.

Who makes the Humanoid Robot

Key components, estimated content value percentage, and key global vendors

AI Chip, AI Computing (10%)
- Alphabet
- AMD
- Intel
- Microsoft
- Nvidia
- OpenAI
- Qualcomm
- Cloudwalk
- Deep Glint
- Horizon Robotics
- Rockchip
- SenseTime
- Mobileye
- TSMC

Vision System (4%)

LiDAR:
- Aisa Optical
- Hesai
- Robosense

Depth Camera:
- Intel
- OFILM
- Orbbec
- Quanta Storage
- Solomon

Heat Management System (2%)
- Sanhua
- Tuopu
- Yinlun

Rotary Actuator Integration (24%):
- Sanhua
- Tuopu

Encoder:
- Nider
- Novanta
- Sensata

Servo Drive:
- Googoltech
- Inovance
- INVT
- Leadshine
- Zhaowei

Frameless Torque Motor (Arms):
- Ace Pillar
- Aerotech
- Chieftek
- Han's Motor
- Haozhi
- Hechuan
- Hiwin Mikra
- Inovance
- Jiecang
- Kinco
- Kallmorgen
- Leadshine
- Leill
- Maxon
- Parker
- VEICHI
- Wittenstein
- Wolong

Reducer:
- Apex Dynamics
- FORE
- HDS
- Hota
- Leaderdrive
- Mirle
- Nabtesco
- Neuart
- Shimpo
- Shuanghuan
- ZD Leader

Bearing:
- Changsheng Bearing
- JTEKT
- NSK
- SKF
- XCC Group

Torque Sensor:
- Ampron
- ATI
- Bota
- Keli Sensing
- Kunwei
- OnRobot
- Robotiq
- Robotous
- Sunrise Instruments
- WACOH-TECH

Bearing:
- Changsheng Bearing
- JTEKT
- JNSK
- SKF
- XCC Group

Encoder:
- Nidec
- Novanta
- Sensata

Force Sensor:
- Ampron
- STI
- Bota
- Keli Sensing
- Kunwei
- OnRobot
- Robotiq
- Robotous
- Sunrise Instruments
- WACOH-TECH

Frameless Torque Motor (Legs):
- Ace Pillar
- Aerotech
- Chieftek
- Han's Motor
- Haozhi
- Hechuan
- Hiwin Mikra
- Inovance
- Jiecang
- Kinco
- Kallmorgen
- Leadshine
- Leill
- Maxon
- Parker
- VEICHI
- Wittenstein
- Wolong

Planetary Roller Screw:
- Belte Tech
- Best Precision
- Ewelix
- GSA
- Hengli
- Rollvis
- Seepin
- Shuanglin
- Zherryu Tech

Servo Drive:
- Googoltech
- Inovance
- INVT
- Leadshine
- Zhaowei

Linear Actuator Integration (27%)
- Sanhua
- Tuopu
- Hengli

Battery (2%):
- CATL
- EVE Energy
- LG Energy Solution
- Panasonic
- Samsung SDI

Dexterous Hand (19%):
- AgiBot
- DLR
- Festa
- Inspire-Robots
- Moon's Electric
- NASA
- RobotEra
- Shadow Robot
- Tesla
- ZhaoWei

Coreless Motor:
- Faulhaber
- Hechuan
- Jiecang
- Leadshine
- Leili
- Maxon
- Moon's Electric
- Portescap
- VEICHI
- Wolong
- ZhaoWei

Encoder:
- Nidec
- Novanta
- Sensata

Gear:
- Apex Dynamics
- FORE
- Hota
- Shaunghuan
- ZD Leader

Mini Screw:
- Best Precision
- Hengli Hwin
- QCMT&T
- TBI Motion

Tactile Sensor:
- Ampron
- Hanwei
- Keli Sensing
- PaXini
- PPS
- Tekscan
- Weiss Robotics

Tendon:
- DSM
- Honeywell
- Kanglongda
- Nanshan Fashion

Data Extracted from: Morgan Stanley Research report

Current Cost of Humanoid Robots by Parts

Shoulder
US $2.1K
4.7% of total

Elbow
US $2.6K
4.7% of total

Waist & Pelvis
US $7.3K
14.2% of total

Hands
US $9.5K
17.2% of total

Others
US $0.5K
0.9% of total

Feet
US $0.5K
0.9% of total

Head
US $2.1K
3.8% of total

Battery Pack
US $0.3K
0.5% of total

Upper Arm
US $1.1K
2.0% of total

Forearm
US $2.2K
3.9% of total

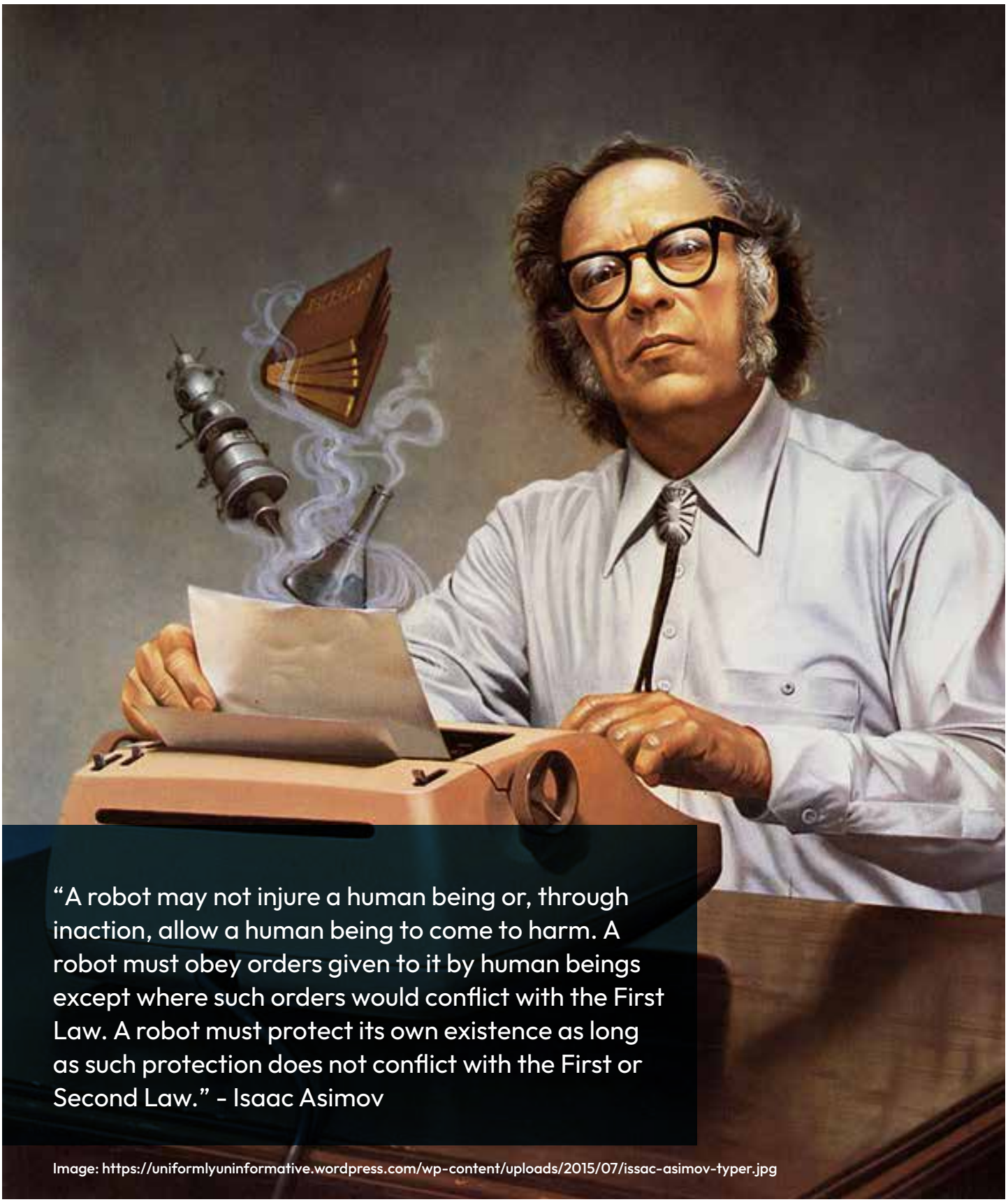
Thigh
US $7.3K
13.2% of total

Calf
US $7.3K
13.2% of total

Feet
US $6.7K
12.2% of total

Data Extracted from: BofA Global Research report

2. Introduction



"A robot may not injure a human being or, through inaction, allow a human being to come to harm. A robot must obey orders given to it by human beings except where such orders would conflict with the First Law. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law." - Isaac Asimov

Image: https://uniformlyuninformative.wordpress.com/wp-content/uploads/2015/07/issac-asimov-typer.jpg

2.1 Background and Context for Humanoid Robotics

Global Context

Humanoid robotics has evolved rapidly, driven by major investments and national strategies, especially in China, Japan, and the US. Robots like Unitree's G1, Figure AI's Figure 02, Sanctuary's Phoenix, and Tesla's Optimus are now deployed in manufacturing, healthcare, and mining to address global challenges.

Distinct from the broader robotics market($34 billion in 2022 and is projected to reach $89.27 billion by 2030[1]), humanoid robots are a niche segment focused on embodied AI and solving labor shortages, with great potential for societal and economic impact.

2.2 What Are Humanoid Robots and Human-Centric Robots?

Humanoid and human-centric robots represent the forefront of intelligent automation—machines built to function intuitively in human environments, extending rather than replacing human capability. They blend mechatronics, AI, sensory systems, and energy management for next-generation automation.

While humanoids mimic human form and motion, human-centric robots include collaborative robots, quadrupeds, wheeled manipulators, and assistive systems. All are designed to work near people, adapt to dynamic environments, and deliver embodied intelligence from task-specific to adaptive systems.

Core Classifications

- **Humanoid Robots:** Anthropomorphic, bipedal machines for dexterous tasks and advanced sensing, locomotion, decision-making.
- **Collaborative Robots (Cobots):** Human-safe machines for factory, logistics, and labs, designed for shared spaces and intuitive programming.
- **Wheeled/Tracked Manipulators**: Mobile platforms for logistics, inspection, and maintenance in industry and public spaces.
- **Quadrupeds/Hybrid Mobility Robots:** Agile, terrain-adaptive systems for inspection, search & rescue, or defence.
- **Assistive/Social Robots:** Support for elder care and rehabilitation, combining cognitive and emotional intelligence with physical assistance.

Why Bipedal Humanoid Robotics?

Bipedal humanoids, walking on two legs, are ideal for human-designed spaces—homes, hospitals, factories, and offices. Unlike wheeled robots, they navigate stairs and uneven terrain, perform physical and social tasks, and use human tools. Their advanced design allows them to augment human labor, especially in industries facing workforce shortages and aging populations. They also boost efficiency and safety by handling repetitive or precision tasks.

As the most advanced embodiment of physical AI, bipedal humanoids don't just work near humans; they're built to function with us and for us in everyday environments.

The global robotics market size was estimated at **$34 billion** in 2022 and is projected to reach **$89.27 billion** by 2030

Key drivers for bipedal humanoid robotics include:
Workforce Challenges: As industries face labour shortages, particularly in healthcare and manufacturing, humanoid robots can augment human labour, filling critical gaps. [2] [3]

Aging Populations: Countries with aging demographics, including Canada, require innovative solutions for elder care and healthcare support.

Efficiency and Productivity: Robots can perform repetitive, high-risk, or precision-based tasks more efficiently, enhancing workplace safety and operational performance.

By focusing on bipedal humanoid robotics, Canada can address both domestic and global challenges while carving a niche in a rapidly growing market.

Expanding the Scope: Strengthening Canada's Human-Centric Robotics Supply Chain

The open-source humanoid robotics project is more than a platform, it acts as a national catalyst to unify and coordinate Canada's robotics supply chain. Anchored by a bipedal humanoid, the initiative delivers a modular, open integration platform advancing human-robot collaboration, enabling service robots for healthcare and logistics, and expanding mobile robot applications in automation and defence.

This nation-building effort consolidates innovation assets, boosts manufacturing, and grows an export-ready supply chain. The initiative creates jobs, attracts investment, and strengthens Canada's capacity for safe, human-centric robotics driving productivity, resilience, and global competitiveness.

2.3 Why This Matters for Canada

Developing humanoid and human-centric robotics in Canada strengthens the national supply chain, integrating semiconductors, sensors, actuators, AI, energy, and communications. As such, they represent a microcosm of the entire robotics industry, demonstrating how hardware, software, and human factors converge to create intelligent, adaptive machines.

By investing in this ecosystem, Canada accelerates:

- **Subsystem integration and standardization across mobile and service robotics.**
- **Collaborative R&D between academia, SMEs, and OEMs in robotics, AI, and advanced manufacturing.**
- **Workforce development through interdisciplinary education and applied engineering.**
- **Economic competitiveness via export-ready capabilities in intelligent automation.**

In essence, humanoid and human-centric robots are physical demonstrations of national capability, visible proof that a country can design, integrate, and scale complex intelligent systems. This offers both a technological challenge and a strategic opportunity: to demonstrate leadership in ethical AI, sustainable robotics, and sovereign innovation while strengthening the supply chain that supports every form of mobile robotics, from drones and autonomous vehicles to collaborative industrial systems. For Canada, they symbolize both technological ambition and a policy commitment to a future where automation enhances human potential and strengthens domestic industry.

3. Strategic Importance of Humanoid Robotics

3.1 Nations Investing in Humanoid Robotics

The global humanoid robotics race is led by nations with robust innovation ecosystems, strategic investments, and supportive policies:

China

China is rapidly scaling its robotics sector, supported by its Made in China 2025 initiative. The country's investments in AI and robotics have positioned it as a global competitor:

- Companies like UBTECH Robotic, Unitree, Deep Robotics, and CloudMinds Technology are creating humanoid robots for education and customer service [4].
- Government-backed programs provide funding and infrastructure for robotics startups, fueling growth [5].

Japan

Japan's dominance in robotics is built on decades of innovation and government support. Key examples include:

- ASIMO by Honda, a humanoid robot that demonstrates advanced capabilities in walking, running, and interacting with humans [6].
- Kaleido by Kawasaki Robotics, a humanoid robot that mimics the movement of a human while walking[7]
- Japan's focus on robotics as a solution for its aging population, with robots deployed in elder care and service industries.

European Union

The EU has prioritized humanoid robotics through initiatives like Horizon Europe, focusing on applications in healthcare, education, and advanced manufacturing. Countries like Germany and France are particularly active, with significant R&D investments.

United States

The U.S. is home to key players like Tesla, Boston Dynamics (owned by Hyundai), Figure, and Apptronik, supported by a mix of federal funding, venture capital, and private sector innovation. Notable developments include:

- Tesla Optimus, a humanoid robot designed for factory work, showcasing Tesla's ambitions to redefine labor in manufacturing [8].
- Boston Dynamics' Atlas, which has advanced capabilities in dynamic motion and collaborative work, setting global benchmarks in humanoid mobility [9].

Below is a list of countries ordered by largest GDP and the associated number of major humanoids companies.

3.2 Opportunities for Canada to Lead

Leverage AI and Robotics Expertise

Canada is uniquely positioned to excel in humanoid robotics due to its leadership in artificial intelligence and advanced manufacturing. Key strengths include:

World-Class AI Ecosystem:

- Institutions like the Vector Institute and MILA are globally renowned for breakthroughs in deep

Countries (listed by GDP)	Notable Active Humanoid Robotics Companies in Each Country	Number of Companies
United States	Tesla (Optimus), Boston Dynamics (Atlas), Agility Robotics (Digit), Figure AI (Figure 02), Apptronik (Apollo), 1X Technologies (Eve, Neo), Borg Robotics, Westwood Robotics (THEMIS), Workfar Robotics (Syntro), Reflex Robotics, KScale (K-Bot)	11
China	UBTech Robotics (Walker), EngineAI (PM01, SE01), Fourier Intelligence (GR-2), Unitree Robotics (H1, G1), Pudu Robotics (D9), Xiaomi (CyberOne), Hanson Robotics (Sophia), Deep Robotics (DR01), Agibot (A2, A2-MAX, X1), Beijing HRIC (Tiangong), Kepler (Forerunner K2), Robot Era (Star1), Xpeng, MagicLab (MagicBot), PNDBotics (Adam), BXI Robotics, EstunCodriod (Codroid2), Astribot (S1), GAC (GoMate), DroidUp (Walker 02)	19
Germany	NEURA Robotics (4NE-1), Devanthro (Robodies)	2
Japan	Kawasaki Heavy Industries (Kaleido), Toyota (THR-3), Kawada + AIST (HRP-2, HRP-3, HRP-4C), Tokyo Robotics (Torobo), AEOLUS, (AEO)	5
India	Addverb Technologies, Invento Robotics (Mitra), Sirena Technologies (KEMPA), H-Bots Robotics (Robocop prototype), Muks Robotics (Spaceco), Vanar (Gen 1)	6
United Kingdom	Engineered Arts (Ameca, Mesmer), Shadow Robot Company (Shadow Hand), Humanoid (HMND 01)	3
France	Pollen Robotics (Reachy), Blue Frog Robotics (Buddy), Aldebaran Robotics (NAO, Pepper)	3
Italy	Oversonic (RoBee)	1
Canada	Sanctuary AI (Phoenix), Mirsee Robotics	2
South Korea	Rainbow Robotics (HUBO), Hyundai	2
Spain	PAL Robotics (REEM-C, TALOS, ARI, Tiago Pro), Macco Robotics (KIME)	2

Note: This list is not exhaustive and represents a selection of major countries and humanoid robotics companies based on available data. [4] [10]

learning and reinforcement learning.
- Canadian researchers, such as Geoffrey Hinton, have shaped the global AI landscape, providing a strong foundation for robotics innovation [11]

Robotics and Automation Hubs:
- Southern Ontario is home to thriving robotics companies and manufacturing hubs that can support the development and commercialization of humanoid robots.
- Colleges and Universities like the University of Waterloo and Conestoga College lead in robotics R&D, producing talent and innovations critical to the field.

Develop a Globally Competitive Strategy

Canada has the opportunity to establish itself as a global leader in humanoid robotics by focusing on three strategic areas:

Innovation and Collaboration:
- Launching a flagship open-source humanoid robotics project would signal Canada's commitment to global leadership in this domain.
- Collaboration with global tech leaders like Magna International and Siemens Canada can provide access to real-world use cases and cutting-edge technologies.

Talent Development:
- Investing in robotics education and training can create a pipeline of skilled workers, reducing reliance on imported talent.
- Programs at institutions like Conestoga College can integrate robotics into hands-on curricula, aligning education with industry needs.

Market Expansion:
- By targeting industries like healthcare, mining, and manufacturing, Canada can create a robust domestic market for humanoid robots while positioning itself as an exporter of advanced solutions.

3.3 A Supply Chain Designed for the Whole Robotics Ecosystem

Canada's robotics sector spans over a few hundred firms, research labs, and technology developers across Ontario, Québec, British Columbia, and Alberta. These entities touch every layer of the robotics value chain, from advanced sensors (e.g., LeddarTech, Aeye) and actuators (e.g., Genesis Robotics) to AI compute (e.g., Tenstorrent, Untether AI) and system integration (e.g., Kinova, OTTO Motors). However, these segments often remain siloed, lacking a shared testbed to validate interoperability, certify safety, and de-risk commercialization.

The humanoid initiative directly fills this structural gap by functioning as a national integration demonstrator, exercising and validating all core subsystems common across the robotics landscape:

Subsystem Layer	Shared Application Across Human-Centric Robots	Canadian Capability Example
Sensing & Perception	Cameras, LiDAR, radar, tactile arrays	Exo Imaging, Neptec
Actuation & Motion	Servo motors, BLDC drives, harmonic gearboxes	Genesis Robotics, Ingeniacity
AI & Compute	Edge AI processors, reinforcement learning, simulation	Tenstorrent, Untether AI, UofT Vector
Power & Energy Systems	Lightweight BMS, solid-state batteries, thermal mgmt	Hydro-Québec labs, Li-Cycle
Software & Middleware	ROS 2.0 frameworks, motion planning, SBOM cybersecurity	Kinova, TMU
Communications & Control	5G/6G mesh, V2X, low-latency middleware	Ciena, Ericsson Canada, D-Wave
Safety & Compliance	Functional safety (ISO 13849/10218), data ethics, privacy	NRC, CSA Group, CyberEco

By anchoring all of these components within a single, complex integration environment, the initiative provides a shared proving ground for suppliers that build across multiple robotics classes, collaborative robots, quadrupeds, assistive systems, and mobile platforms. This will have a downstream economic and policy impact:

Policy Impact Area	Summary
Supply-Chain Growth and Commercialization	Canada's robotics market is projected to exceed CAD $5.4 billion by 2030. A national integration project could unlock $800–$900 million in procurement and supplier opportunities within five years, with 60–70 SMEs contributing subsystems for humanoid platforms.
Job Creation and Skills Development	Expected to create 350–500 direct engineering jobs and 1,500–2,000 indirect skilled jobs. Builds a talent pipeline via partnerships with universities like Waterloo, Ontario Tech, and Polytechnique Montréal.
Investment Leverage	For every $1 public investment, $2.5–$3.0 in private-sector funding is projected, potentially attracting $150–$200 million in private capital and R&D over five years.

Policy Impact Area	Summary
Policy and Strategic Alignment	Aligns dual-use civil and defence robotics with national innovation policy. Enhances supply chain sovereignty by domesticating production and testing. Supports clean tech integration and workforce development in robotics engineering, AI ethics, and quantum computing.

3.4 Risks of Inaction: Missed Global Opportunities

Falling Behind Global Peers

The global humanoid robotics race is accelerating, with nations like China, India, Japan and the USA leveraging significant resources to dominate the market. Canada risks:

- **Losing its edge in AI and robotics (Automation).**
- **Becoming a follower rather than a leader in shaping the future of humanoid technologies.**

Missed Opportunities in Innovation and Talent Development

Failing to act now could result in:

Economic Losses:
Missing out on a projected market valued at $211 billion by 2035. [12]

Brain Drain:
Top Canadian talent may relocate to countries with more vibrant robotics ecosystems [13] [14] [15]

Diminished Global Influence:
Canada's absence in this space would limit its ability to shape ethical and technological standards for humanoid robotics.

Conclusion

Humanoid robotics is not just an emerging technology, it is a cornerstone of the future of innovation and economic growth. With strategic investments, Canada has the potential to establish itself as a global leader in this transformative field. However, inaction could lead to missed opportunities, talent attrition, and diminished competitiveness. This report highlights the urgency for Canada to act decisively, leveraging its strengths to build a future where humanoid robotics drives economic prosperity and societal advancement.

4. Economic Benefits

Humanoid robotics represents a transformative industrial sector where Canada has a second chance to lead globally. While Canada excels in AI research, it has historically lagged in translating innovation into sovereign industries, as seen in the electric vehicle market. Strategic investment in humanoid robotics offers an opportunity to secure economic leadership, create high-value jobs, and build an export-driven innovation economy.

Market Potential

Humanoid robotics represents a transformative industrial sector where Canada has a second chance to lead globally. While Canada excels in AI research, it has historically lagged in translating innovation into sovereign industries, as seen in the electric vehicle market. Strategic investment in humanoid robotics offers an opportunity to secure economic leadership, create high-value jobs, and build an export-driven innovation economy.

Jobs and Talent Development

This initiative could create 6,000+ direct jobs in robotics, AI, and manufacturing, plus 15,000+ indirect roles. Embedding humanoid robotics into education will strengthen STEAM programs, create a talent pipeline, and attract global expertise. Upskilling initiatives will help transition workers into high-tech roles, boosting productivity.

GDP and Exports

Investments in humanoid robotics could add $1.2B+ to GDP in five years, with every $1 in R&D yielding $4–$5 in spillover benefits. Canada can export robotics solutions, components, and Robotics-as-a-Service (RaaS) offerings worldwide, developing high-value nodes in the global robotics supply chain.

Global humanoid robot revenues are projected to reach $211B by 2035 and $5T by 2050[12]

Global Context and Lessons

Countries like China, the U.S., and Japan are heavily investing in humanoid robotics, supported by strong industrial ecosystems. Successful initiatives emphasize early investment, public-private collaboration, and targeted applications. Canada risks losing its competitive edge without similar action.

Conclusion

Humanoid robotics is a nation-shaping opportunity to modernize manufacturing, drive innovation, and unite Canada's AI, robotics, and energy strengths under one national strategy. Strategic investment today can secure a leadership position in this emerging $5T industry.

5. Technological Advancements

The development of humanoid robotics represents the convergence of multiple cutting-edge technologies, each contributing to the functionality, adaptability, and utility of these systems.

This section examines the key technologies driving humanoid robotics, evaluates Canada's current capabilities, and identifies areas where further development is necessary to ensure global competitiveness.

5.1 Physical AI: Bridging the Digital and Physical Worlds

Physical AI is a rapidly emerging field that integrates artificial intelligence with real-world robotics, enabling machines to develop human-like perception, adaptability, and decision-making in physical environments. Unlike traditional AI, which operates in digital domains, Physical AI enhances a robot's ability to interact with and learn from its surroundings.

The Role of Physical AI in Humanoid Robotics

Sensory-Motor Learning:
Robots leverage AI-driven sensory inputs (vision, touch, and proprioception) to refine movement precision, adapting to unpredictable environments [16].

Adaptive Behavior:
Machine learning algorithms allow humanoid robots to adjust their responses based on real-time feedback, optimizing task execution [17].

Human-Environment Interaction:
Advanced AI models facilitate naturalistic movements, enabling robots to integrate seamlessly into human-centric spaces [18].

Recent Advances in Physical AI

Neural Networks for Real-World Adaptability:
Researchers are developing AI models that process multi-sensory data for improved environmental awareness and adaptability .

AI-Powered Dexterous Manipulation:
Robotic hands, such as the Psyonic Hand [19] and Shadow Dexterous Hand [20], demonstrate real-time tactile feedback, allowing robots to handle delicate objects with human-like precision.

Bio-Inspired Locomotion:
AI-driven control systems replicate biological movement patterns, enhancing balance, speed, and energy efficiency [21].

5.2 Canada's Position in Physical AI

Canada is a global leader in artificial intelligence research, with institutions like the Vector Institute and MILA advancing deep learning and ethical AI. However, it trails in Physical AI, the fusion of AI with real-world robotic systems.

While companies like Clearpath Robotics and Kinova show promise, Canada lacks large-scale robotics OEMs, national testbeds, and the infrastructure needed to turn AI breakthroughs into commercial robotics products. This gap limits the country's ability to compete with global leaders like the U.S., China, and Japan in humanoid and service robotics.

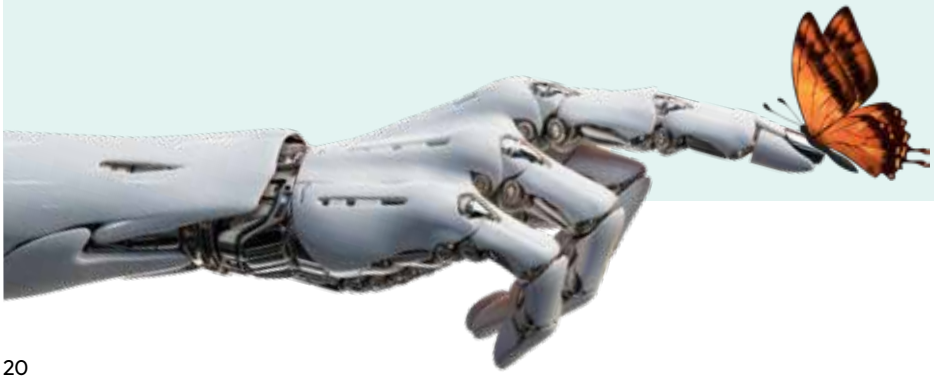
Physical AI: Extending Industrial Intelligence into the Real World

As Artificial Intelligence becomes increasingly embedded across Canada's industrial landscape, the next strategic evolution lies in Physical AI, the convergence of intelligence, motion, and embodiment in machines that interact directly with the physical world. Where Industrial AI focuses on optimizing processes, supply chains, and decision systems within factories, logistics networks, and energy systems, Physical AI extends that intelligence beyond data and into motion, enabling machines to sense, act, and learn autonomously in complex, human-designed environments.

This transition marks the beginning of an era where digital intelligence becomes physically operational, forming the backbone of next-generation manufacturing, logistics, and field robotics.

Industrial AI	**Physical AI**
Uses data analytics, predictive maintenance, and digital twins to optimize production systems.	Embeds AI into machines — humanoids, cobots, AMRs — that operate autonomously in the physical world.
Improves productivity and reduces cost through process intelligence.	Extends human capability and safety through embodied intelligence.
Centers on compute, data, and cloud infrastructure.	Centers on integration of sensors, actuators, energy, and cognitive systems.
Requires AI governance and cybersecurity frameworks.	Adds physical safety, trust, and ethical design frameworks.

Industrial AI and Physical AI are complementary pillars of Canada's emerging intelligent manufacturing ecosystem. Physical AI depends on high-value domestic manufacturing, sensors, drives, embedded AI chips, and simulation frameworks, all of which align with Canada's industrial policy focus on supply chain sovereignty and dual-use innovation. By integrating AI-driven perception, adaptive control, and embodied learning into industrial systems, Canada can move from automation to autonomy, positioning itself at the forefront of global robotics and intelligent systems design.



6.Policy and Regulations in Canada

Introduction: The Need for a National Robotics Policy

The rise of humanoid robotics and AI creates vast opportunities but also regulatory gaps. Canada, despite AI research leadership, lacks a cohesive robotics policy, slowing commercialization, talent retention, and adoption. Countries like the U.S., China, Japan, and the EU already have strategic frameworks. Without action, Canada risks remaining a consumer, not a creator, of robotics technologies.

6.1 The Impact of Policy on Humanoid Robotics

Federal initiatives shape competitiveness but lack a focus on physical AI.

Pan-Canadian AI Strategy:

- Focuses on AI research with a $125M AI Innovation Fund but no dedicated robotics policy.
- Future iterations should explicitly support humanoid robotics.

Strategic Innovation Fund (SIF):

- Funds R&D in clean energy and manufacturing; lacks a robotics-specific stream.
- Recommendation: Add a dedicated humanoid robotics category.

Provincial Robotics Test Zones:

- Ontario, Quebec, and B.C. could host testing zones to accelerate commercialization.

Global Robotics Policy Benchmarking

United States

Policy Framework

National AI Initiative Act (2020), Defense Innovation Unit (DIU) Robotics Program[22]

Key Strengths

Strong public-private funding, DARPA backing, tax credits for robotics R&D

Gaps / Challenges

No national robotics regulation yet, highly defense-focused

Lessons for Canada

Need for public-private R&D incentives & fast-track commercialization programs

China

Policy Framework

Robotics Industry Development Plan (2016-2025), Made in China 2025[23]

Key Strengths

Massive government investment ($10B+), robotics clusters, workforce training programs

Gaps / Challenges

Heavy state control, limited ethical AI discussions

Lessons for Canada

Strategic industrial policy and direct R&D investments are crucial

European Union

Policy Framework

EU AI Act (2023), Civil Law Rules on Robotics[24]

Key Strengths

Strong ethical & safety focus, regulatory clarity for robotics companies

Gaps / Challenges

Overregulation risk slowing deployment

Lessons for Canada

Balance between regulation & innovation to prevent stifling growth

Japan

Policy Framework

New Robot Strategy (2015, updated 2022) [25]

Key Strengths

Humanoid robotics leadership, incentives for elder care & industrial automation

Gaps / Challenges

High R&D costs, slow commercialization outside of Japan

Lessons for Canada

Government incentives for humanoid applications (e.g., healthcare, aging workforce)

South Korea

Policy Framework

Intelligent Robot Development Act (2008, updated 2023)[26]

Key Strengths

$1.5B investment in robotics R&D, AI-powered humanoid focus, “Robot-Friendly Cities” program

Gaps / Challenges

Heavy focus on domestic market, limited global reach

Lessons for Canada

City-scale robotics pilot programs for real-world testing

Germany

Industry 4.0 Strategy, National AI Strategy

EU AI Act (2023), Civil Law Rules on Robotics[27]

Key Strengths

Strong industrial robotics ecosystem, tax breaks for automation firms

Gaps / Challenges

Less focus on humanoid robotics, more on industrial automation

Lessons for Canada

Align robotics strategy with advanced manufacturing policies

AI and Data Privacy Regulations

Humanoid robots collect sensitive data, raising privacy and security concerns.

Key Needs:

- Clear consent mechanisms for vision/audio sensors.
- Transparency and explainability requirements (via AIDA).
- Strict cybersecurity standards for healthcare and public robots.
- Clean energy-powered compute infrastructure.
- Bias prevention in AI decision-making.

Policy Recommendations

- Establish a robotics privacy framework.
- Mandate AI audits and ethical certifications.
- Develop a Canadian AI trust label for robotics.

Provincial Policies: Which Provinces Are Best Suited

Ontario: AI/manufacturing hub with strong talent and incentives but lacks test zones.
Quebec: Major AI funding and clean energy; more software than hardware focus.
B.C.: Robotics startup hub, home to Sanctuary AI; higher costs and fewer clusters.

Canada Needs a National Robotics Policy

Without a strategy, Canada risks slower commercialization, talent loss, foreign dependency, and missed economic growth. A national policy could unify academia, government, and industry to accelerate innovation and exports.

Geopolitical Risk and Supply Chain Sovereignty

Critical robotics components such as actuators, rare earth magnets, and precision sensors are predominantly manufactured in China and a handful of other countries. This geographic concentration exposes Canada to significant supply chain vulnerabilities, particularly as global tensions and export restrictions intensify.

Developing resilient, sovereign supply chains will not only reduce dependence on geopolitically sensitive imports but also position Canada as a trusted supplier within allied networks. Building this foundation is essential for advancing both commercial and security-related applications of robotics technologies.

Human-Centric Robots: A Strategic Dual-Use Opportunity

Within this context, human-centric robotics represents a strategic dual-use opportunity, one that bridges civil and defence innovation priorities. The Canadian Global Affairs Institute (CGAI) urges moving from procurement to production, recognizing commercial technologies as critical to defence [28]. Ottawa is building sovereign platforms, including a cloud, to secure AI and data for robotics. The Defence Industrial Strategy will link spending to domestic production and supply chains.

Why do humanoid & human-centric robots fit the dual-use moment?

1. They are inherently dual-use. Human-centric robots serve civilian markets like manufacturing and healthcare, as well as defence uses such as disaster response. Shared subsystems make them ideal for dual-use.
2. They exercise the whole supply chain. These robots integrate the full mobile robotics stack, supporting suppliers in sensors, compute, power, actuators, and cybersecurity, aiding drones and autonomous vehicles.
3. They align with sovereign digital infrastructure. Advanced robots require secure, domestic cloud and AI computing to reduce foreign dependence and support healthcare and defence.
4. They meet the industrial strategy test. Rising defence spending seeks programs building factories, skilled labour, and supply chains. Human-centric robotics fits both civil and defence procurement.

Why now?

Canada is meeting NATO targets, mapping dual-use SMEs, and adopting industrial policies favoring national resilience. A human-centric robotics program, covering collaborative robots to humanoids, turns policy into concrete dual-use capabilities with near-term civilian benefits and defence pathways—growing suppliers, talent, exports, and national security.

6.2 Building a National Robotics Policy Framework

A. National Humanoid Robotics Strategy

- Integrate robotics into Canada's Innovation Plan.
- The shift from procurement to production emphasizing Canadian content.
- Create regional robotics clusters and regulatory sandboxes.
- Invest in domestic actuator and magnet R&D.
- Requirement for sovereign digital infrastructure deployment.

B. Funding & Tax Incentives

- Create a $500M humanoid robotics stream under SIF.
- Offer R&D tax credits and robotics investment incentives.
- Lead by example with government procurement and pilots.
- Strategies for co-funding innovation tied to defence budgets.

C. Governance & Ethics

- Establish a Robotics Ethics & Safety Board.
- Set legal liability, safety, and transparency standards.
- Building national testbeds for HRI safety and cybersecurity standards
- Require AI risk assessments and audits.

The Three-Pillar Policy Framework for Humanoid Robotics

Innovation & Investment Policy – National fund, R&D credits, accelerators, and procurement to scale robotics startups.

Regulatory & Ethical Governance – Liability laws, AI ethics, privacy standards, and HRI guidelines.

Industrial & National Security Strategy – Supply chain sovereignty, talent retention, and defense applications.

A Call to Action for Policy Acceleration

Without action, Canada risks losing talent and sovereignty in a $211B market. A clear robotics strategy will strengthen competitiveness, ethics, and innovation. By acting decisively, Canada can secure a leadership role and create a sustainable robotics industry for decades to come.

Image: https://www.winnipegfreepress.com/canada/2019/02/02/destruction-of-a-dream

7. Conclusion

Vision for Canada's Role in Humanoid Robotics

Humanoid robotics is a transformative convergence of AI, manufacturing, and human-machine collaboration. Canada has the opportunity to lead this global shift, creating a sovereign robotics sector that drives economic growth, talent retention, and technological independence.

The open-source humanoid initiative can:

- Create thousands of high-value jobs in AI, robotics, and manufacturing.
- Build advanced supply chains and domestic production capacity.
- Establish Canada as a global hub for ethical, open-source robotics innovation.

Establish Leadership in Innovation

Canada can pioneer open-source collaboration, define global standards, and strengthen domestic manufacturing sovereignty, positioning itself as a leader in responsible AI and robotics development.

Economic and Societal Benefits

This industry is projected to reach $211B by 2035. Capturing even a fraction of this market will deliver billions in GDP, export growth, and jobs while enabling solutions for elder care, healthcare, education, and accessibility.

Reversing Brain Drain and Building Sovereignty

A national robotics initiative would keep talent in Canada, attract global innovators, and anchor intellectual property and manufacturing at home, reversing decades of dependency on foreign OEMs and supply chains.

Supply Chain Independence

Investing in domestic component and system production will reduce reliance on volatile global supply chains, strengthen trade relationships, and establish Canada as an exporter of advanced robotics.

Call to Action

Humanoid robotics demands coordinated leadership from government, academia, and industry. Immediate steps include:

Launching the initiative with clear funding and partnerships.

- Building innovation hubs and talent pipelines.
- Aligning robotics strategy with Canada's Innovation and Skills Plan.
- Establishing ethical and safety standards to earn public trust.

Final Thoughts

This initiative is a generational opportunity to secure Canada's place as a leader in robotics, AI, and manufacturing. It offers economic resilience, global competitiveness, and inclusive innovation while addressing societal challenges like labor shortages and aging populations.

By acting decisively, Canada can reclaim leadership, shape global standards, and create a thriving, sovereign robotics industry.

This is not just another project - it is Canada's moonshot.

Global humanoid robot revenues are projected to reach $211B by 2035 and $5T by 2050[12]

About the Authors and Organizations

Centre for Designing Change (CDC)

The CDC is a not-for-profit innovation agency advancing sustainable, human-centered innovation through design thinking, systems thinking, and emerging technologies. It builds partnerships across academia, government, and industry to accelerate commercialization in AI, cybersecurity, manufacturing, and smart infrastructure.

Co-founders Kulbir [Colin] Singh Dhillon and Sumit Bhatia bring over 40 years of combined leadership in design-driven innovation, cybersecurity, AI ethics, and ecosystem development. CDC plays a key role in shaping Canada's humanoid robotics sector by bridging policy, technology, and society.

Waterloo RoboHub

Based at the University of Waterloo, RoboHub is Canada's leading robotics research and testing facility, hosting a unique fleet of humanoid robots (e.g., TALOS, REEM-C). It integrates research, education, and real-world applications, training talent and supporting advancements in human-robot interaction, mobility, and collaboration.

Waterloo Region Ecosystem: The region hosts 90+ robotics and automation companies, top-tier startups like Clearpath Robotics, and strategic infrastructure, making it Canada's robotics innovation hub.

Conestoga College – SMART Centre

Conestoga's SMART Centre offers applied research, rapid prototyping, cybersecurity, and robotics training through state-of-the-art labs. With 54 engineering programs and deep industry partnerships, Conestoga develops hands-on talent and supports robotics innovation from concept to commercialization, emphasizing sustainability and workforce adaptation.

NGen (Next Generation Manufacturing Canada)

NGen is Canada's Global Innovation Cluster for Advanced Manufacturing, driving national-scale projects, SME growth, skills development, and global competitiveness. It funds robotics and automation initiatives to ensure Canadian manufacturers lead in Industry 4.0 innovation.

Appendices

A. Project 1 – Open-Source Humanoid Robot Project

Overview

This flagship initiative proposes Canada's first open-source bipedal humanoid robot as a reference platform to accelerate innovation, commercialization, and global competitiveness. Leveraging strengths in AI, advanced manufacturing, and robotics, the project will create a collaborative ecosystem where startups, academia, and industry build on a shared foundation, positioning Canada as a leader in AI-powered humanoid robotics.

Background and Proposal

Humanoid robotics development is costly and concentrated in proprietary systems in the U.S., China, and Japan. Canada's open-source approach offers a strategic advantage by pooling resources, reducing costs, and standardizing frameworks. It will:

- Lower R&D expenses through collaboration.
- Provide a standardized platform for interoperability and rapid innovation.
- Attract and retain global AI and robotics talent.
- Help Canadian firms compete internationally.

Project Objectives

- Build a scalable, modular humanoid platform for research and commercialization.
- Launch Canada's first AI-powered robotics testbed for real-world deployment.
- Integrate emotional AI, reinforcement learning, and advanced HRI models.
- Enable open-access data and industry adoption across key sectors.

Economic & Industrial Impact

Metric	Projected Impact
GDP Contribution	**$1.2B** over five years
Direct Jobs	**6,000+** in AI, robotics, and manufacturing
Indirect Jobs	**15,000+** across supply chain, education, and logistics
Industry Growth (CAGR)	**20%** with full deployment
Startups Catalyzed	**30+** by 2030
Export Potential	High, targeting North America, Europe, Asia

Methodology and Source Validation

Projections draw on benchmarks from NGen, SCALE.AI, and global robotics clusters. GDP multipliers, job ratios, and startup growth align with prior Canadian innovation programs, assuming $250–300M investment over five years.

Technical Approach & Infrastructure

Hardware: Modular design, advanced mechatronics, and integrated sensors (LIDAR, haptics, cameras) for real-world applications.

Software: Cognitive and emotional AI, reinforcement learning, and an open-source framework for scalable deployment and adaptation.

Call to Action

This initiative is a national innovation platform—not just a research project. Backed by funding, policy support, and multi-stakeholder engagement, it will:

- Foster collaboration through open-source robotics.
- Create thousands of high-tech jobs and export opportunities.
- Anchor Canada's leadership in AI-driven robotics.

Canada must seize this opportunity to lead globally in humanoid robotics through bold, collaborative investment.

B. About the Authors

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Kulbir Colin Singh Dhillon is a futurist, national strategist, and bestselling author with 25+ years of leadership in mobility, smart cities, AI ethics, and manufacturing ecosystems. As President of ImagineQ Inc. and Co-Founder of the Centre for Designing Change (CDC), he spearheads Canada's first open-source humanoid robot initiative and advises on AI, caregiving, and clean energy innovation. A global keynote speaker, Colin authored The Three Houses and Soulful AI and has received the Queen Elizabeth II Diamond Jubilee and King Charles III Coronation Medals.

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Sumit Bhatia

Sumit Bhatia, has 20+ years' experience building innovation ecosystems across academia, government, and tech. He co-founded The Centre for Designing Change(CDC), launched Canada's first national cybersecurity startup accelerator, and shaped ethical tech policy frameworks. Sumit advises startups, universities, and global incubators, and is a leading voice on AI ethics, cybersecurity, digital transformation and strategic foresight.

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https://uwaterloo.ca/scholar/vrajendr

Arundhati Kandan Ramdas

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John Laughlin

John Laughlin, CTO of NGen, has 25+ years of experience in global manufacturing, aerospace, and mobility innovation. Formerly at Innovate UK, he directed $8.5B in R&D investments and helped establish the UK's CAV testing infrastructure. A Chartered Engineer and Fellow of IET, he continues to align policy, research, and industry to strengthen Canada's innovation leadership.

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Humanoid Robots are coming within Less than 5 years

- Jensen Huang, CEO, Nvidia.

“A robot may not injure a human being or, through inaction, allow a human being to come to harm. A robot must obey orders given to it by human beings except where such orders would conflict with the First Law. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.”

- Isaac Asimov

“If you want to understand consciousness, you need to build it.”

- Suzanne Gildert

"At Amico, we believe the next generation of infrastructure won’t just be concrete and steel, it will be intelligent. Humanoid robots have the potential to revolutionize how we build, maintain, and interact with the built environment in Canada, while improving safety by allowing robots to take on high-risk, repetitive, or physically demanding tasks that protect our workforce."

- Dominic Amicone, CEO, Amico Infrastructures

At Magna, we see human like capability and humanoid robotics as a natural evolution of smart manufacturing. As these systems mature, they will become vital co-workers on the shop floor—enhancing safety, productivity, and flexibility in a global production environment.

- Todd Deaville, VP Advanced Manufacturing & Innovation, Magna International

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April 2025.
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Back Image:

https://www.robotics247.com/article/figure_ai_raises_70m_series_a_commercialize_humanoid_robot

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Canada's Next Frontier:
A National Strategy for Global Leadership in Humanoid Robotics.