The AI Data Robotics Association

Strategic orientation towards an **AI**, **Data**, **Robotics** roadmap 2025–2027

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Abbreviations:

ADR - AI, Data, and Robotics
EU – European Union
AI – Artificial Intelligence
R&D – Research and Development
IoT – Internet of Things
SME – Small and Medium-sized Enterprises
ML – Machine Learning
EU – European Union
SDG – Strategic Development Goals
WP – Work Programme
AAAI - Association for the Advancement of Artificial Intelligence
ICML - International Conference on Machine Learning
IJCAI - International Joint Conferences on Artificial Intelligence
CVPR - Computer Vision and Pattern Recognition
ICCV - International Conference on Computer Vision
ICRA - International Conference on Robotics and Automation
IROS - International Conference on Intelligent Robots and Systems
NeurIPS - Neural Information Processing Systems
PAMI - IEEE Transactions on Pattern Analysis and Machine Intelligence
HRI - Human-Robot Interaction
HRC - Human-Robot Collaboration
AutoML - Automated Machine Learning
HPC - High Performance Computing
SRIDA - Strategic Research, Innovation and Deployment Agenda

Background

The purpose of this document is to provide an overview of the strategic position of the ADR Partnership from the Adra members perspective, resulting in several recommendations for the upcoming European work programs. The position is motivated by global challenges and more specific challenges related to Artificial Intelligence (AI), data, and robotics. The first part describes the global challenges and the major strategic objectives for the ADR partnership to address. The second part describes the recommendations for the EU strategic plan for 2025-2027 in alignment with the strategy.

Global Challenges

The recent world crises and global disruption are causing severe challenges to Europe's future sustainable development and welfare. Access to essential resources[1] such as food[2] [3], energy, and water are constrained by the continuous increase in world population, decrease of arable land, and increasing global demands for these resources. Moreover, factories and brains are continuously migrating for other ecosystems outside Europe. Climate changes[4] are leading to more unstable weather conditions, more frequent and disruptive natural disasters, and potentially global displacement of large groups of people. Demographic changes lead to a shrinking working-age population that needs to provide for and take care of an ageing population. Geopolitical instabilities[5] from increasing tension between major countries in the world to political unrest are reducing global cohesion and cooperation. This is especially challenging when dealing with global disruptions such as pandemics, natural disasters, and war.

Luckily, Europe still has high living standards with a well-developed welfare system. However, it is under severe pressure. Three choke points are:

1. Europe's dependency on world supply for essential resources (e.g., energy) makes its society and industries vulnerable to global crises.

2. Europe's increasing workforce needs make it vulnerable to demographic changes and global competition.

3. Europe's dependency on the world supply of key technologies and materials (e.g., semiconductors, active pharmaceutical ingredients) makes its society and industries vulnerable to global disruptions.

AI, Data, and Robotics (ADR) are essential elements that can enable sustainable security and strategic autonomy in Europe for food, energy, key technologies, and industries. Europe has world-leading industries in robotics (26% market share in 2021)[6], machine vision and Trustworthy AI technologies, with a considerable global market share and a well-established ecosystem of developers, suppliers, system integrators, end-users, and scientists around them. However,

1. https://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf
2. https://info.bml.gv.at/en/topics/food/food-security-in-europe-through-climate-change-research.html
3. https://www.wri.org/insights/how-sustainably-feed-10-billion-people-2050-21-charts
4. https://www.faccejpi.net/en/faccejpi.htm
5. https://www.cer.eu/hot-topics/geopolitical-eu
6. https://www.precedenceresearch.com/robotics-technology-market

the best European university ranks 11 in robotics[7], 13 in computer vision[8], 6 in AI[9] according to 2023 list based on number of citations and publications ratings. Europe is in the path to become a global leader in trusted and federated data sharing and is developing a strong data value ecosystem through the establishment of common European data spaces[10,11]. This trend continues, but the rapid development of computer vision and AI-based robotics, both in Asia and North America, pose risks to technology leadership and opportunities, for example, in the development of worldwide standards to enable clear guidance for the implementation and adoption of these technologies. Therefore, Europe should exploit this position to maintain this leadership with further investments that can speed up the digital transformation. Investments in ADR will further secure sustainable production of essential resources for Europe, such as energy, food, and other key elements, as well as efficient waste management. ADR has the potential to drastically increase our capacity in production infrastructure, transportation, and workforce for operations and maintenance of assets as future tasks will eventually become unmanageable by humans alone, where robots and AI systems should be engaged to work side by side with humans to increase capacity and safety. For example, food security would require people to engage in agriculture. However, the population tends to leave rural areas for urban areas, thus reducing staffing for food production. Even worse, the amount of arable land is drastically decreasing[12], so food production infrastructures must be developed in other areas (e.g., oceans and remote areas). In short, ADR is a strategic investment in Europe to establish autonomous and intelligent systems that can fill the workforce gap to strengthen European commitment to sustainable growth, welfare, and innovation.

The Strategic Research Innovation and Deployment Agenda (SRIDA) aims to build on the fundamentals of Europe to be world-leading in ADR for both enhancing the revenue-generating potential for companies' business models and enriching our society as a whole. Aligned with the SRIDA's vision[13], the work programme 2021-2022 (WP21-22) tackled ADR for smart and agile manufacturing, for the green deal, for people at work environment and industry optimisation. It also addressed technologies and solutions for data sharing in common European spaces with topics on compliance privacy, data management, data trading, monetizing, exchange, and interoperability. WP 21-22 also tackled topics on robotics cognition, AI for human empowerment, increased robotics capabilities for key sectors trustworthy AI and European coordination for trustworthy ADR. WP23-24 addresses integrating data lifecycle, cognitive computing continuum, AI-driven data operations, and compliance technologies. It also tackles Novel paradigms and approaches for AI-driven autonomy, a step change in autonomy, and collaborative intelligence between machines and humans. Finally, WP23-24 also encompasses open innovation on grand challenges in AI, efficient trustworthy AI, explainable and robust AI, and natural language understanding and interaction.

7. https://edurank.org/engineering/robotics/

8. https://edurank.org/cs/computer-vision/

9. https://edurank.org/cs/ai/

10. https://ec.europa.eu/digital-single-market/en/policies/building-european-data-economy

11. https://data-spaces-business-alliance.eu/

12. https://www.canr.msu.edu/news/feeding-the-world-in-2050-and-beyond-part-1

13. "Zillner, S., Bisset, D., Milano, M., Curry, E., García Robles, A., Hahn, T., Irgens, M., Lafrenz, R., Liepert, B., O'Sullivan, B. and Smeulders, A., (eds) (2020) "Strategic Research, Innovation and Deployment Agenda - AI, Data and Robotics Partnership. Third Release." September 2020, Brussels. BDVA, euRobotics, ELLIS, EurAI and CLAIRE" https://adr-association.eu/wp-content/uploads/2020/09/AI-Data-Robotics-Partnership-SRIDA-V3.0-1.pdf

As a continuation of these efforts and following the new developments, the strategic plan 2025-2027 should further elaborate on the grand challenges of ADR, such as trustworthy AI, robotics autonomy, flexible functionality, new paradigms, and improved standards for efficient data processing and computing. It should also further elaborate on the smart and cognitive manufacturing as well as increased autonomy and resilience of production by exploiting ADR for remanufacturing, recycling and waste management and revalorisation. Finally, considerable effort should be further invested into human-machine collaboration, ethics, and compliance for ADR at the service of society.

ADR Vision 2030

The ADR partnership aims to enable a responsible AI-powered green digital transformation for an attractive, sustainable, prosperous, secure, and resilient multicultural society, based on European values, with the highest living standard in the World. By 2030 Europe will have created a shared secure data infrastructure balancing the need for privacy with the need for effective and correct information that is interoperable with the rest of the world. Increasingly autonomous robotic systems in many shapes and forms are increasing the effectiveness, safety, and energy efficiency in a human-friendly manner in a wide range of sectors, including agriculture, transportation, and healthcare. Sophisticated and trustworthy AI-based systems provide effective and actionable decision support to individuals, groups, companies, and governments based on accurate and up-to-date information. The global share of technical solutions in AI, data, and robotics provided by European companies is steadily increasing, providing cost-effective solutions respecting our human rights and values. With a new era of European Trustworthy AI-first companies, together with the quality of life and sustainable living, European talent is realising their ambitions in Europe, and Europe is attracting global talent in increasing numbers. Most leading global companies have significant research, development, and production in Europe. On the global scene, through competence and resolve, Europe is seen as a stable and trustworthy partner, showing the way towards a promising future for all of humanity.

To achieve this vision, it is necessary to have a strong multi-stakeholder ecosystem pulling in the same direction capable of developing and deploying next-generation technology in accordance with society's values at an increasing speed, scale, and complexity, creating impact and offering new business opportunities. The future is data-driven, AI-powered and involves increasingly autonomous and sophisticated robotic systems. The ADR Partnership is key to enabling the future and establishing a strong, effective, and sustainable ecosystem for AI, data, and robotics. By building bridges between disciplines as well as research, innovation, and deployment, the ADR partnership will reduce the fragmentation of the European ADR landscape and contribute to establishing a sustainable ADR ecosystem achieving global impact and value creation.

ADR Mission

1 Creating a strong, coherent, and effective ecosystem for AI, Data, and Robotics

2 Maintaining and strengthening European industrial leadership in robotics, computer vision and Trustworthy AI technologies

3 Integrating and connecting the European research landscape around AI, data, and robotics

4 Developing a powerful strategy for attracting skills and talents to Europe

5 Developing ADR technologies with high socio-economic impact to reinforce a strong and global competitive position of Europe

6 Ensure societal trust in AI, data, and robotics

Creating a strong, coherent, and effective ecosystem for AI, Data and Robotics

Europe needs a functioning ecosystem covering AI, Data and Robotics that can establish the foundation for boosting value created by the innovative development and deployment of these technologies. No single player can achieve this alone; the sharing of assets, technology, skills, and knowledge is crucial. In addition, for scaling the deployment of these technologies in real-world applications, a critical mass of engaged stakeholders is needed. Although Europe has strong ecosystems around AI, Data, and Robotics, it needs to develop a single interconnected ecosystem that joins across the technical areas and across Europe. An ecosystem that connects and leverages European efforts in each of these areas needs to reflect the complexity and diversity of its constituents. It must encompass the three dimensions of AI, Data, and Robotics and ensure that knowledge is cross-fertilised. In addition, this requires effective engagement from all stakeholders and alignment between them to ensure efficient collaboration. *This is the key mission of Adra.*

Strengthening leadership of European Industries in vision and robotics technologies

Those who control digital technologies are increasingly able to influence economic, societal and political outcomes. The EU's ability to defend and promote its interests, and its credibility as a strong foreign policy actor, will largely be a function of its technological command. In order to achieve the digital transformation and tackle the societal challenges according to its values and in respect of its socioeconomic model, Europe is leading in vision and robotics and must master and shape further digital technologies and their fast evolution. This requires significant investments in research and innovation in key digital technologies such as AI, data and robotics. It is also important to continue strengthening the EU's capacity to ensure adequate reskilling/upskilling of the workforce; to support socioeconomic transformations in a fair manner; to develop and implement advanced materials, ADR technologies and processes; and to stay competitive and avoid future strategic dependencies. The acceleration of digitalisation and the significant supply chain disruptions caused by the COVID-19 pandemic and the geopolitical tensions have intensified the political discourse on EU technological and data sovereignty and open strategic autonomy[14].

Integrating and connecting the European research landscape

Europe has a strong AI, Data, and Robotics research capability and capacity in academia and research organisations. However, their activities are fragmented between different communities and remain siloed around disciplines and within member states. This reduces both the effectiveness of European companies and their impact, both within Europe and globally. It also reduces our capacity to translate research into innovative smart solutions, as well as feeding research with real-world questions and challenges. Fragmentation must be addressed. Otherwise, the investments in research, innovation, and deployment will not be maximally efficient and effective due to redundant and sometimes even counterproductive activities.

Developing a powerful strategy for attracting skills and talents to Europe

A coherent approach to skills development is needed across Europe, from primary education to university to the job market. Small-scale nationally based initiatives need to be covered at a European level. As the ADR uptake accelerates across Europe in the next decades, there is a need to ensure that the workforce has the skills to deploy, install, and maintain ADR systems. This is in addition to the need to deliver technologists able to design and develop such systems. A failure to address the issue of skill mix in the economy will block future deployment, as skill shortfall can only be partially solved by technology. The creation of a coherent European approach to skills that deliver at the right level will be an essential component to ensure maximizing productivity gains from new technology.

More alarming for AI, data and robotics, a steady flow of EU citizens with exceptional skills andeducation levels are emigrating, mainly to the US. These experts would have a huge potential for wealthcreation in Europe. Europe, therefore, must act to establish processes and actions that can boost the attractiveness of existing European innovation ecosystems or develop new ones.

14. European Commission, "Horizon Europe Strategic Plan 2025-2027 Analysis", May 2023.

Establishing ADR technologies with high socio-economic impact

From ADR Partnership proposal: A recent study from PwC and Microsoft[15] highlights that using AI or environmental applications has the potential to boost global GDP by 3.1% to 4.4% and will help to lower the worldwide greenhouse gas emissions by 4% in 2030. Furthermore, smart systems can provide a valuable contribution to sustainability at large, addressing challenges such as (with an arbitrary choice of concrete examples): climate change monitoring and understanding[16], natural resources[17] and ecosystem[18] management, reduction of the carbon footprint of industrial[19] and human processes[20], energy efficiency[21] and management, mobility management[22], and infrastructure planning[23]. In these contexts, the scale and complexity of the problems to be solved pose new challenges to current AI techniques that need to be scaled, made global, made more efficient, incorporated into hybrid AI systems and integrated with knowledge coming from human experts. In addition, security issues arising from terrorism-related issues, natural disasters, and epidemics, can also be addressed and better managed through smart systems.

Societal trust in AI, data and robotics

There are many misconceptions and much misinformation about AI, Data and Robotics in societal debates, and the technology is not fully accepted by society in all application areas. This will slow uptake, especially where there is unfounded mistrust, and may also damage markets where the real dangers are not fully understood.

15. https://www.pwc.co.uk/sustainability-climate-change/assets/pdf/how-ai-can-enable-a-sustainable-future.pdf
16. Better extreme events forecast by the US National Oceanic and Atmospheric Administration
17. https://www.bestpractice.ai/studies/deepmind_increases_value_of_wind_power_by_20_by_predicting_supply_36_hours_in_advance
18. https://slideslive.com/38917860/deep-learning-for-wildlife-conservation-and-restoration-efforts
19. https://www.bestpractice.ai/studies/otto_predicts_with_90_accuracy_what_products_will_be_sold_within_30_days_driving_automated_purchasing_and_reduction_of_annual_returns_by_2m
20. https://slideslive.com/38917853/towards-a-sustainable-food-supply-chain-powered-by-artificial-intelligence
21. https://www.bestpractice.ai/studies/st__vincents_hospital_achieves_20_in_energy_savings_by_implementing_a_predictive_energy_control_system_for_its_hvac_from_buildingiq
22. https://slideslive.com/38917841/truck-traffic-monitoring-with-satellite-images
23. https://slideslive.com/38917845/planetary-scale-monitoring-of-urban-growth-in-high-flood-risk-areas

ADR Goals

The ADR Partnership is committed to contributing to the following high-level goals.

1 Boosting European industry in AI, data, and robotics increasing the competitiveness and accelerating their digital and green transformation in accordance with the Digital Decade

2 Achieving European strategic autonomy in AI, data, and robotics

3 Achieving global research impact in AI, data, and robotics

4 Maximising the societal and environmental benefits of AI, Data and Robotics to tackle the major societal challenges on climate, food, energy, health, and security

Significantly boosting European industry

Achieve a hotbed of Innovation for Industries Made in Europe. It is of paramount importance to boost the innovation ecosystem for European industries to stay globally competitive. It is even more important to enable European industries serving European security in essential resources, key technologies, and materials. Europe must facilitate creative thinking for existing and new businesses that can strengthen Europe resilience and independence on production and supply for basic elements e.g., food, energy, semiconductor, and pharma.

The responsible AI-powered green digital transformation is accelerating, and European companies are in a good position to leverage and drive the development. This trend should be fostered with a regulated framework on compliance and legislation to strengthen solutions deployment and acceptance. However, American, Chinese and other Asian companies invest heavily in AI, data, and robotics. The World Economic Forum estimates that 70 percent of all new value over the next ten years will be digital. According to McKinsey, Europe needs to take immediate action to invest in enabling/ horizontal technologies since "Technology is now permeating all sectors via transversal technologies such as artificial intelligence,

the bio-revolution, and the cloud." McKinsey continues: "Although Europe has many high-performing companies, in aggregate European companies underperform relative to those in other major regions: they are growing more slowly, creating lower returns, and investing less in R&D than their US counterparts. This largely reflects the fact that Europe missed last technology revolution lagging on value and growth in information and communications technology and on other disruptive innovations."

To close this gap, Europe needs to take immediate measures to increase the volume of investments both from the public side and from the private side, involving both new companies and new business domains as well as established companies. Cooperation and integration across regulatory and technological domains are essential for societal well-being, economic growth, and technological progress. AI-enhanced and data-powered robots can be customized to specific high-impacts application domains (e.g., healthcare / assisted living, manufacturing and logistics, food, forestry, inspection & maintenance of infrastructure, large power and industrial plants and other service robots e.g., home robots, shopping, education, entertainment). This is where role of initiatives like ADR Partnership becomes central.

One approach to drive the development and get an advantage is to develop tools and processes that enable companies to increase their value creation. Often these are based on international standards, consensus-based and very often de facto standards. Thus, it is necessary to actively engage in standardisation work, preferably being able to steer them towards European interests. Well-balanced regulation is becoming more important and can become a competitive advantage for Europe if we invest in research, tools, engineering frameworks and sandboxes to facilitate compliance and to accelerate the emergence of new types of innovation in the complex regulatory landscapes. A key goal for the ADR partnership is to contribute to pre-standardization activities bringing research experts to work with regulators, industry, and standardization bodies to accelerate the definition of European Standards and to position European Standards worldwide.

Achieving European strategic autonomy

To maintain strategic autonomy, Europe needs to make sure that it has all the relevant competences and capabilities that we need. This involves both learning existing methods, often adapting, and improving them to our needs, and developing new unique methods. Both the application of methods and the methods themselves can be unique. To achieve this, we will have to have systematic approaches to transferring setup research projects, with the goal of both developing the technology further but also learning how the existing technology works. Having European companies involved in research projects with the leading researchers outside of Europe could also be a way of bringing that know-how to European companies. Furthermore, tightening the education, research and field applications will both strengthen competencies with specific domain knowledge. In other words, the gap between education, research and professional deployment should be minimised through establishment of joint infrastructures that allow practical training for business cases for students and scientists to extend their theoretical knowledge with real scenarios.

Achieving global research impact

To get global impact it is often necessary to work on the current hot topics and publish in the most prestigious venues. It is even better to be the first with the next. This is highly desirable and something to strive for, but it cannot be planned as science is characterised by that it is essentially impossible to predict. If we knew how long it would take, then it would be development. This is a major challenge when we prepare for a work program starting in two years, where we must predict what the next thing will be in 3 years from now. It is still possible to see trends and predict in what general directions research will take. However, this is harder in research fields that move very fast, such as AI, data, and robotics. Results that were produced in 2021 are now considered old, since within a single year there is often significant progress on the most active research topics. There is also the aspect that if we knew what it would be today, then we should do it now, not in three years. A viable alternative is to set a goal of having a significant impact on the major conferences and journals in the area. For example, publish at least 100 papers each in high-impact conference proceedings and journals venues such as AAAI, ICML, IJCAI, CVPR, ICCV, ICRA, IROS, NeurIPS, PAMI, Nature, Science, etc. every year. This could, for example, be achieved by having a yearly call for Next-Generation High-Impact Methods in AI, Data, and Robotics.

Enabling significant progress on major societal challenges

Major societal challenges described in the first section (e.g., climate, energy and food security) shows that the ADR technology being developed in the ADR Partnership are enablers and opportunities to address these challenges. It is therefore an important goal for Adra to ensure that Europe develops ADR technology strengthening its position on business leadership, but also for societal welfare and sustainability. For example, AI-enhanced and data-power robotics can serve for strengthening societal objectives such as green economy (recycling, remanufacturing, agri-food, inspection), ageing well (healthcare and assisted living), welfare at work (HRI, HRC, agri-food, dirty, dull, and dangerous tasks), ethics in robotics (safety) and strengthening industrial policy for European industries.

Major Trends and Gaps

The focus of Adra is on the cross-sections between AI, data and robotics with the long-term goal of achieving a convergence of the areas. However, as ADR is not yet an area of its own, the trends and gaps analysis is based on the three existing communities, which all have significant overlaps and interactions.

There is currently a huge interest in generative AI, especially large language models. The last year has seen tremendous progress in both text and image generating models such as ChatGPT and Stable Diffusion. The next step is to generate sound and video of comparable quality. The next major step is to increase the control of the generation, increase the quality of the generated content including reducing bias and inappropriate content, and adding additional modalities so that the same model can generate multi-modal content. One potential issue is that the size of the models grows faster than the availability of data to train them on. This leads to the interesting gap of extracting more valuable content from the same amount of data, or ideally even less data. A major challenge is to verify the content that has been generated. A very interesting research direction is to take generated text and verify its correctness by showing the logic behind the arguments and corroborating facts with references. Another, related research direction is to generate scientifically correct answers to questions, potentially replacing encyclopaedias with generators. The most limiting factor for European involvement in large-language models is the capacity to develop and deploy really large-scale models.

Another major trend is learning from human feedback. Seen as a few-shot learning problem, this provides opportunities for individuals to personalise models or to steer them towards styles and topics that are relevant for them. This can also be a way to reduce the need for every increasing amount of data.

In general, what we see is impressive progress in dealing with relatively simple data, text, images, and sound. The next major challenge is to deal with more complex data such as social networks, molecular structures, transportation networks and other graph-based structures. There is also very active work in geometric learning, which deals with both these types of complex structures but also deals with incorporating physical knowledge into neural networks in a principled manner.

A fourth trend is neuro-symbolic hybrid AI methods which are trying to find systematic and well-grounded approaches to combine symbolic and neural representations. It often also entails a principled approach to combine reason and learning. Considering the need for guarantees related to the upcoming AI regulation, these hybrid approaches are seen as one major avenue to be able to live up to the regulation. This is an area where Europe is making significant contributions.

A fifth trend is AutoML, an area which to a large degree is being driven by European researchers, where the process of configuring the machine learning pipelines, selecting the appropriate model architectures, and performing systematic hyper parameter optimisation

is automated. This line of research has great potential of lowering the thresholds for organisations to take advantage of the latest AI advances without having deep technical knowledge and significant hands-on experience. This could be the key enabling technology especially for SMEs that don't have the resources or the time to have dedicated AI engineers. The main gap here is to scale up the approaches to deal with larger and more complex pipelines and models.

There are also several strategic gaps in relation to important areas of robotic development. Robots are highly application specific machines but built on a set of methodologies and building blocks that are common. Focus is needed to set European standards around modularity and around the development of design, certification and validation tools that accelerate the development of supply chains and, where modularity is not appropriate, around processes that speed up time to market. This work needs to be conducted on a European scale and actively involve regulators and test facilities to bring results that align with the market sector by sector. We need to invest on community building, regulatory issues, and support to tackle standardisation / legalisation and thus involve European networks of DIH / networks of excellence. The problems that need to be solved are sector specific and detailed and generic approaches will not suffice.

Robotics needs to focus impact on specific sectors, for example Construction, Cities, Healthcare, Agri-food, and Energy supply etc. because of the application specific nature of robotics. While partnerships exist in these areas their natural focus is on the major priorities related to the area, not on new technology. For example, while Healthcare might recognise that robotics has a role to play it will not be prioritised over vaccine development or public health or drug discovery. It is therefore important that the ADR Partnership joins forces with sector specific communities and partnerships addressing those applications and verticals in the work programme.
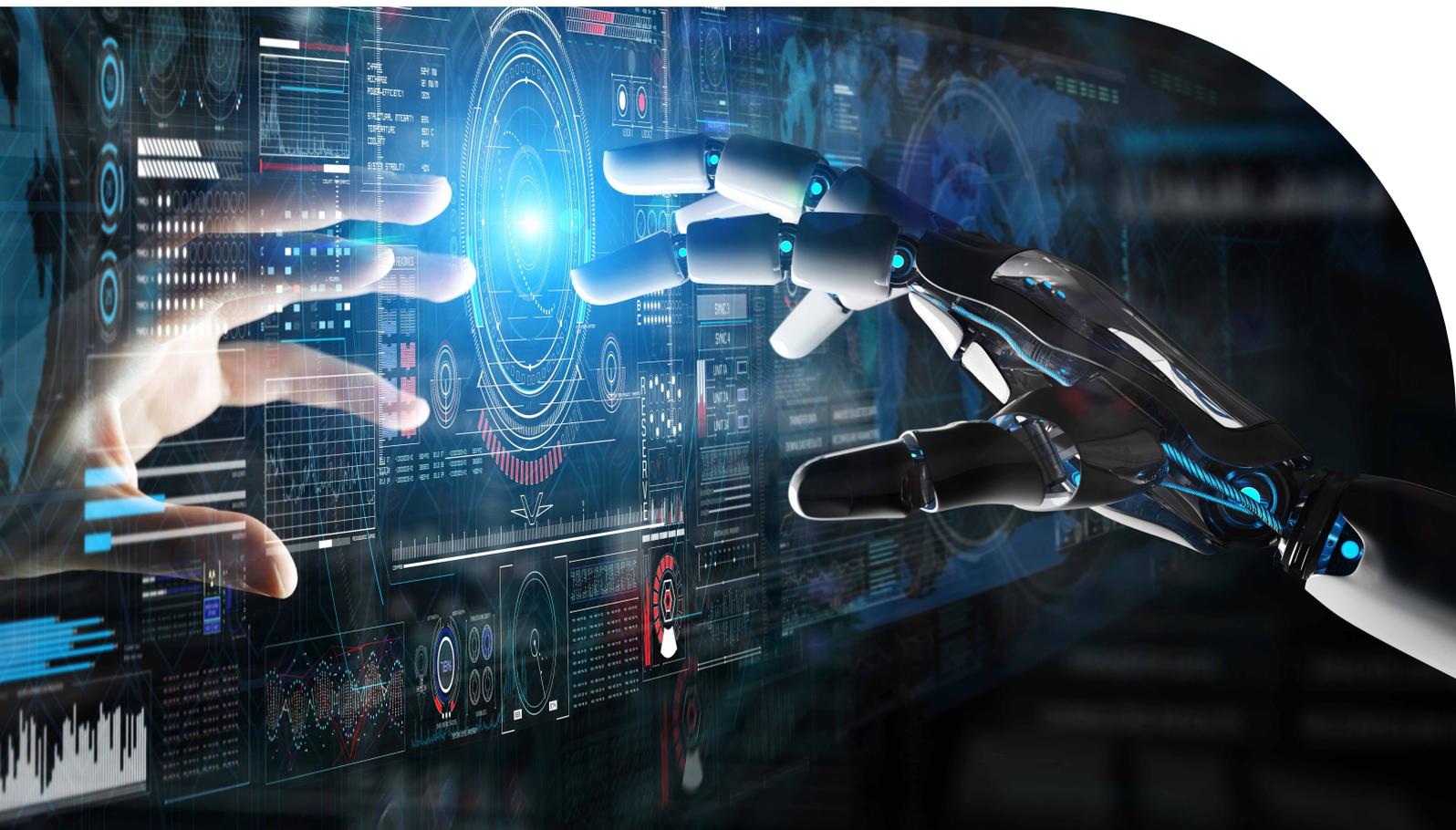
There are also considerable technical and procedural challenges to reach basic robot abilities and technologies independent of application domains. There is a need to integrate AI-data and robotics and other technologies (e.g., HPC, IoT / robot middleware and operating systems) that can enable self-awareness / understanding the environment / planning. We need novel architectures and components (mechatronics and control) for achieving soft robotics, small-scale robots, flying robots, water robots that are completely autonomous. Human robot interaction and collaboration: physical and non-physical as well as robot-robot interaction and collaboration, swarm robotics should follow safety and process regulation. Other challenges include biomimetic perception and control, extended reality in robotics, dexterous grasping and manipulation and navigation, localisation, and mapping.

The linkage between materials and robotics, exemplified by the trend towards "Soft Robotics" and micro and small-scale robotics exemplified by "origami robots". There is significant materials research across Europe and there is a strong need to connect this to the development of future robotic systems which move away from the "box on wheels" configuration that is currently prevalent.

European wide networks need to be focused on key European strengths or around the development of ecosystems where there is underlying strength that needs coordination. To date these networks have been broad based with little attempt to align. Options exist to align networks to missions, or to specific functional expertise, or to specific emerging sectors. Tighter focus around networks of excellence will help to develop key strengths.

When it comes to data, innovators, SME's, and start-ups, in particular, need good access to world-class, large-scale, federated, and secure infrastructure, including access to data and resources such as HPC and test environments, etc. Strong investments in HPC are taking place thanks to the EuroHPC JU but additional efforts are needed towards computing-big data management-ML convergence and in providing access to federated data experimentation and infrastructures. The lack of accessible and excellent infrastructure will slow market development and limit success.

Another key challenge is the uncertainty on the effect that the new data and AI regulations (Data Governance Act, Data Act, AI Act) will have in the market. Companies, in particular SMEs, will require tools and support to address compliance, data access and exchange, data quality, right to explain and trustworthiness. New roles and business opportunities (e.g., data intermediaries) are emerging in the context of the new regulations, and new markets and novel applications can also emerge in this context. Strong investments in research, research-industry collaboration, methods, tools for compliance, support, and access to experimentation through European-wide federated secure experimentation environments offering support and sandboxing opportunities for companies are certainly needed to transform a potential perceived thread into a strong opportunity for European Industry worldwide. A multidisciplinary approach is also a must to address this challenge.

Another important existing challenge is the complexity and cost in creating deployable systems based on data knowledge and the availability of pre-competitive big data sets to train AI models. This can be a game changer for EU. Industry Large-scale pilots and applications using those datasets (synergies ADR) are needed to demonstrate impact.

Privacy, trust, security, and ethics (beyond compliance) are also key topics to address in the engineering and deployment of new ADR systems.

Another gap is that many European organisations lack the skills to manage or deploy smart technical solutions that can be built on these technologies. An increase in talent education is needed. However, a global competition for talent in these areas is underway. Regions with the most vibrant technology landscape are better positioned to attract skilled professionals and retain local talent. Talents are only attracted and retained in the case where conditions are compelling.

Finally, there is a lack of business opportunity understanding. Developing business impact using these smart technologies requires a full understanding of the market, the technology and its impact on business processes and models. Because this requires the integration of knowledge from multiple stakeholders, it can result in low levels of uptake driven by uncertainty and a lack of knowledge. In addition, the novelty of these technologies means that emerging business potential may not be obvious from the outset, which in turn slows the return on investment.
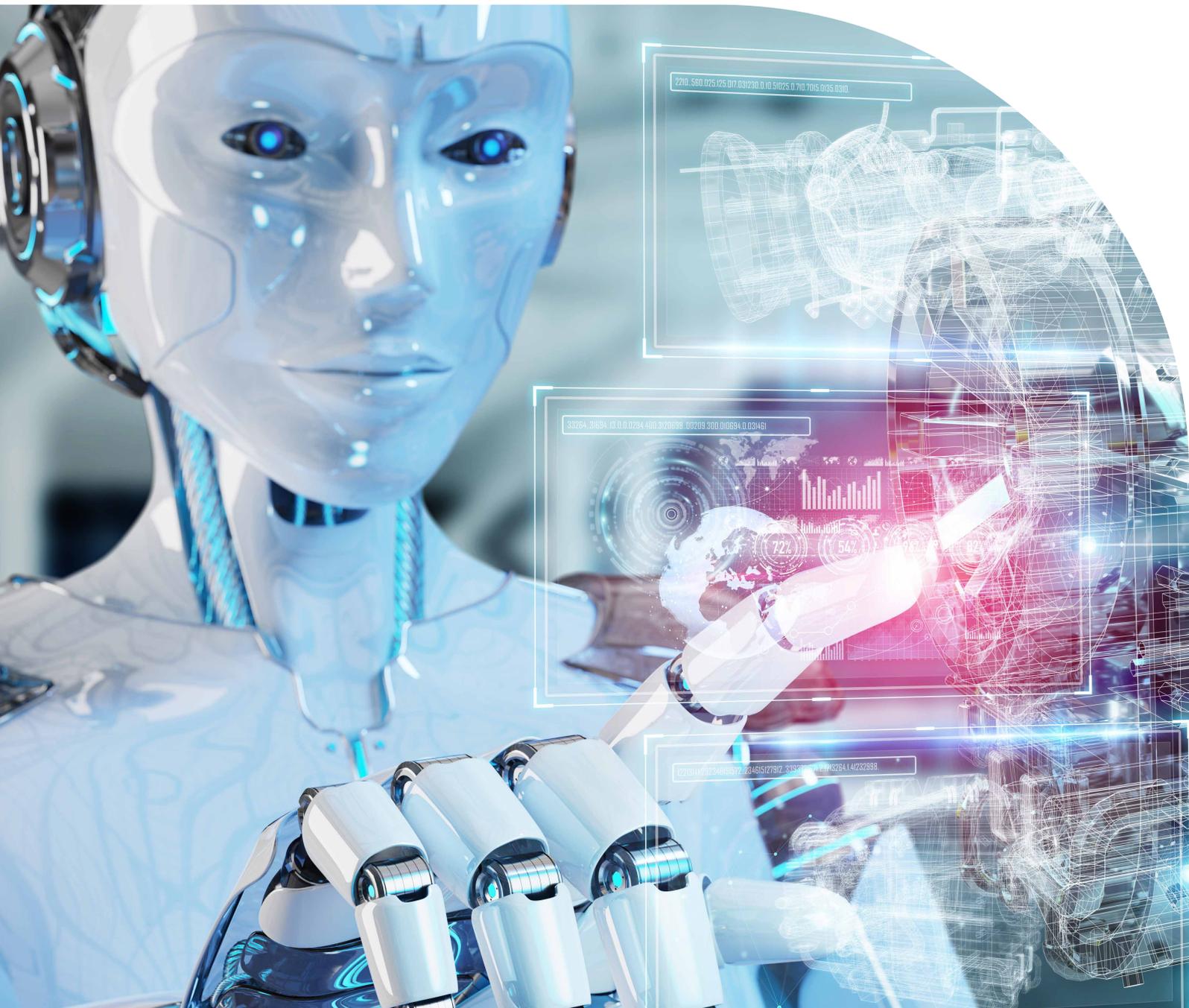
Societal, political, or scientific developments after adoption of the Strategic Plan 2021–2024

The geopolitical focus on energy resonates with robotics applied to all areas of the energy generation and supply infrastructure. Areas such as nuclear fusion cannot operate without robotics, renewable energy generation will increasingly rely on robotics for long term maintenance. Also, the energy crisis is calling for a smarter use of our energy and investment in AI and data to establish intelligent management and control over our energy resources for efficient utilisation. While these have been enduring areas of excellence for European robotics the current partnership has failed to focus its work on sectors. Instead, its focus has been narrowly concentrated on the technological overlap between AI, data and robotics without proper attention being paid to sectoral translation of research and the scale-up of SMEs.

The decreased security of Europe caused by the War in Ukraine has highlighted the use of robotics as a means of war. While this is an area fraught with ethical issues there is nevertheless an opportunity to align military and civil use of robotics. While this has been prohibited in the past with the "dual use" control it is perhaps time to acknowledge that the parallel development of civil and military robotics needs to be examined. Especially if this increases the security of Europe with sovereign technology. Furthermore, there is a global insecurity, and we need investment in robust supply chains and technical sovereignty. The war in Ukraine is calling for security and defence investments, including the use of drones in wars. Inappropriate energy policies in combination with the weaponisation of energy and the corresponding need to drastically change European energy policies, including more versatile energy sources which are less reliable and require more coordination and management. The coming of age of prompt-based general/versatile large generative models, first text-to-text, then text-to-image and today text-to-video. In the long run we can expect text-to-anything. The importance of scale has been shown several times. Thus, there is a need to construct larger models and apply them to larger problems in larger contexts. Everyone is bringing up the importance of education and competence. A major gap is how to significantly scale-up education in and about AI. There is also a huge need to scale-out education from its technical core to all other professions and subjects.

Also, the new US national security strategy, published on 07th October 2022[17], that shows the new measures on export control on advanced computing and semiconductor manufacturing to China, is raising big threats on the development and ownership of Europe on technologies for AI and Data. There is a need for urgent action to develop new processes and provide investment opportunities to European organisations to intensively rebuild the semiconductor business in AI, Data and Robotics that can face these geopolitical developments.

24. https://www.whitehouse.gov/wp-content/uploads/2022/10/Biden-Harris-Administrations-National-Security-Strategy-10.2022.pdf

The Next Strategic Plan 2025-27

Inspired by the Taiwan model in semiconductors business[25], the collaboration between education, research and businesses should be tightened in a systematic way to exploit the synergy between fundamental knowledge and applications and strengthen competencies with specific domain knowledge. In other words, the gap between education, research and professional deployment should be minimised through the establishment of joint infrastructures that allow practical training for students and scientists on field trials and business cases and to extend their theoretical knowledge with experiences on real scenarios. This collaboration can be both beneficial for skill development for a continuous highly competitive workforce that can be fed to European industries and organisations.

Europe hosts several centres of excellence in ADR that are comparable to anything the rest of the world can offer, but these centres are not always receiving the visibility they deserve. In the global battle for attracting the future generations of talent, each of these centres can try to cope on their own and compete, but a much better strategy is to collaborate within Europe and pool the resources together under a unifying umbrella, like is done for example with the concept of the multi-centric network of AI lighthouses. A network of this type of lighthouses can offer an impressive portfolio of research challenges, great innovations, exciting partners, and career opportunities, so in many respects this type of networks can compete with the offerings of the tech giants or other institutions outside Europe. Continuing to enforce the creation of this type of networks and brands is essential for Europe's future.

However, one area where competition is difficult is when there is a need for a coherent, often centralised, effort to develop a single large-scale system or application, as the case of the large language models that are starting to emerge. Loose federations will most likely never be able to deliver the same result as the diversity and extra costs of coordination will make it too expensive and slow.

The new strategic plan should address the following high-level concerns:

- Trustworthy ADR technology made in Europe in compliance with the regulation including the AI Act, the Data Act, and the Data Governance Act. Meeting regulation with innovation. Emphasis on SMEs and leveraging DIHs to support tech transfer, innovation, creation of new products and services based on ADR technology. Support achieving the goals in the Digital decade, especially reaching 75% of companies using Cloud, AI, or Big Data. (Big Ticket E.)

- European strategic autonomy in ADR technology and the use of ADR technology to support strategic autonomy in other areas, e.g., to optimize production cost and relocate production to EC. Including the development of a strong semiconductor industry in Europe that can boost AI, data and robotics. (Big Tickets A.-C.)

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25. Taiwan is the world's leader in semiconductor manufacturing with more than 60% of world market share. It is astonishing for a small country with just over 23 million people to dominate one of the most complex businesses in the world. Especially, if we consider that Taiwan does not own any on the ingredients needed for the manufacturing (i.e., raw materials, design technologies and tools, chipmaking machines). The strength of Taiwan lies in its large pool of high-skilled workers and supportive government policies. For instance, the new semiconductor factories being built in USA and Japan are dependent on few thousands of workers from Taiwan to operate them based on a deal with the Taiwanese government. More under: https://medium.datadriveninvestor.com/how-taiwan-came-to-dominate-the-semiconductor-industry-cc7ac08c557a

- Increasing the resilience of our society to crisis, both natural and man-made. Improved preparedness as well as rapid, fast, and efficient response in catastrophic situations. Security and cybersecurity. Support for fragile people at home or in institutions. (Big Ticket A.-E.)

- Green deal, sustainable society, zero carbon emission. Operation, maintenance, and inspection of the circular economy and resource management. Urban mining, AI, perception and robotics solutions for recycling and sorting waste. (Big Ticket A.-E.)

  Education on AI, Data and Robotics, with a focus on scaling-up educational capacity and scaling-out education to other professions and subjects as ADR are general purpose technologies. (Big Ticket A.-E.)

The new strategic plan should address the following technological concerns:

- Large-scale general purpose/versatile generative ADR technology. For example, open Large scale GDPR compliant European language models handling both language and cultural differences in Europe. Both speech-to-text, text-to-text, and text-to-speech.

- Large-scale complex ADR testbeds together with end-users for example in healthcare, food production, transportation, energy, or smart cities.

- Multi-stakeholder development, verification, validation, and integration of automated decision making in socio-technical systems both for public and private sector.

- Collaborative autonomous systems interacting with both the environment and people. This includes autonomous drones in controlled airspace, last mile delivery, and self-driving vehicles.

- Metrics for measuring progress in ADR, with a special emphasis on Trustworthy ADR technology.

New considerations and instruments for synergies to missions

The focus on combining AI, Data and Robotics has impact at a high level when considering end user needs and provides impact when considering SDGs and Missions relevant to Europe. While such grand challenges provide a shared objective facilitating convergence, the danger of such an approach is that it fails to develop the individual areas where significant technological developments are needed to bring novel products to market. There needs to be a balance between focusing on the intersections and focusing on the individual disciplines. All three disciplines will benefit from a renewed focus on their individual strengths in the second half of Horizon Europe. This would provide a valuable balance from the first half that focused only on the intersections. Such an approach also needs to recognise that the investment profiles, research methodologies and translation paths for each of AI, data and robotics are significantly different. Therefore, we should balance between the support to the individual themes and the interfaces between the themes for maximizing impacts in science and business growth.

To complement this balancing there is an opportunity to focus AI, data and robotics around the European Missions and to develop focused excellence around each Mission. It is important that any focus on Missions is targeted rather than generic. For instance, it is very important to collaborate with the European Chips Act that is striving to lift-up Europe's competitiveness and resilience in semiconductor technologies and applications. This is of vital importance for AI, data and robotics as the semiconductors (e.g., chips) are fundamental to sensing, computing, actuation and their developments will boost the European technological security and their application in critical sectors (energy, food, transport…etc.)

The new acts and directives in AI, data, Medical Device Regulations, cyber-resilience and Machinery present new opportunities for companies placing products on the market, but at the same time they can have an inhibitory influence on innovation when companies fail to adapt to the new regulatory environment. We need large and complex testbeds which forces the integration of many different techniques and solutions into complex systems-of-systems. The development of the components has reached a sufficient level of maturity to enable real world deployment, but there is still a large gap between this technical capability and the ability of end users to easily integrate them in complex systems-of-systems thereby solving real-world problems that exist in healthcare, food production, energy, transport, or smart cities. Large scale test beds that can integrate AI, Data and Robotics with existing systems in highly realistic environments are a first stage necessity that can create greater understanding of the impact, functionality, and effect of combining these technologies and applying them to the real world. It is important not to underestimate the complexity of the integration task and the need for direct investment in it. In parallel it is important to create sandpits for real world testing where regulatory norms are adjusted to allow

autonomy to flourish within controlled and well-defined bounds. These regulatory sandpits are the bedrock of testing in the real world and essential for the accelerated deployment of complex socio-technical systems. Since barriers are often created by national and even local regulation care must be taken when placing these facilities to ensure that the combination of European and local regulation is viable. This is particularly critical as Europe is setting a high compliance bar with the AI Act for working environments, and for AI driven systems making high risk decisions.

We also need instruments that allow start-ups and smaller companies to benefit from ADR and to be an active part in developing the next generation smart technologies. Instruments designed to suit their needs should be developed. Example instruments can include "researchers for loan" where companies can rent using a simple process, researchers with key knowledge for a short-term period based on a pool of EU experts can be more lucrative for small companies to strengthen their innovation and growth.

In summary the Big Tickets in ADR for 2025-2027 are:

A. **Ground-breaking** technological **foundations** in ADR
(Autonomy, high-performance and predictability)

B. Next generation **smart embodied robotic systems**
(soft robotics, autonomy, manipulation, configurability, human robot interaction)

C. **Effective and Trustworthy General-Purpose AI** actions
(personalised, creative processes, hybrid sources)

D. **Interoperable** and **integrated** framework for data ecosystems
(large natural language models, automation, precompetitive datasets, security)

E. **R&I and tools for compliance**
(Trust, privacy, security beyond compliance).

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