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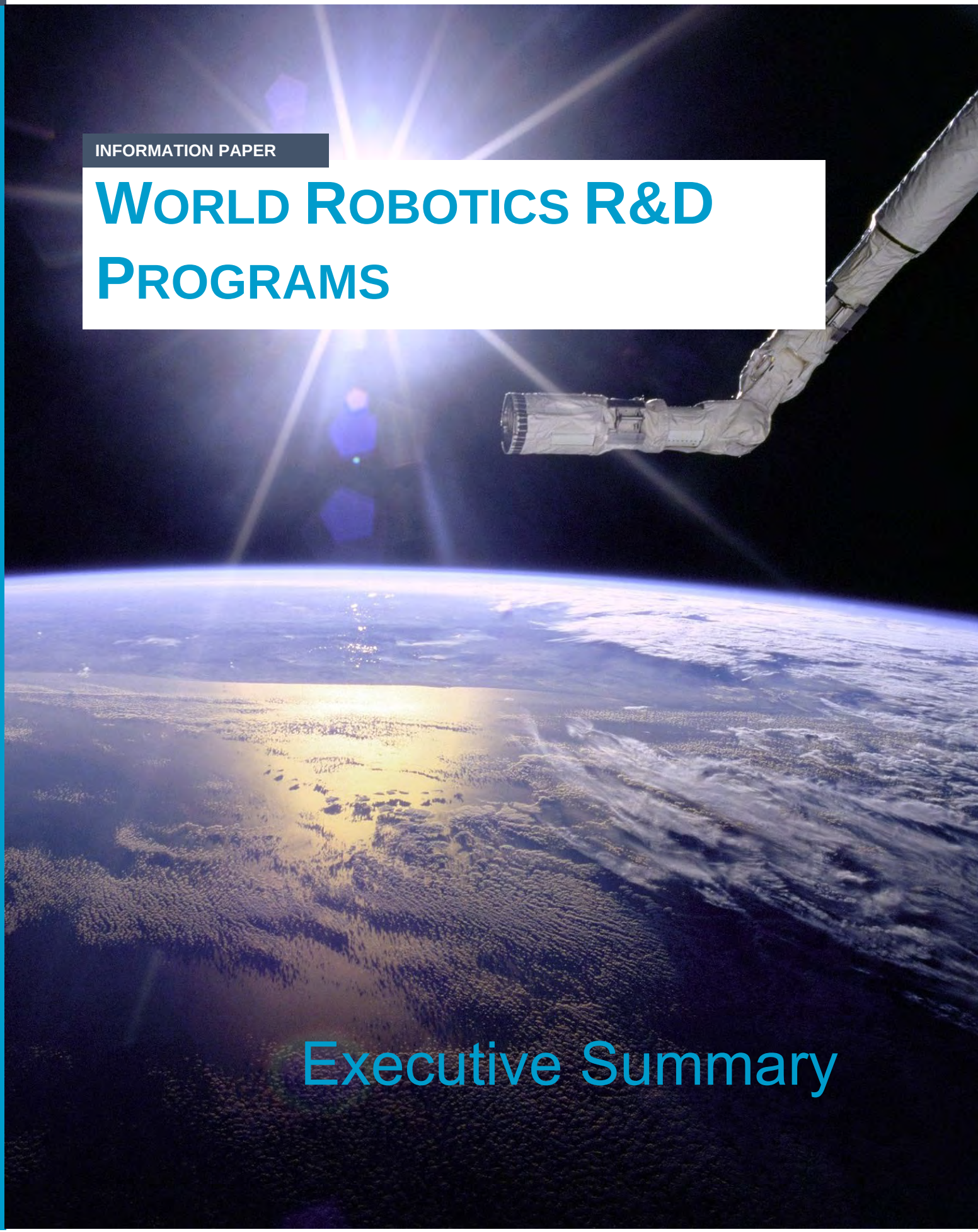

INFORMATION PAPER

# World Robotics R&D Programs

## Executive Summary

# Executive summary

Basically, each country plans and allots budgets per program, but some ambiguity exists in terms of the duration of such programs across nations. There are also external controls. These should be taken into consideration with a review of the following:

- China:
  - The Chinese government provided 45.2 million USD (329 million CNY) in general funding and 44.5 million USD (324 million CNY) for the Key Special Program on Intelligent Robots in 2023 and 2024. The other programs are not included, primarily due to difficulty in accessing governmental sources.
  - Ranked third globally in robot density (for industrial robots) and active in the global humanoid robot market.
- Japan:
  - A budget of 334 million USD (50 billion JPY) was allocated to robotics-related projects in the Moonshot Research and Development Program over a period of five years from 2020 to 2025.
  - The Japanese government provided more than 660 million USD (99 billion JPY) in support in 2023. The figure is 6 billion JPY less than that of the previous year.
- Korea:
  - The Korean government allocated 163 million USD (230 billion KRW) in funding for the 2023 Action Plan for the Intelligent Robot.
  - The Korean government is planning to budget 128 million USD (180 billion KRW) in 2024 for the 4th Basic Plan for Intelligent Robots.
- European Union:
  - The European Commission is expected to provide a total of 183.5 million USD (174.0 million EUR) for the robotics-related work program (2023-2025) in Cluster 4 under Horizon Europe.
  - The European Space Agency is planning to provide feasibility study funding (max: 0.53 million USD (0.50 million EUR)) for Commercial Applications of Space-Enabled Robotics in 2024.
- Germany:
  - The German government will provide approximately 69.12 million USD (70 million EUR) annually until 2026 (total budget: 369.19 million USD (350 million EUR) for five years).
- United Kingdom:
  - The UK's funding for robotics in 2023 and 2024 is around 28.8 million USD. This amount has been invested into three programs, including Made Smarter Innovation, Transforming Food Production, and the Driving the Electric Revolution Challenge, all of which are affiliated with the Industrial Strategy Challenge Fund.
- United States of America:
  - The budget for Intelligent Robotics and Autonomous Systems (IRAS) R&D programs at the National Science Foundation (NSF) was 53.8 million USD in 2023 (supplemental funding: 4.6 mil. USD) and 69.9 million USD in 2024.
  - (DoD) In the 2023 and 2024 fiscal years, the DoD defense budget invested 10.3 billion USD in FY23 (approximately 1.21% of the total DoD budget and 3.7% of the RDT&E and procurement budget) and a requested amount of 10.2 billion USD (approximately 1.21% of total DoD budget and 3.2% of RDT&E and procurement budget) agency-wide for autonomy and robotics technologies.
  - (NASA) For the Artemis program, the US government is planning to allocate a budget of 53 billion USD for 2020 through 2025. In 2023, approximately 10.67 billion USD was granted for NASA's Artemis I mission.

## China

China's development of industrial robots began in 1972 and gained momentum with R&D efforts in spraying, spot-welding, arc-welding, and transport robots during the 7th Five-Year Plan (1986-1990). The 863 Program, launched in 1986, provided substantial government

funding for robot-related R&D, marking a pivotal moment in China's robotics industry.

In the 1990s, welding robots became a focus, with investments in nine industrialization hubs and seven R&D centers. Key manufacturers like Shenyang Siasun, Harbin Boshi Automation, and Beijing Research Institute of Automation emerged.

Made in China 2025, which was launched in 2015, prioritized innovation in advanced robots and mechanical tools. The 13th Five-Year Plan (2016-2020) promoted innovation in manufacturing and integrated AI into robotics development. The Robot Industry Development Plan (2016-2020) aimed to strengthen China's robotics industry, focusing on areas including welding, cleaning and industrial robots, and human-machine cooperation. Core components, including high-precision reducers, motors, and sensors, were also targeted for development.

As part of national science and technology initiatives, key projects like Intelligent Robots were launched between 2017 and 2021 with significant funding. In 2020, the Ministry of Science and Technology allocated 9.13 million USD (66.4 million CNY) to the program. In 2022, Intelligent Robots received 43.4 million USD (316 million CNY) under the 14th Five-Year Plan, marking the robotics industry as one of China's key sectors for the next five years.

In 2023-2024, the 14th Five-Year Plan (FYP: 2021-2025) for the National Economic and Social Development of the People's Republic of China was announced by the Central Committee of the Communist Party of China, in which the robotics industry was included in eight key industry categories for the next five years. In order to implement arrangements of national science and technology innovation during the 14th FYP, Intelligent Robots has thus far been launched under the National Key R&D Plan. It is according to the deployment of this program that the annual project declaration guides for 2023 and 2024 were released. Intelligent Robots received 45.4 million USD (330 million CNY) in 2023 and 44.7 million USD (325 million CNY) in 2024 under the 14th Five-Year Plan. Access to documents on robotics R&D programs funded by the Chinese government is still quite limited. The fact remains, however, that China's robot density ranks third worldwide as of 2023, and dozens of Chinese humanoid robots have already been released in the global market.

## Japan

In Japan, the national R&D program on robotics is planned and funded by the Economic Revitalization Policy and Science, Technology, and Innovation Policy.

In February 2015, the Japanese government announced the New Robot Strategy (the headquarters for the nation's economic revitalization) based on the revised 2014 Japan Revitalization Strategy as a key policy of the Abenomics Growth Strategy. After this strategy was announced, the robot-related budget for the 2016 fiscal year stood at 258.7 million USD (29.4 billion JPY), an increase of 83% over the previous fiscal year. The budget for the 2019 fiscal year is 332.6 million USD (37.8 billion JPY). The New Robot Strategy presented action plans in five sectors to pursue over five years (2016-2020): manufacturing; service; nursing and medical; infrastructure, disaster response, and construction and; agriculture, forestry, fishery, and food industry.

As of 2020, follow-up measures are in progress. Additional funding of 17.6 million USD (2 billion JPY) for 2019 (up from 0.88 billion USD (100 billion JPY) for 2018) was allocated to the Moonshot Research and Development Program to address the concerns of population decline and aging. These projects aimed to develop robots that could enhance the human body's physical and mental limitations and AI robots that are able to evolve alongside humans.

From 2021 through 2022, the New Energy and Industrial Technology Development Organization (NEDO), a national R&D agency, launched projects related to robotics and AI technology to cope with the explosive spread of COVID-19, thereby broadly affecting socioeconomic activities worldwide and brought about unprecedented change to the daily lives of individuals. These projects focus on developing new industrial robots and self-driving robots to strengthen supply chains and maintain logistics services with 79.81 million

USD (9.07 billion JPY) in funding for 2021 and 67.48 million USD (7.68 billion JPY) for 2022.

In December 2023, the Cabinet Office (CAO) decided on Moonshot Goal 10: Realization of a dynamic society in harmony with the global environment and free from resource constraints, through diverse applications of fusion energy, by 2050 in the Moonshot Research and Development Program. Ten Moonshot Goals (MS goals) were decided in the area of society, environment, and economics, of which the first (Overcoming limitations of body, brain, space, and time) and third (Coevolution of AI and robots) are robot-related. The Ministry of Economy, Trade and Industry (METI) and NEDO launched robotics R&D projects with 640 million USD (99 billion JPY) in funds for 2023.

## Korea

Korea's robotics industry evolved through multiple stages of government-industry collaboration. Initially, in 1978, welding robots were introduced in car manufacturing, and independent R&D began without government support. In 1987, the government initiated the Common Core Technology Development Project to support the development of manufacturing robots. Funding decreased drastically, however, during the Asian Financial Crisis of 1997. By 2002, intelligent robots emerged, for which the government ramped up support, establishing the robotics industry as a key growth sector by 2003. From 2002 to 2007, the government invested 345.5 million USD (486.5 billion KRW) into R&D and market creation.

The Intelligent Robot Development and Supply Promotion Act was passed in 2008, followed by the First Intelligent Robot Basic Plan (2009-2013) in 2009. These focused on three key areas: manufacturing robots, new market creation (e.g., education, cleaning, surveillance), and assuming a leading position in terms of technology (e.g., medical, traffic, wearable robots). The government invested 540.3 million USD (760.7 billion KRW) into all three, resulting in a boost in corporate sales and technological development.

The Second Basic Plan (2014-2018) focused on specialized services, such as disaster response and healthcare robots, and emphasized the merging of robotics with sectors such as manufacturing, automobile, and defense. The government allocated 77.7 million USD (109.45 billion KRW) in 2014. This figure increased to 120.5 million USD (169.7 billion KRW) by 2018.

In May 2023, the Action Plan for the Intelligent Robot was released by the Ministry of Trade, Industry, and Energy (MOTIE). Its purpose was as follows:

- Expand the market size of the robotics industry to 10.7 billion USD (15 trillion KRW) by 2023.
- Increase the number of companies valuing at least 71.0 million USD (100 billion KRW) that specialize in robotics to 20 by 2023 at the latest.
- Increase the number of manufacturing robots in operation to 700,000 (cumulative) by 2023.

The total funding provided for 2023 was 163 million USD (230 billion KRW).

In January 2024, the government announced an investment of 128 million USD (180 billion KRW) in the 4th Basic Plan for Intelligent Robots to support the development of the robotics industry as a core industry for the Fourth Industrial Revolution, as well as innovation in manufacturing and services.

## Singapore

In August 2016, the National Robotics Program (NRP) was officially established in Singapore as part of the Research, Innovation, and Enterprise Initiative, which is grounded in the Robotics R&D Taskforce convened in 2014 for the goal of identifying opportunities for the country in robotics. NRP aims to catalyze differentiated robotics capabilities in Singapore through the funding of use-inspired research and use-driven development and is a multi-agency national platform hosted by A*STAR (The Agency for Science, Technology, and Research), which oversees the research, development, and translation of robotics enablers and solutions. NRP also seeks to develop capabilities in robotics for societal and

economic impacts, going beyond technologies to include growing the local talent pool, identifying applications and shaping Singapore's robotics environment. In its early days, NRP funded robotics R&D projects through two funding initiatives (FI): Robotics Enabling Capability Technology (RECT) and Robotics Domain Specific (RDS). RECT focuses on building applicable robotics technologies, inspired by potential use in domain sectors that Singapore is keen to develop, whereas RDS co-funds projects with public agencies in Healthcare, Built Environment, and Environmental Services to innovate robotics solutions for each's problems and use cases. This two-prong system has since been changed to one FI to fund both capability-building and translation projects under the RoboCluster initiative. Since the start of NRP, 11.3 million USD (15.1 million SGD) has been provided on average per year for robotics R&D projects.

In March 2024, the Singaporean government announced that it will be providing 44.8 million USD (60 million SGD) for NRP for the goal of technology translation. A key pillar of NRP's efforts in this area is the RoboCluster initiative, which is comprised of robotics innovation clusters aligned with prioritized R&D focus areas and industry sectors: namely, manufacturing, logistics, facilities management, healthcare, aviation, and maritime. Through RoboCluster, NRP will bring together public R&D institutions such as A*STAR and Institutes of Higher Learning, end-users, robotics and automation companies (including Singapore-based foreign companies), trade associations, VCs, and government agency stakeholders to align and synergize robotics R&D capability-building with industry needs, foster collaborations and catalyze a larger volume of translation from R&D to adopted robotics products.

In 2024, the NRP announced the National Robotics Technology Vistas, outlining nine focus areas of robotics R&D: Assistive Robotics, "Universal" End Effectors, Reconfigurable Robotics, Navigation & Perception, Human-Robot-Interaction, System Capabilities, Trusted Robotics, Data-Driven Robotics, and Multi-Robot Systems. The strategy showcases the key R&D activities in each of the focus areas together with analyses of associated challenges and an envisioning of future developmental over the short-, medium-, and long-terms.

## Australia

In Australia, funding for robotics-related R&D projects has been provided via key initiatives such as the Next Generation Technologies Fund, CRC for Trusted Autonomous Systems, Advancing Space: Australian Civil Space Strategy 2019-2028, and CSIRO Robotics and Autonomous Systems Group. In addition, as with other fields, robotics research projects are funded by the Australian Research Council.

In January 2022, the Australian government unveiled the Robotics and Automation on Earth and in Space Roadmap 2021-2030, a key priority area under the Australian Civil Space Strategy 2019-2028 that is the third in a series of technical roadmaps aiming to be achieved by the Australian Space Agency. The roadmap is considered an important milestone on the road to creating 20,000 new jobs and tripling the size of Australia's civil space sector to 7.8 billion USD (12 billion AUD) by 2030.

In August 2022, the Australian government pledged an investment of 0.65 billion USD (1 billion AUD) in critical technologies as part of the National Reconstruction Fund to support home-grown innovation and value creation in the AI, robotics, and quantum industries.

In May 2023, the government updated its list of Critical Technologies in the National Interest, including seven critical technology fields, of which one is related to robotics (Autonomous systems, robotics, positioning, timing, and sensing).

In May 2024, Australia's first National Robotics Strategy was released with the goal of responsibly developing and using robotics/automation technologies to strengthen competitiveness, boost productivity and support local communities. The government stressed that the strategy will help to build a stronger and more unified robotics industry and harness the benefits of robotics and automation across Australia. It is believed that developing, manufacturing, and using such technologies will improve productivity, grow the economy, help revive domestic manufacturing, and

combat major challenges like climate change, aging population, geopolitical risks, labor market pressures, and rising costs of living.

The National Robotics Strategy sets out goals and objectives organized around four themes that represent areas of focus: 1) National Capability; 2) Increasing Adoption; 3) Trust, Inclusion, and Responsible Development and Use; and 4) Skills & Diversity.

## European Union

Framework Programs (FPs) have been abbreviated as FP1~FP7, with "FP8" replaced with "Horizon 2020".

The European Union has implemented multi-year programs since 1984 to fund R&D. These programs transitioned from durations of five to seven years starting with FP7.

FP7 (2007-2013) emphasized technological development, particularly in robotics, supporting 130 projects with a large fund of approximately 565.1 million USD (536 million EUR). This program advanced technologies such as perception, action-cognition, and intelligent systems. Other funds for robotics-related elements amounted to 179.2 million USD (170 million EUR).

Horizon 2020, the eighth EU Framework Program, ran from 2014 to 2020 and covered a range of research and innovation themes, one of which was robotics. It was structured into three work phases: 2014-2015, 2016-2017, and 2018-2020. Robotics projects within Horizon 2020, shaped by consultations in the SPARC program, span multiple areas, including Information and Communication Technologies (ICT), Future and Emerging Technologies (FET), and societal challenges. The program provided approximately 738.1 million USD (700 million EUR) for various robotics research projects with a focus on the manufacturing, healthcare, transportation, and agricultural sectors.

The 2014-2015 phase allocated 165.6 million USD (157 million EUR) to 36 projects aiming to improve robot robustness, flexibility, and autonomy across industries. The 2016-2017 phase, with a budget of 127.6 million USD (121 million EUR), expanded into areas such as human-robot interaction and navigation, helping to apply research outcomes to practical applications. The final phase, 2018 to 2020, focused on digitizing industries with robotics, advanced AI and cognitive technologies, and human-robot cooperation with 164.5 million USD (156 million EUR) in funding.

Horizon Europe (2021-2027) was built on Horizon 2020 for the goal of supporting research and innovation for a future of environmental conscientiousness, digital sophistication and healthier humans. The Strategic Research, Innovation, and Development Agenda (SRIDA) focuses on advancement in AI, data, and robotics and sets goals and priorities for research and innovation, with robotics under Cluster 4: Digital, Industry, and Space (Work Program 2023-2025: Cluster 4: Digital, Industry, and Space was announced on April 17, 2024). Robotics-related R&DI projects will focus on the digital transformation of the manufacturing and construction sectors, autonomous solutions that alleviate the burden of human workers, enhanced cognition, and human-robot collaboration based on research in digitization, AI, data sharing, advanced robotics and modularity. The robotics-related work program 2023-2025 in Cluster 4 will provide 183.5 million USD (174.0 million EUR) in funding (total).

Commercial Application of Space-Enable Robotics is a new program by the European Space Agency (ESA). Announced on March 7, 2024, it supported feasibility studies with a maximum of 0.53 million USD (0.50 million EUR) in funds and demonstration projects (funding by case assessment) for commercial applications that integrate satellite technologies with autonomous robotics systems.

## Germany

In 2006, Germany's High-Tech Strategy (HTS) was introduced to help the country become a global leader in innovation. It aimed to quickly turn good ideas into products and services and thereby foster collaboration among companies, universities, and research institutions. A key part of this strategy is Industry 4.0, an initiative that focuses on robotics R&D as a means of maintaining Germany's leadership in digital products and their manufacturing.

From 2009 to 2014, the AUTONOMIK program funded 46.4 million USD (44 million EUR) for robot-related projects in manufacturing, logistics, and assembly. It explored smart tools and autonomous systems and led to the development of the AUTONOMIK für Industrie 4.0 program (2013–2017), which received the same amount of funding and aimed to combine industrial production technologies with info-communication technologies. The projects explored areas such as human-robot interaction and cognitive features for autonomous systems.

In 2016, the PAiCE program, with 52.7 million USD (50 million EUR) in funding, continued the work of AUTONOMIK and focused on digital platforms for industry, especially in robotics. PAiCE supports service robotics in logistics, manufacturing, and other fields.

The High-Tech Strategy 2025, adopted in 2018, set a goal of investing 3.5% of Germany's GDP annually in R&D until 2025. The affiliated Together Through Innovation program was launched in 2020, with the Federal Ministry of Education and Research (BMBF) slated to provide approximately 73.8 million USD (70 million EUR) annually until 2026 for robotics-related research.

## Italy

The Italian government contributes to research funds that are managed by the EC, and Italian researchers actively participate in the European HORIZON 2020 ICT, NMBP, and other programs that involve robotics. As part of the FP7 (2007-2013) program, 16.5% of funding for robotics projects was awarded to Italian institutions.

In December 2020, the National Program for Research 2021-2027 was approved and extended through public consultation to public and private stakeholders and interests as well as civil society. The National Research Program (PNR), provided for by Legislative Decree 204/1998, is a document that guides research policies in Italy, the realization of which public players contribute to through the coordination of the Ministry of University and Research. Robotics is one of the primary areas of research and innovation in PNR 2021-2027, as indicated below:

- Robots increasingly more pervasive and personal
- Six priority areas for the overall supply chain, from fundamental research to application: 1) Robotics in a hostile environment; 2) Robotics for Industry 4.0; 3) Robotics for inspection and maintenance of infrastructure; 4) Robotics for the agro-food sector; 5) Robotics for health; 6) Robotics for mobility and autonomous vehicles

After the COVID-19 pandemic, Italy launched the National Recovery and Resilience Plan as part of the NextGenerationEU program, an 819 billion USD (750 billion EUR) recovery package agreed to be provided by the EU in response to the pandemic. Italy's plan includes investments worth 209 billion USD (191.5 billion EUR), financed through the Recovery and Resilience Facility.

Some activities of national relevance on robotics were launched in Italy, including the following:

- RobotHeart: RoboHeart is a national exhibition on industrial robotics, automation, related technologies and solutions, components, systems, and AI.
- National Course on Industrial Automation and Robotics: The Italian Association of Robotics and Automation (SIRI) has a long tradition of organizing the annual National Course on Industrial Automation and Robotics. In 2024, the 47th run, titled "Industrial Robotics: Between Regulation and Innovation," was held in Ancona.
- Ph.D program in robotics and intelligent machines: The new National Doctorate (https://drim.i-rim.it/en/) is characterized by an interdisciplinary and international outlook and strong industrial vocation for the advanced training of the country's young talent in the areas of robotics and intelligent machines.

## United Kingdom

The UK recognizes robotics as a transformative technology for enhancing productivity and economic growth that is driven by advancements in microelectronics and data processing. It was anticipated that automation

and robotics would provide significant economic benefits over the next decade in the following ways:

- 233.2 B USD (183.6 B GBP) of value to the UK industry
- 19 B USD (15 B GBP) of cost savings for consumers
- 127,000 workplace injuries avoided

This has resulted in significant amounts of funding becoming available from UK Research and Innovation (UKRI)-related organizations to support the R&D and commercialization of Robotics and Autonomous Systems (RAS) technologies. In 2016, the Industrial Strategy Challenge Fund (ISCF) was announced with four challenging themes and 22 programs, of which two of the themes and four of the programs are related to robotics R&D. In 2022, the biggest instance of funding for robotics research (Robots for a Safer World) was 142 million USD (112 million GBP), which was invested into 153 projects and 212 organizations and complemented by over 745 million USD (500 M GBP) in industry-matched funding.

Funding for robotics in 2023 and 2024 has focused on several significant initiatives and challenges across two themes (Clean Growth, Future of Mobility) and three programs (Made Smarter Innovation, Transforming Food Production, Driving the Electric Revolution), reflecting the country's strategic priorities in innovation and technology development. Total funding for robotics in 2023 and 2024 was approximately 28 million USD (22 million GBP).

## Sweden

Vinnova, a Swedish public innovation agency, promotes robotics and automation by funding R&D projects across multiple sectors. It established the VINNVÄXT program in 2001 to support regional sustainable growth, with notable funding recipients including Robotdalen (2003) and Automation Region (2016). In addition to VINNVÄXT, Vinnova collaborates with universities, research institutes, and private companies to advance robotics, AI, and automation by supporting a large number of innovative projects.

## Switzerland

- Switzerland's research funding, driven by SNSF and Innosuisse, supports industry-academia collaboration in both basic and applied sciences. NCCR Robotics, which was active from 2010 to 2022, advanced robotics research and bolstered the nation's global competitive edge. Its legacy continues through Innovation Booster Robotics, a program launched in 2022 that focuses on innovation in medical and mobile robotics via networking and technology transfer.

## United States

Robotics R&D programs managed by the United States in 2020 were mainly reviewed in the key categories of "Space Robotics," "Military Robotics and Autonomous Systems," and "Ubiquitous Collaborative Robots."

The National Aeronautics and Space Administration (NASA), the US' premier space robotics R&D organization, has been promoting the Mars Exploration Program (MEP). MEP is a long-term mission on exploring Mars with NASA funds. At the beginning of the 21st century, MEP missions concentrated on the "Follow the Water" goal (e.g., Mars Odyssey (2001), Mars Exploration Rovers (2003), Mars Reconnaissance Orbiter (2005), and Mars Phoenix Lander (2007)). Since then, MEP has moved away from "Follow the Water" to a characterizing of the climate and geology of Mars with Curiosity, the Mars Science Laboratory's rover (2011), and Mars Atmosphere and Volatile Evolution (2013). In September 2013, NASA launched Opportunity, another rover, for scientists/researchers to propose and develop exploratory instruments, including the Sample Caching System for storing Martian soil. MEP instruments were selected in July 2014 after an open competition based on the scientific objectives set out in 2013. Mars 2020 has been carried out by MEP with a planned launch on July 17, 2020, and a touchdown in Mars' Jezero crater on February 18, 2021. The rover in the Mars 2020 program is based on the design of Curiosity but with extra scientific instruments embedded in it to explore a site likely to have been habitable. The

budget for MEP in 2017 was comprised of 647 million USD from the US government and a NASA fund of 408 million USD for Mars Rover 2020 and 239 million USD for other missions/data analysis, respectively. In 2019, MEP funded approximately 604.5 million USD, with NASA supporting 348 million USD for Mars 2020 and 253.5 million USD for other missions/data analysis, respectively.

Following the Mars exploration program, NASA launched Artemis, a lunar program, in May 2019. The purpose of Artemis is to send astronauts to the lunar surface by 2024 and construct promising capabilities for Mars missions post-2024. Artemis' missions can be divided into two phases: Phase 1, from 2020 until 2024, and Phase 2, from 2025 to 2029 (ant.). Phase 1 focuses on getting systems in place to support the first human lunar surface landing since the 1960s. It will proceed through three steps: Artemis I (the first launch of the SLS and Orion spacecraft), Artemis II (taking a crew on a flight around the moon), and Artemis III (taking a crew to the Gateway and then down to the lunar surface). Phase 1 also includes lunar research for the goal of studying polar volatiles and the geology of the South Pole-Aitken Basin and landing at a lunar swirl to make the first-ever direct magnetic measurement. Phase 2 comprises the capabilities necessary to establish a sustainable human presence on and around the moon. However, in November 2021, plans to send astronauts to the moon by 2024 were canceled. On November 16, 2022, Artemis I was successfully carried out with the launch of the first unmanned flight of the SLS and Orion, completing a mission that included a distant retrograde orbit around the moon. Artemis II was planned for September 2025, with Artemis III delayed to September 2026. The total budget for Artemis adds up to 53 billion USD for fiscal years 2021-2025.

The DoD manages many programs on developing unmanned military systems and robotic vehicles. Ever since the RDE Focus of the US Secretary of Defense was released in 2010, "Autonomy" has become the DoD's Science & Technology (S&T) priority. The DoD annually releases progress reports and plans associated with the development of military autonomous vehicles and the integration of such vehicles/systems with each department. Key research focuses include Machine Perception, Reasoning and Intelligence (MPRI), Human/Autonomous System Interaction and Collaboration (HASIC), Scalable Teaming of Autonomous Systems (STAS), Test, Evaluation, Validation, and Verification (TEVV), with core technologies including sensors/payloads, navigation/control, weapons, comms/data management, autonomy, propulsion/energy, and mobility. The DoD invested 9.6 billion USD in autonomous systems in 2019, with funding spread across the Navy, Army, Air Force, and various agencies. Budgets for unmanned systems have decreased slightly in recent years, with 7.54 billion USD allocated in the 2021 fiscal year and 8.2 billion USD proposed for the 2022 fiscal year.

In the 2023 fiscal year, the DoD defense budget allocated 10.3 billion USD (approximately 1.21% of the total DoD budget and 3.7% of RDT&E and procurement budget) and a requested agency-wide fund of 10.2 billion USD (approximately 1.21% of total DoD budget and 3.2% of RDT&E and procurement budget) for autonomy and robotics technologies.

For fundamental robotics R&D, the National Robotics Initiative (NRI) was launched in 2011 (the US government has since advanced the NRI from NRI-1.0 to NRI-2.0). Initially, the goal of NRI-1.0 was to accelerate the development and use of robots in the United States through innovative robotics research and applications emphasizing the realization of such co-robots working in symbiotic relationships with human partners. Since NRI-2.0 was released in 2016, the NRI's goals have focused on research on the fundamental science, technologies, and integrated systems needed to achieve ubiquitous collaborative robots and to assist humans in every aspect of life with "Ubiquity: Seamless integration of co-robots." The budget of NRI-2.0 in 2019 was funded with 35 million USD for foundational (FND) and integrative (INT) projects in multiple agencies of the federal government. The US government supported NRI-2.0 with 32 million USD in 2020.

In 2020, the United States released the 2020 US National Robotics Roadmap on the implementation of robots for purposes of economic growth, improved quality of life, and empowerment of people. Based on this

roadmap, R&D programs related to Intelligent Robotics and Autonomous Systems (IRAS) have been launched to advance intelligent robotic systems, including R&D in robotics hardware and software design and applications, machine perception, cognition and adaptation, mobility and manipulation, human-robot interaction, distributed and networked robotics, and autonomous systems. IRAS strategic priorities and related key programs aim to promote safe and efficient human-robot teamwork, improve validation and verification of robotic and autonomous systems, and advance intelligent physical systems. The IRAS budget accounts for 4% of the FY 2021 budget of 6.5 billion USD requested by the president for federal agencies' Networking and Information Technology Research and Development (NITRD)-related R&D. NRI-3.0, which was released in 2021 as part of IRAS efforts to support fundamental research in the United States to advance robotics integration, supports research on this area for the benefit of humans in terms of safety and independence. The main goals of NRI-3.0 are to strengthen the robotics research community, foster innovation and workforce development, accelerate progress, demonstrate novel capabilities, build environments (ecosystems) for innovation, and, above all, to promote original and integrated approaches to the challenges of accountability, interoperability, ethical operation, and trust which will be engendered by integrated functional and ubiquitous robots. On May 3, 2022, the NSF announced the termination of NRI-3.0, which had over 250 million USD invested in more than 300 pioneering research projects over its 12-year lifespan.

The budget for IRAS R&D programs at NSF was 53.8 million USD in 2023 (supplemental funding: 4.6 million USD) and 69.9 million USD in 2024 according to the NITRD in the 2024 fiscal year. Funding was provided via different programs, such as Human-Centered Computing (HCC); Mind, Machine, and Motor Nexus (M3X); Cyber-physical Systems (CPS); Dynamics, Control and Systems Diagnostics (DCSD); Foundational Research in Robotics (FRR); Robust Intelligence (RI); Smart Health and Biomedical Research in the Era of AI and Advanced Data Science, Disability and Rehabilitation Engineering; America's Seed Fund; Partnerships for Innovation; Broadening Participation in Computing (BPC); the NSF Research Traineeship Program; Energy, Power, Control, and Networks; Perception, Action & Cognition (PAC); Mechanics of Materials and Structures (MOMS); Science of Learning and Augmented Intelligence; and Research on Innovative Technologies for Enhanced Learning (RITEL).

## Canada

In Canada, the national R&D program for robotics is planned and funded by Innovation, Science and Economic Development Canada and the Canadian Space Agency.

Canada's R&D program is propped up by two pillars: In March 2019, the Canadian Space Agency, which launched a new national space strategy in March 2019, and The National Research Council Canada, which announced the National Research Council Canada Strategic Plan 2019-2024 in February 2020.

Space robotics is the number one R&D player among Canadian manufacturing industries. In 2018, the aerospace manufacturing industry invested 1 billion USD (1.4 billion CAD) in R&D, contributing close to 25% of total manufacturing R&D in Canada and achieving over five times higher R&D intensity than the manufacturing average.

Canadarm* is a government-led robotics R&D program that is regarded as Canada's best-known contribution to the field. A manipulator able to withstand the harsh radiation levels of outer space, it was first used by the crew of the Columbia, the NASA space shuttle, in 1981. On subsequent missions, Canadarm2 and Dextre were used to construct and maintain the International Space Station. The third Canadarm's letter of interest, "Lunar Gateway Robotics_Canadarm3," was announced on July 26, 2019. In it, the CSA proposed to include the following elements: 1) the eXploration Large Arm and its tools (XLA); 2) the eXploration Dexterous Arm (small arm or XDA); 3) various robotic interface fixtures, platforms, and receptacles and; 4) ground segment and robotic integration. To contribute an AI-enabled robotics system to Gateway, a US-led lunar outpost, the Canadian government pledged 152 million USD (209 million CAD) in 2019 in

funding to be devoted from 2019 until 2024 to develop Canadarm3 under a policy entitled "Canada Reaches for the Moon and Beyond." On June 27, 2024, Minister of Innovation, Science and Industry François-Philippe Champagne announced that MDA Space, a Brampton-based company, will receive 730 million USD (999.8 million CAD) to continue work on Canadarm3 and begin detailed design, construction and testing. This milestone marks the last steps in finalizing the design, construction and testing of the Canadarm before delivering it to Gateway.

Canadarm3 and Dexter have led to the development of many technologies, such as neuroArm and IGAR. Canadarm3, which incorporates advanced AI technologies, is expected to open the door to a new level of robotics.