Artificial Intelligence Technology Strategy

(Report of Strategic Council for AI Technology)

Strategic Council for AI Technology

March 31, 2017

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1. Conditions Surrounding Artificial Intelligence Technology, Data, and Computing

- As a result of promotion of machine learning, starting with deep learning, advancement of accumulation of enormous amounts of data on the Internet, acceleration of communication speed due to broadband, and the popularization of compact, high-performance computers such as smartphones, research and development of artificial intelligence (AI) technology has progressed. Domains in which AI can be used and applied have also expanded, and a social change known as the "Fourth Industrial Revolution" is beginning.
- The AI technology that is currently progressing is specialized AI technology for carrying out specialized tasks, and is used only to supplement human capabilities. Based on the progression of AI technology, various inferences have become possible from past data, image recognition, language recognition, etc. By using and applying AI technology as a service based on data, the capabilities of human beings are drawn out to the fullest extent, human society has become abundant, including sustainability of society and approaches to social issues such as environmental problems, and economic and industrial benefits are yielded.
- The dramatic progress of the use and application of AI technology over the last few years was led by IT companies in the United States that have Internet platforms such as search engines, from the perspectives of data quality and volume.
- Currently, IoT-related technology such as sensing has expanded to industries and real society, such as in people's lives. Data collection in the real world is progressing, domains in which AI technology such as image recognition is being used and applied are expanding, and international competition is becoming fiercer. In addition, U.S. companies are accelerating social implementation of natural language processing, such as through diagnostic support based on analysis of medical papers and others, expansion towards a variety of services for dialogue systems based on voice recognition, etc.
- In Japan, high-quality data has been utilized to improve productivity at *monozukuri* manufacturing sites since the past. Sectors such as arts and culture that Japan has cultivated over long periods of time contain contents that can be boasted to the world. It is necessary to integrate such strengths of Japan with AI technology, and to link this to strengthening industrial competitive strength. Although it has been said that "Japan loses in business, even if it wins in technology," it is important to link technology to business, by strategically taking the initiative in international standards and holding intellectual property, and using cooperative domains and competitive domains for different purposes.
- As Japan moves forward with various forms of industrialization based on utilizing and applying AI technology, the following kinds of issues are evident.
    1) When looking at the number of papers related to AI technology, the number of Japanese papers falls below the number of papers in the U.S. and China, and it is clear that there is insufficient investment in research and development by both the public and private sectors, and that it is necessary for both the public and private sectors to develop a research and development environment. When doing so, ensuring opportunities for social implementation and development in terms of institutional aspects, while making considerations to the roles of the public and private sectors, such as by having the government be the central player in carrying out basic research, are issues.

2) As mentioned above, data is indispensable to use and application of AI technology, and data itself may become competitive power. In Japan, various data exists currently, but there are also cases where there is data that has not been digitized, and other cases where considerations are necessary towards personal information protection and usage restrictions. In the future, it is necessary for industry, academia, and government to make collective efforts towards developing an environment where information input/output devices such as sensors and so on can be installed, in various sectors such as medical care, transportation, distribution, and infrastructure. When doing so, there are many issues that need to be resolved, such as reliability, security, system flexibility, personal information protection, balance between oligopoly and utilization and application of data, and coordination among data.

3) Although social needs for AI technology have heightened, there is a shortage of AI technology researchers as well as engineers and data scientists (AI personnel) who handle AI technology. In addition, development of vocational abilities of laborers in association with reform of the industrial structure may be required. Based on such a background, it is necessary to move forward with measures for fostering researchers and AI personnel immediately.

4) In using and applying AI technology, open innovation-type projects in which various players who cross over sectors participate are the focus. In particular, there are expectations for start-ups that have mobile power and human resources such as researchers and freelancers to play roles in industrialization through development, use, and application of AI technology. It is desired for large companies that are already in existence to coordinate with respect to funding start-ups and commercialization, and to form platforms. In order to promote robust development as a business, it is also important to appropriately evaluate AI technology and establish prices that correspond to the provided services.

5) Although high performance of computers has advanced through high integration of semiconductors up until now, it has been said the limitations for refinement are drawing near, and thus, progress has been made in developing semiconductors that are specialized for AI applications, such as learning and inference that pursue processing speed more so than accuracy. In the future, in order to utilize and apply AI technology at sites in real-time, further power consumption reduction and miniaturization of high-performance computers are necessary. The development of completely new architecture such as neuromorphic and quantum architecture, and the construction of devices and systems that use such architecture are important challenges. Also, in order to transmit information from wide-area sensors and the like securely and with ultra-low delay, and to make judgments in real-time using AI technology, combination with innovative networks (5G and so on) is important.

2. Promotional Structures Related to Development of Artificial Intelligence Technology by the Government

(1) Structures of Relevant Ministries

- Based on instructions issued by the Prime Minister in “Public-Private Dialogue towards Investment for the Future” in April 2016, the national government

established the "Strategic Council for AI Technology". The Council, acting as a control tower, has come to manage five National Research and Development Agencies that fall under the jurisdiction of the Ministry of Internal Affairs and Communications, Ministry of Education, Culture, Sports, Science and Technology, and Ministry of Economy, Trade and Industry. In addition to promoting research and development of AI technology, the Council coordinates with industries related to the industries that utilize AI (so-called "exit industries"), and is moving forward with social implementation of AI technology.

- In particular, the Council coordinates with the three research centers ("three centers") below that are attached to the National Research and Development Agencies that are run by the Ministry of Internal Affairs and Communications, Ministry of Education, Culture, Sports, Science and Technology, and Ministry of Economy, Trade and Industry, and plays a central role in promoting research and development of AI technology.
  1) Center for Information and Neural Networks (CiNet) and Universal Communication Research Institute (UCRI) of the National Institute of Information and Communications Technology (NICT)
  2) RIKEN Center for Advanced Intelligence Project (AIP) of the Institute of Physical and Chemical Research (RIKEN)
  3) Artificial Intelligence Research Center (AIRC) of the National Institute of Advanced Industrial Science and Technology (AIST)
     *At NICT, research is conducted mainly on natural language processing, multilingual speech translation, and brain information communication; at AIP, research is conducted mainly on basic research and infrastructure technology such as for new algorithms that enable for high-precision learning from small amounts of data; at AIRC, research is conducted mainly on utilizing these results and linking them to application in industrial sectors that realize optimal movement of robots.
- Projects are also being implemented through the following institutions.
  4) Japan Science and Technology Agency (JST)
  5) New Energy and Industrial Technology Development Organization (NEDO)
- In addition to the three ministries mentioned above, ministries that possess big data and have jurisdiction over exit industries, such as the Cabinet Office (Cross-ministerial Strategic Innovation Promotion Program (SIP)), Ministry of Health, Labour and Welfare, Ministry of Land, Infrastructure, Transport and Tourism, and the Ministry of Agriculture, Forestry and Fisheries are also planning projects that utilize and apply AI technology.

(2) Examination Structure of the Strategic Council for AI Technology

- When the Strategic Council for AI Technology was established in April of last year, the Research Coordination Council and Industry Coordination Council were also established. The Research Coordination Council progressed with giving shape to linkages in research and development carried out by the three ministries. The Industry Coordination Council carried out surveys and investigations on (1) establishing a roadmap for industrialization, (2) fostering of human resources, (3) data maintenance/provision and open tools, and (4) measures such as for fostering start-ups and financial linkages, in aiming towards research and development carried out

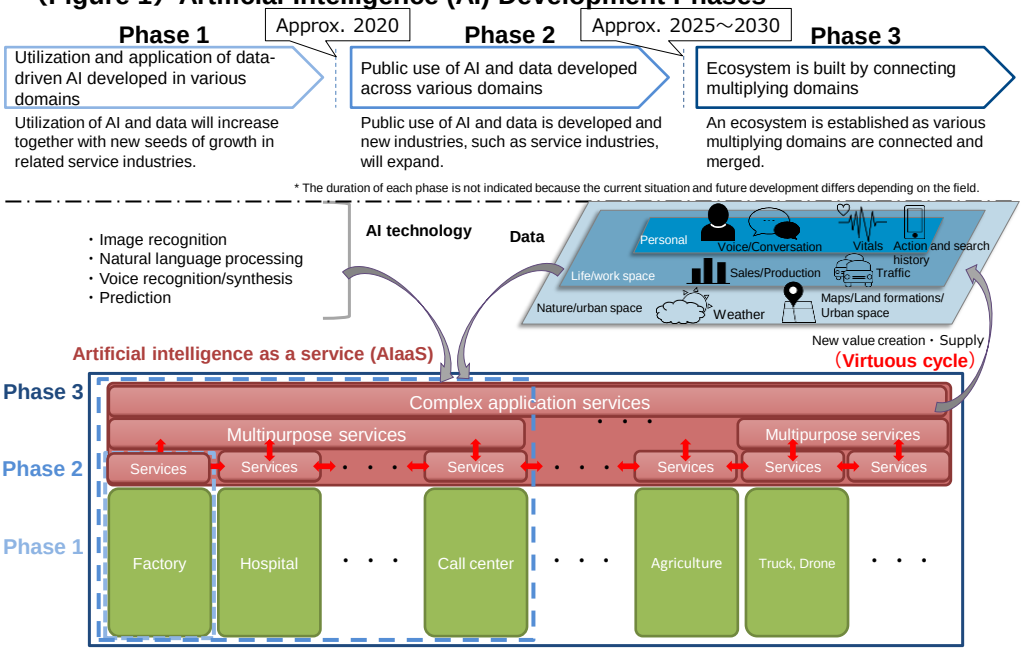
by the three ministries and social implementation of other businesses. The results of these activities will be mentioned hereinafter.
- With regard to ethical aspects of AI technology, intellectual property rights, personal information protection, and promotion of open data, separate opportunities for examinations have been established by the government as cross-sectional items.

3. Industrialization Roadmap Projected by Fusion of AI and other related Technologies (Attachment 1)
- New services and products are born from the utilization and application of AI technology. Fusion of AI technology with other related technologies largely includes the possibility of resolving various social issues. Even when looking at past technologies after the Industrial Revolution, solutions to social issues, such as automobiles, have grown into large industries.
- In order for Japan to lead the world, it is necessary to come up with a challenging roadmap oriented towards industrialization based on AI technology and other related technology, based on the on-site strengths that Japan possesses with regard to social issues that Japan and the world are directly faced with. It is also necessary for the wisdom of industry, academia, and the government to be assembled, and for consistent approaches, from research and development to social implementation, to be accelerated.
- "Industrialization Roadmap Projected by Fusion of AI and other related Technologies (Industrialization Roadmap)" has been formulated from such a perspective.

(1) Priority Areas
- As priority areas that should be taken up for the time being as part of the Industrialization Roadmap, in addition to the three areas of "productivity," "health, medical care, and welfare," and "mobility" that were determined as a result of conducting reviews from the perspectives of (1) necessity of urgent solutions for social issues, (2) contribution to economic ripple effects, and (3) expectations for contributions based on AI technology, a fourth area of "information security" was also specified as a cross-sectional area.

(2) Organization of Phases
- AI technology is simply a service. Its usage and application expand to various domains only through combination with various data (= "AI as a service (AIaaS)").
- The development of industrialization was organized based on dividing it into three phases (Figure 1).
  1) Phase 1: Utilization and application of data-driven AI developed in various domains
  2) Phase 2: Public use of AI and data developed across various domains
  3) Phase 3: Ecosystem built by connecting multiplying domains

（Figure 1）Artificial Intelligence (AI) Development Phases



Note: The concept of AIaaS is borderless and developed across fields.

- The boundary between Phase 1 and Phase 2 is anticipated as being approximately 2020, and the boundary between Phase 2 and Phase 3 is anticipated as being roughly 2025 to 2030. These phases were organized based solely on possibilities in terms of technology, and since it is necessary to resolve issues such as system development, social receptivity, etc. before social implementation, it is possible that more time will be required. Also, in fields such as automatic operation, it is necessary to take into consideration that the possibility of technological development progressing faster than expected is large.
- The possibility that the domain in which AI technology will expand is not only industry, but that other unanticipated axes will appear, such as various social axes including the sphere of life, owned resources/resource saving, and business, is large.
- Individual technology levels and data environments, including semiconductor architecture that makes up AI technology, quality of used data, location of information processing, data accumulation, etc., are related deeply to the development of phases.

(3) Industrialization Roadmap for Various Areas

- With regard to each of the areas of “productivity,” “health, medical care, and welfare,” and “mobility,” the image of society that should be aimed for, and the image of industrialization for each phase oriented toward realizing such a society were organized.
- The image of society and image of industrialization that should be aimed for in each area are as follows.

1) Productivity

Image of society that should be aimed for

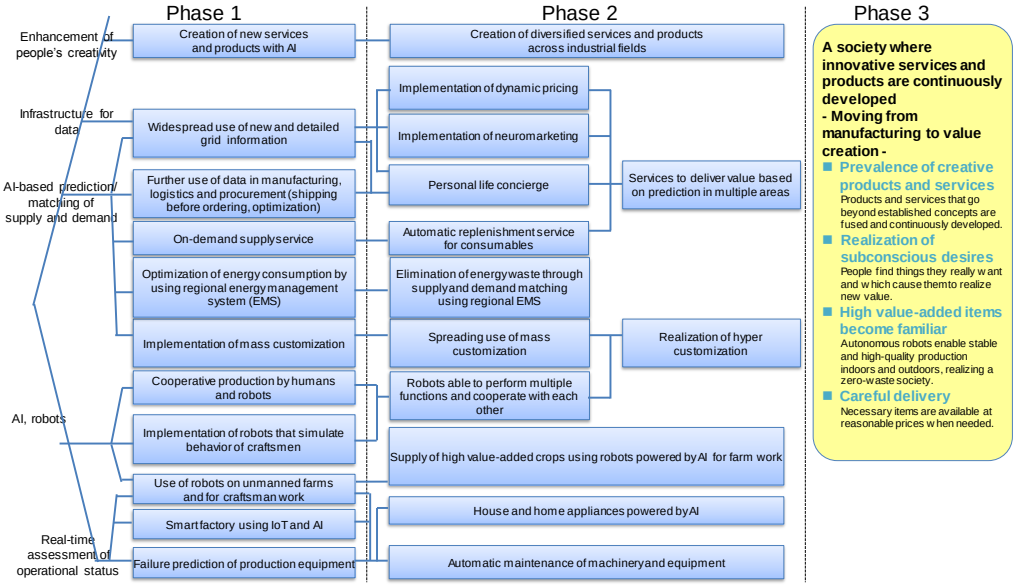
- To realize user-driven hyper customization through the realization of automation and optimization of production systems, efficiency improvement and optimization

of service industries, and matching needs with goods and services, leading to the integration of manufacturing, distribution and services for items such as energy and food, which allows for the establishment of an ultimate ecosystem that is efficient and that will enhance productivity in society as a whole.

- To enhance people's creativity, leading to a society where innovative services and products can be continuously created.

Image of industrialization (Figure 2)

（Figure 2）Industrialization Roadmap Projected by the Fusion of AI and other related Technologies (Productivity)



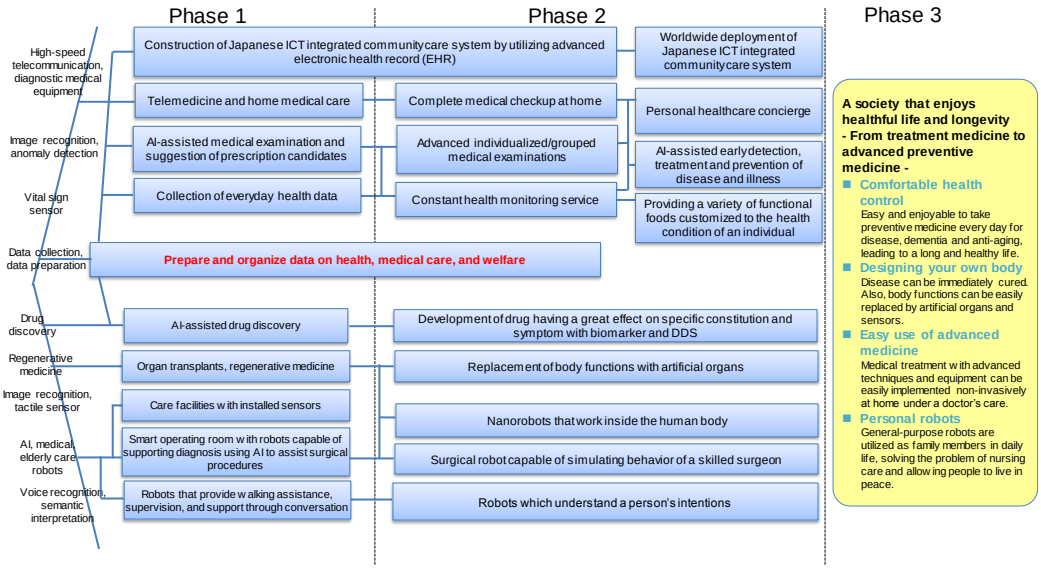
2) Health, Medical Care, and Welfare

Image of society that should be aimed for

- To be the leader in medical care and welfare technologies by utilizing big data together with AI as Japan becomes the world's most rapidly aging society.
- To be the leader in industries for health and longevity by advancing preventive medicine to avoid diseases. In 2030, over 40% of the Japanese population will be elderly, and at the age of 80, people who are willing can work actively. This will not only increase individual life satisfaction but also reduce social security expenses and address the social issue of a shrinking workforce.

Image of industrialization (Figure 3)

（Figure 3）Industrialization Roadmap Projected by the Fusion of AI and other related Technologies (Health, Medical Care, Welfare)



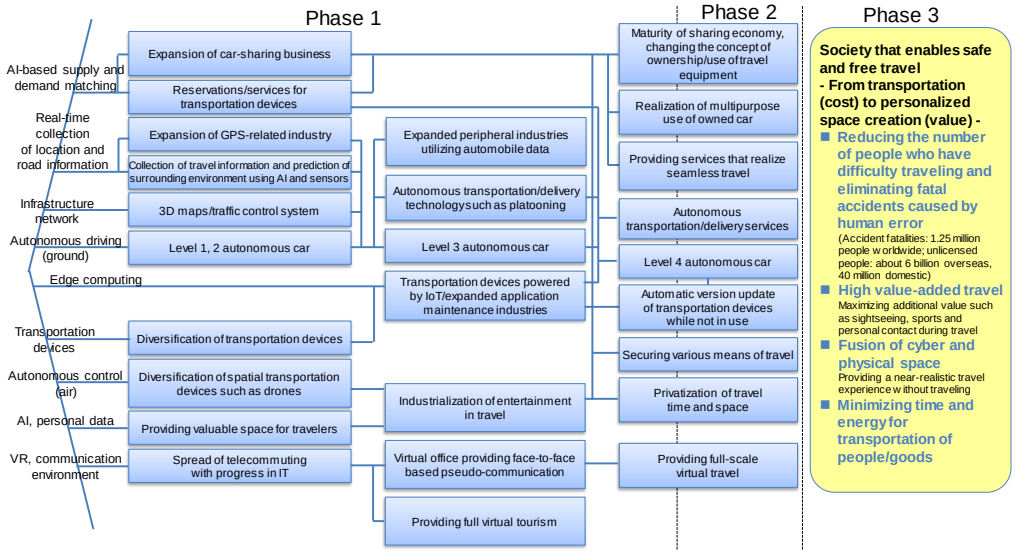
3) Mobility

Image of society that should be aimed for

- To make travel time and space not just for travel, but for work, life, and entertainment.
- To build a society where anyone can travel safely and freely, and to realize environmentally-friendly travel by building a sharing economy with transportation equipment for both people and goods, aiming for zero accidents caused by human error in 2030 and achieving minimal social cost associated with travel.
- To realize a society where new value is generated by creating high value-added travel, autonomous automatic delivery, and virtual travel.

Image of industrialization (Figure 4)

（Figure 4）Industrialization Roadmap Projected by the Fusion of AI and other related Technologies (Mobility)



4) Information Security

- The information security sector is a cross-sectional sector in which technological development and implementation move forward, in line with the development of AI in other sectors. With regard to "information security" technology, not only will reliability and stability be emphasized, but the confidentiality of technology will also be emphasized and technological development will progress.

4. Approaches Related to R&D and Social Implementation of Artificial Intelligence Technology Focusing on the 3 Centers

- In realizing the Industrialization Roadmap, it is necessary to take approaches by gathering the wisdom of industry, academia, and government. However, national institutions starting with the three centers should take on the role of platforms for industry, academia, and government, such as development of infrastructure technology, fostering of skilled human resources, maintenance of public data, and support for start-ups.

(1) R&D

1) Priority Research Policies

- The key to research and development of AI technology is contact with society, more so than for other technologies. In national projects focusing on the three centers, among the themes in the Industrialization Roadmap, research for practical application and research on fundamental /infrastructure/elemental technologies that contribute to advancement are promoted in a mutual and complementary manner for several themes that should be approaches with priority. In particular, approaches will be made actively for challenging themes in Phases 2 and 3 of the Industrialization Roadmap.

2) R&D Objectives Based on Coordination among the 3 Centers (Attachment 2)

- Based on the Industrialization Roadmap, the three centers will coordinate and make approaches toward the research and development themes that should be approached in a manner where the National Research and Development Agencies play a central role in particular.
- The themes that should be approached based on the three centers coordinating with each other are selected from the following perspectives.
  - Those for which approaches should be made consistently, from basic research to social implementation.
  - Those for which short-term monetization cannot be expected, and development does not move forward based on only the private sector.
  - Those in cooperative domains, such as international standardization and shared infrastructure technology.
- Concretely, approaches will be made toward the following kinds of research themes.

  i) "Productivity": Research and development of next-generation production technology that enables for small lot production of many products at proper timings and in proper amounts that reflects the demand of consumers, in an aim to realize hyper customization (RIKEN, AIST)

ii) “Health, medical care, and welfare”: Early discovery of diseases including dementia, selection of optimal cure methods, research and development of systems that enable for handling in an aim to realize healthcare in which diseases are avoided through advancement of preventive medicine (NICT, RIKEN, AIST)

iii) “Mobility”: Research and development of smart mobility that realizes high added values of travel space based on universal communication technology and significance of map data, while coordinating with automatic traveling systems in SIP (NICT, AIST)

3) Promotion of R&D Projects Based on Industry-Academia-Government Collaboration

- Although not all research and development of AI technology will be covered by only the three centers, the three centers will serve as hubs, and research and development projects will be promoted based on open innovation through industry-academia-government collaboration.
- Coordination with projects of relevant ministries that have jurisdiction over exit industries, such as the Ministry of Health, Labour and Welfare, Ministry of Land, Infrastructure, Transport and Tourism, and the Ministry of Agriculture, Forestry and Fisheries, will be promoted, including the Cabinet Office’s SIP.
- Starting last year, the government has made it an objective to increase investments by companies in universities and Research and Development Agencies by three-fold over the next ten years. Even with regard to research and development of AI technology, private investments are being promoted.

Concrete Examples of Approaches

- Research and development of AI technology related to brain information communication and natural language processing (Ministry of Internal Affairs and Communications, NICT)
- “IoT/BD/AI Information Communication Platform” social implementation promotion project (Minister of Internal Affairs and Communications)
- AIP Network Lab (JST)
- Industry-Academia-Government Project at Global Research Bases Related to Artificial Intelligence (AIST, University of Tokyo)
- Research and development for revolutionary software and hardware technologies, and development of trial manufacture/design environment for the latest devices for such research and development (Ministry of Economy, Trade and Industry)

(2) Fostering of Human Resources (Attachment 3)

- In realizing research and development objectives and the Industrialization Roadmap, as it has been pointed out that there is a shortage of AI personnel, the fostering of top-level AI personnel, particularly in Phase 1, as immediately effective players based on strong industry-academia-government collaboration is a pressing necessity.
  * There are expectations for such personnel to possess a variety of knowledge/general-purpose abilities related to AI (problem-solving), and be able to drive knowledge on computer science/programming techniques (realization),

as well as apply concrete social issues (utilization).

- As utilization and application of AI technology in broader industries is anticipated in Phases 2 and 3, it is necessary to foster human resources who can disseminate the value created by AI technology as industries.
- To exhibit the effects of fostering of AI personnel, it is important to ensure opportunities where AI personnel can participate actively, from the perspective of environment development that attracts AI personnel. From this viewpoint, it is necessary for NICT, RIKEN, and AIST to worthily treat young researchers from Japan and abroad who can participate actively in global standards and to make not only their salaries but their work environments and contents attractive, and to promote approaches such as welcoming researchers from joint research partners and conducting exchanges with collaborating graduate schools and external researchers.
- As there are also issues such as development of an educational environment corresponding to social needs and treatment and matching at companies, it is also necessary to move forward with discussions related to such issues as well.

Concrete Examples of Approaches

1) New approaches for fostering immediately effective workers

- Education program for fostering immediately effective workers (aim for members of society engaged in AI to acquire the latest knowledge on sectors required in their work and systematic knowledge on AI, and to improve value creativity through practice of real common data)

2) Collaboration between universities and the industrial world

- Joint research between universities and the industrial world, and unfolding of approaches such as fostering of human resources through OJT (popularization of education programs, examination of enhancement of internships, etc.)

3) Past approaches by the government and research institutions, and further enhancements

- Fostering of young human resources through JST funding
- Program for fostering data-related human resources

(3) Environmental Maintenance of Data and Tools Owned by Industry, Academia, and Government (Attachment 4)

1) Strengthening of data maintenance in priority areas

- Data is essential to technical development of AI technology. It is necessary to carry out environmental development and utilize data that is linked to social needs, such as in the sectors of health, medical care, welfare, transportation, agriculture, forestry and fisheries. To do so, it is also necessary for the three centers to coordinate with relevant ministries.
- In addition to data itself, AI work products that is generated from data has a more important value. Building a mechanism where AI work products can be distributed is an important issue.

Concrete Examples of Approaches

- Implementation of projects with the objective of data maintenance (NEDO and others)
- Maintenance of latest AI data test beds (NICT)
- Maintenance of mechanism for smooth and fair utilization of anonymously

processed information

2) Strengthening of data maintenance/provision based on industry-academia-government collaboration

- Large burdens are associated with maintenance and provision of data by universities and research institutions. It is necessary to identify the necessary data, and to develop and strengthen a support system for effectively maintaining and managing data.
- It is also necessary to develop mock environments, simulators, and demonstration environments based on industry-academia-government collaboration to efficiently maintain and provide data.

Concrete Examples of Approaches

- Strengthening of system of institutions dedicated to data maintenance (NICT, JST, RIKEN, and others)
- Development of mock environments, demonstration environments, and AI clouds at global research bases related to AI (AIST)

3) Promotion of utilization and application of data owned by the private sector

- Due to enactment of the Basic Act for Promotion of Public and Private Data Utilization, it is necessary for the national government, local public bodies, and private business operators to cooperate and make approaches toward expanding data distribution.
- With regard to utilization of privately-owned data, it is difficult to make judgments on competitive domains and cooperative domains for the data itself, and there are many issues that should be resolved, such as handling of personal information. Examples of success, such as of the Data Distribution Acceleration Working Group in the IoT Acceleration Consortium, will be shared to promote necessary data utilization.
- It is also important to move forward with developing rules related to data profile standardization, such as data formats, and information utilization.

Concrete Examples of Approaches

- Data Distribution Acceleration WG (IoT Acceleration Consortium)
- Building of a model for utilization of medical care and health data (PHR and others) (AMED)
- IoT demonstration projects oriented towards standardization of data profiles and so on

(4) Start-up Support (Attachment 5)

1) Strengthening of start-up support through open innovation

- In promptly and flexibly moving forward with development of AI technology, it is desired for existing large companies to coordinate in terms of funding start-ups and commercialization, and for open innovation-type platforms to be formed.
- In addition to developing opportunities for matching large corporations with start-ups, it is important to specify the skilled human resources at large corporations and to form a network.
- In addition, it is also important to identify issues of large corporations, and foster coordinators who can link them to start-ups that have the technology to resolve

such issues.

Concrete Examples of Approaches

- Japan Open Innovation Council
- NEDO Pitch (NEDO)
- Dispatch of coordinators (AIST, Organization for Small & Medium Enterprises and Regional Innovation)

2) Fostering/securing of human resources who are responsible for start-ups

- There is still a shortage of people who bear responsibility for start-ups centering on the AI sector, such as there being people who have techniques but not management know-how. In addition to fostering human resources for start-ups, it is necessary to support challenges toward commercialization using new technology and support funding at the pre-seed stage, when funding from large corporations is difficult.

Concrete Examples of Approaches

- Outreach community (AIST)
- AI Challenge Contest
- Technology-based Startup Support Program (NEDO)
- ICT Innovation Creation Challenge Program (I-Challenge!) (Ministry of Internal Affairs and Communications)

(5) Promotion of Understanding Related to Development of AI Technology

- Although there are voices of concern regarding negative impacts on existing industries and employment caused by advancement and popularization of AI technology, it is important to overcome these negative impacts, utilize the capabilities of human beings to the fullest extent by using AI technology as services, make human society abundant, and ferment understanding that AI technology brings benefits to the economy and industries.
- Although there are still some aspects that remain unexplained, in principle, such as deep learning, it is important that development itself should not be restricted because of this, and for sufficient demonstrations to be carried out upon progressing with development.
- The performance and safety of AI technology partially depends on the used data and environment, and not only algorithms and devices. It is necessary for not only manufacturers, but service providers and users to understand AI technology as well.

5. Follow-up of Artificial Intelligence Technology Strategies

- The Strategic Council for AI Technology will conduct regular follow-ups on the approaches described in these strategies.
- It is necessary for relevant ministries to make continuous approaches from a medium- and long-term perspective, without stopping during temporary booms, taking into consideration the Industrialization Roadmap. Utilization and application of AI technology have been progressing rapidly, and relevant ministries and research institutions should move forward with approaches that take the latest trends into consideration.
- For matters that require institutional examinations in implementing these strategies, information will be provided to investigatory organs, such as the Council on

Investments for the Future, and timely examinations will be promoted.

- Dialogues with relevant economic organizations and academic societies will be held with regard to these strategies, and approaches by private corporations and universities will be promoted.

Strategic Council for AI Technology
Roster

Chairman

Yuichiro Anzai	President of Japan Society for the Promotion of Science

Adviser

Kazuo Kyuma	Standing Member of the Council for Science, Technology and Innovation, Cabinet Office

Constituent members

Takeshi Uchiyamada	Chair of Committee on New Industry and Technology, Keidanren
Tadashi Onodera	Chair of Committee on New Industry and Technology, Keidanren
Taihei Kurose	Vice President of National Institute of Information and Communications Technology
Makoto Gonokami	President of University of Tokyo
Ryoji Chubachi	President of National Institute of Advanced Industrial Science and Technology
Shojiro Nishio	President of Osaka University
Michinari Hamaguchi	President of Japan Science and Technology Agency
Kazuo Furukawa	Chairman of New Energy and Industrial Technology Development Organization
Hiroshi Matsumoto	President of RIKEN

（1-1）Artificial Intelligence (AI) Development Phases

Phase 1 — Utilization and application of data-driven AI developed in various domains

Utilization of AI and data will increase together with new seeds of growth in related service industries.

Approx. 2020

Phase 2 — Public use of AI and data developed across various domains

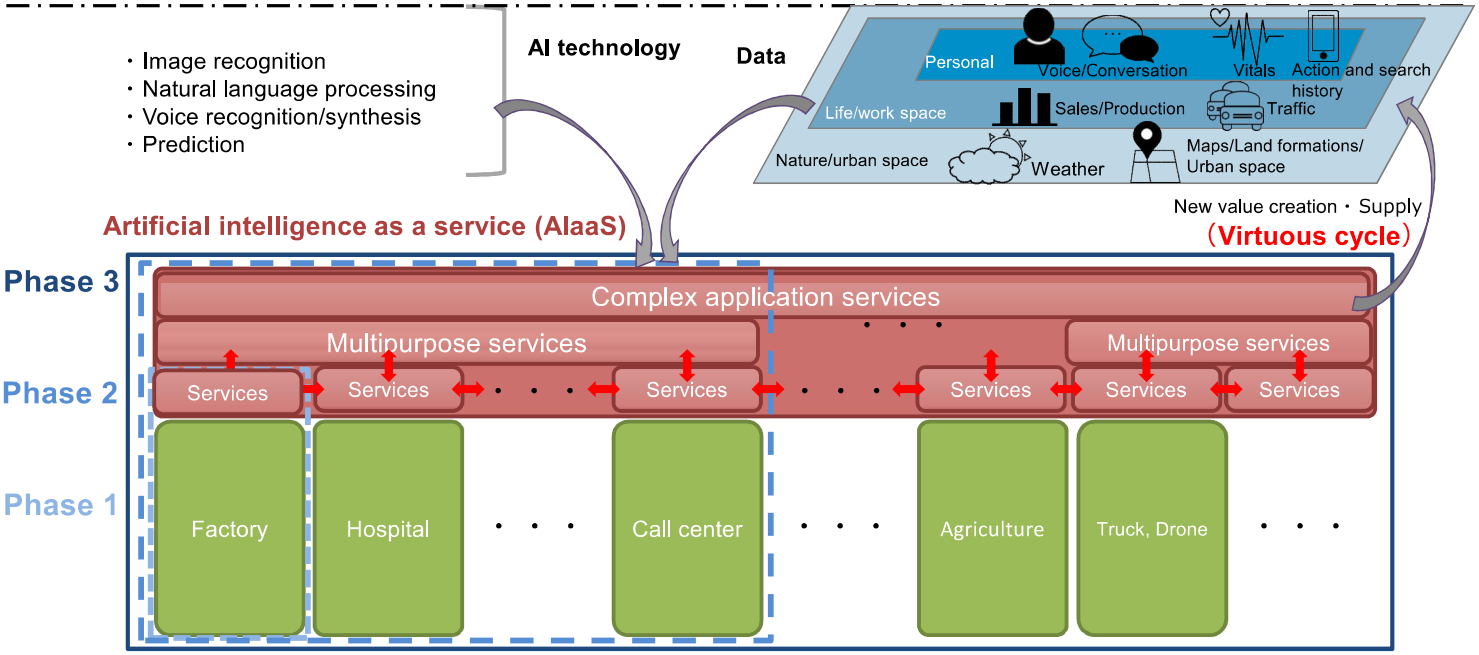
Public use of AI and data is developed and new industries, such as service industries, will expand.

Approx. 2025～2030

Phase 3 — Ecosystem is built by connecting multiplying domains

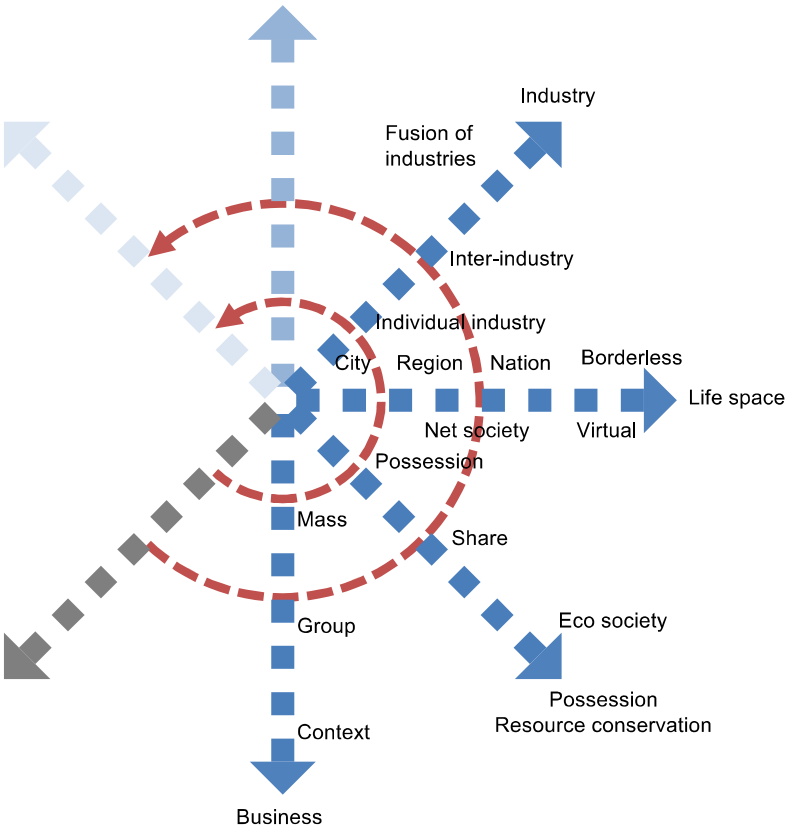
An ecosystem is established as various multiplying domains are connected and merged.

* The duration of each phase is not indicated because the current situation and future development differs depending on the field.

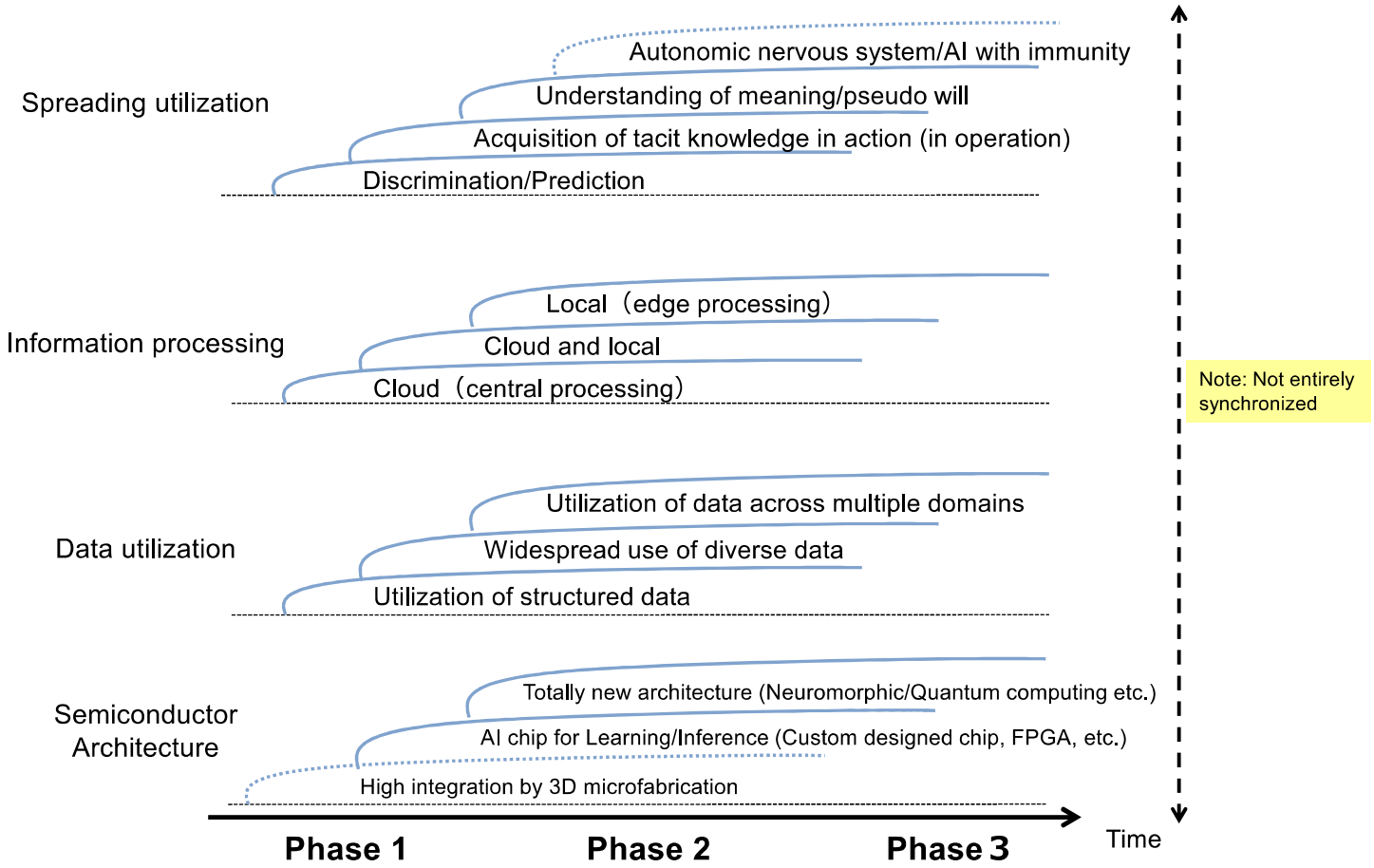


Note: The concept of AIaaS is borderless and developed across fields.

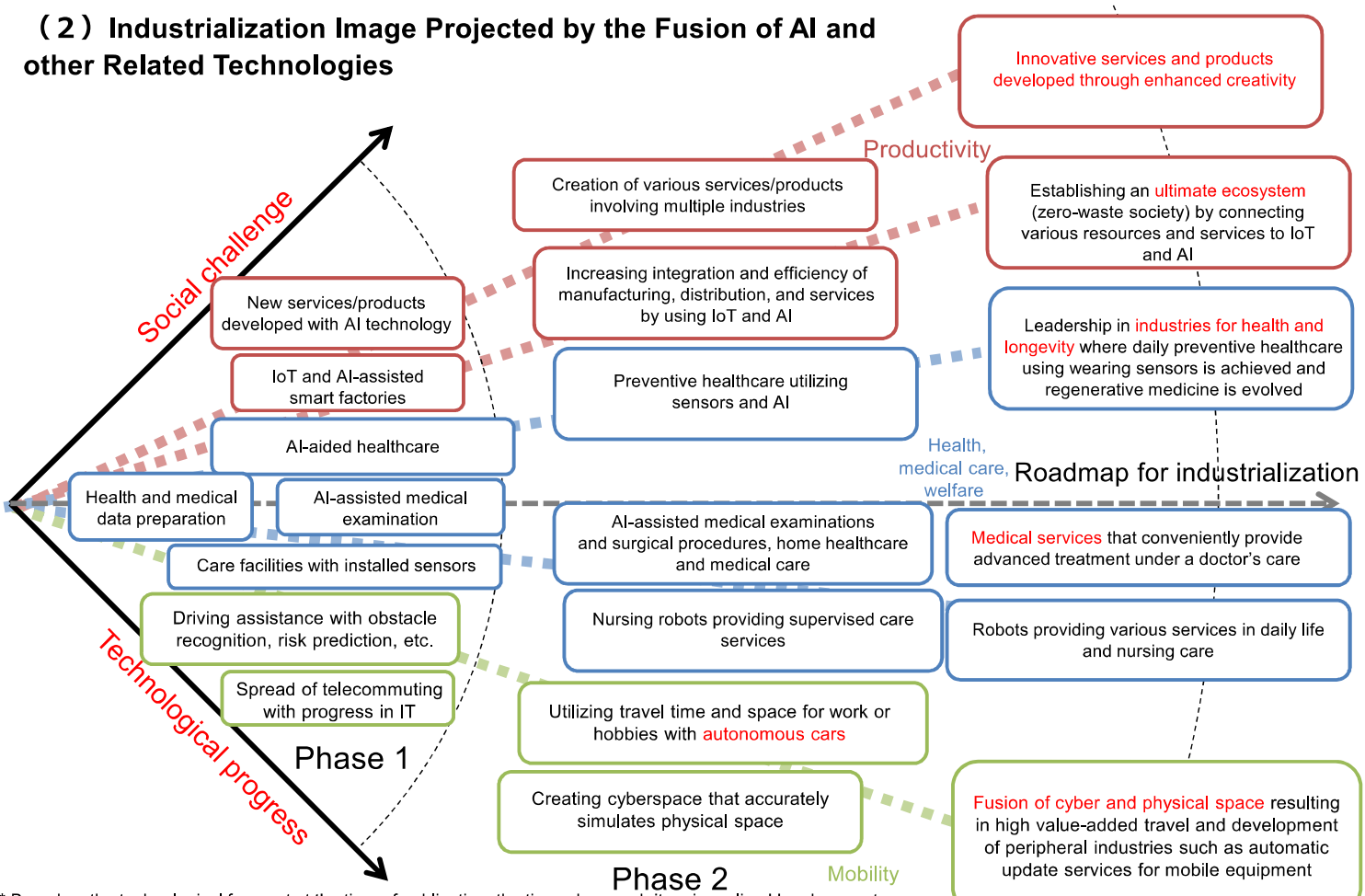
（1-2）Development of Industries with Axes Connecting Different Domains



（1-3）Evolution of System, Data, and Hardware as the basis of Artificial Intelligence utilization



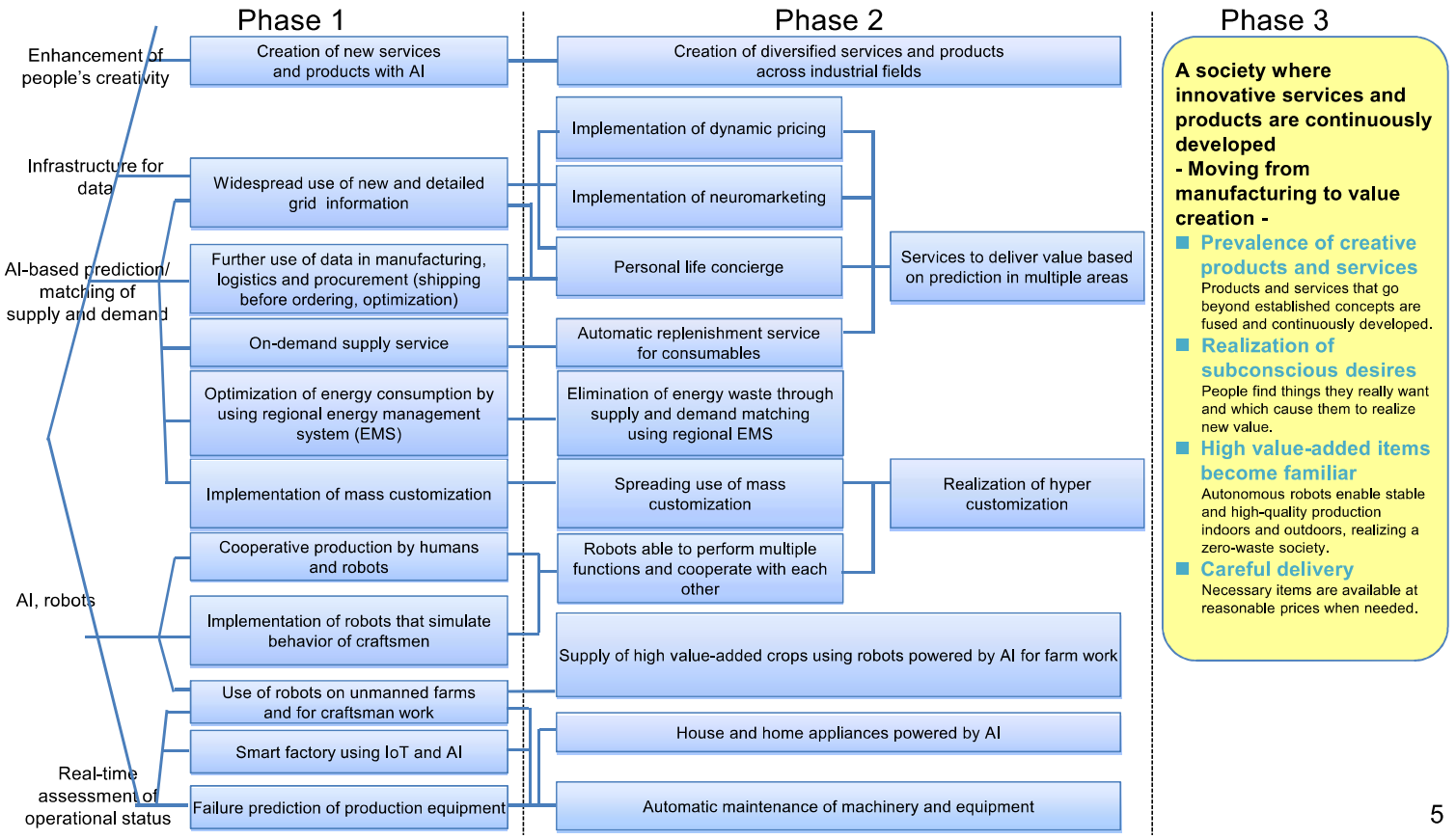
（2）Industrialization Image Projected by the Fusion of AI and other Related Technologies



* Based on the technological forecast at the time of publication, the time when each item is realized has been set from a technical point of view. There are uncertainties about when each item can be realized as social implementation depends on regulations, systems, and social receptivity.

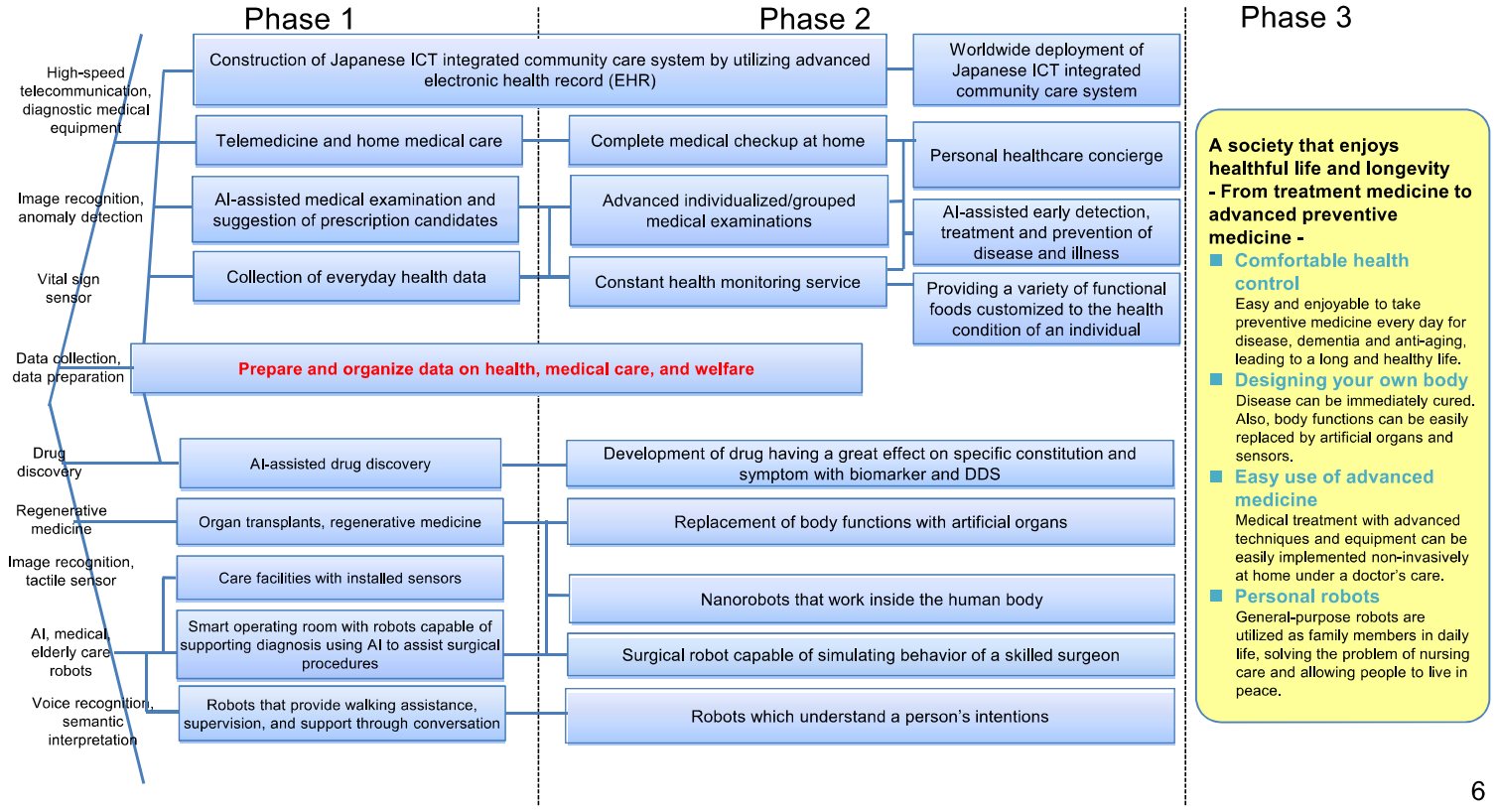
(3-1) Industrialization Roadmap Projected by the Fusion of AI and other related Technologies (Productivity)

- To realize hyper customization through the realization of automation and optimization of production systems, efficiency improvement and optimization of service industries, and matching needs with goods and services, leading to the integration of manufacturing, distribution and services for items such as energy and food, which allows for the establishment of an ultimate ecosystem that will enhance productivity in society as a whole.
- To enhance people's creativity, leading to a society where innovative services and products can be continuously created.



(3-2) Industrialization Roadmap Projected by the Fusion of AI and other related Technologies (Health, Medical Care, Welfare)

- To be the leader in medical care and welfare technologies by utilizing big data together with AI as Japan becomes the world's most rapidly aging society.
- To be the leader in industries for health and longevity by advancing preventive medicine to avoid diseases.
  In 2030, over 40% of the population will be elderly, and at the age of 80, people who are willing can work actively. This will not only increase individual life satisfaction but also reduce social security expenses and address the social issue of a shrinking workforce.



(3-3) Industrialization Roadmap Projected by the Fusion of AI and other related Technologies (Mobility)

- To make travel time and space not just for travel, but for work, life, and entertainment.
- To build a society where anyone can travel safely and freely, and to realize environmentally-friendly travel by building a sharing economy with transportation equipment for both people and goods, leading to a reduction in accidents caused by human error and achieving minimal social cost associated with travel.
- To realize a society where new value is generated by creating high value-added travel, autonomous automatic delivery, and virtual travel.

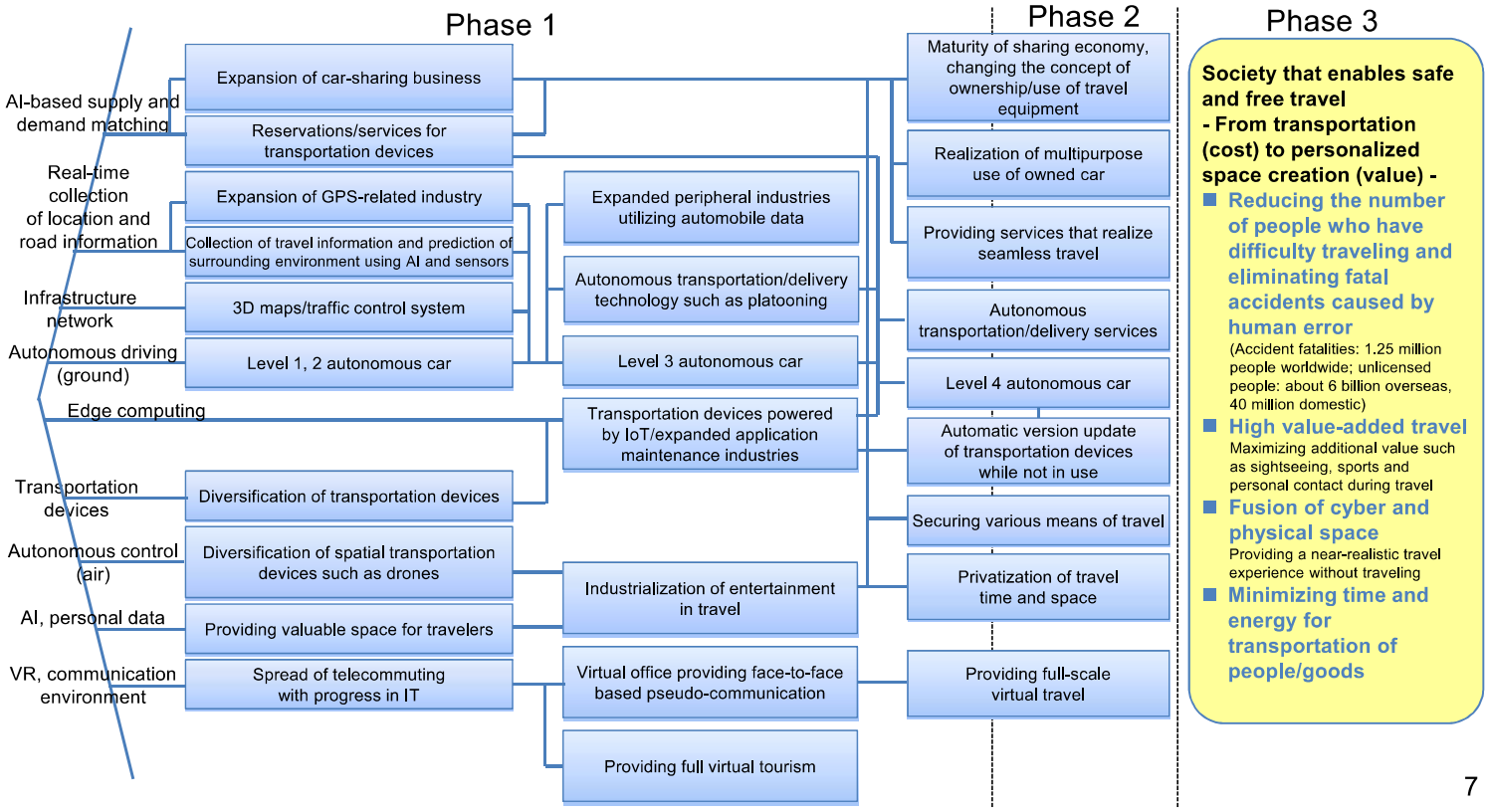


Image of Research Objectives Based on Collaboration Among the 3 Centers [Attachment 2]

* Research issues, used data, and so on will be continuously examined in the future
* Establishment of project leader for each issue will be examined in the future

Legend: NICT / RIKEN / AIST / Other / Three centers

FY2016 FY2017 FY2018 FY2019 FY2020 and onwards

Implementation of research and development based on open innovation
(towards coordination among three centers/ three institutions & industry-academia-government collaboration)

Image of Planning of Joint Projects by the 3 Centers

Image of linkage of data platforms of three centers

Data infrastructure development
- Skilled engineer data / Life phenomenon data / Geospatial data
- Language processing data / Brain activity data / AI security infrastructure data / Remote sensing data and so on
- Health/medical data (FY2017 data platform business)

Common platform development
- Advanced module development
- AI middleware development
- General-purpose infrastructure technology development (Theoretical study/algorithm development)

• Implementation of smart mobility that realizes safe and efficient transportation means/valuable mobility

Three-dimensional environment construction, development of automatic traveling technology based on inexpensive sensors
Development of high-accuracy markers for personal mobility → Construction of positioning system

Development of universal communication technology that contributes to smart mobility
Research and development of dialogue technology in which valuable information and knowledge can be communicated in order to realize adding of value to travel space

Linkage with SIP "automatic travel system" (to a semantic map)

→ Feasibility evaluation (Three centers/three institutions & industry-academia-government collaboration)

Collaboration with automobile manufacturers and the like

- Data used:
  Map data, dynamic maps (SIP)
  Web data, SNS data, and so on
- Demonstration environment used:
  Road environment

Mobility

• Realization of next-generation production technology that enables for small lot production of many products at proper timings and in proper amounts, that reflects consumer demand

Research related to high functionality of human-friendly factories
Collection/analysis/modeling of big data on manufacturing processes → Abnormality detection/failure prediction/maintenance efficiency
Construction of CPS at human-friendly factories → Development of a variable product and variable quantity production system based on integration among factories

Construction of infrastructure technology for a manufacturing revolution based on manufacture informatics
Streamlining based on cutting back on the shortening process for the lead time for searching for the optimal process and manufacturing time, through developing data acquisition technology and combining acquired data with high-accuracy simulations

→ Feasibility evaluation (Three centers/three institutions & industry-academia-government collaboration)

Collaboration with relevant companies

- Data used:
  Various product data, anthropometry data, and so on
- Demonstration environment used:
  Factory simulation environment (AIST)
  Structure simulation environment

• Realization of increased productivity of service industries (transportation, tourism, retail, and so on) and high-quality services

Construction of customer behavior prediction/intervention system based on collection/analysis/modeling of big data on customer behavior

Development of universal communication technology that contributes to improved productivity and quality
Research and development of multilingual speech translation systems

Construction of a platform that links environmental information that changes with each passing moment to people's intentions and preferences in real time, which contributes to provide tourism information for inbound based on new IoT to Human technology
Construction of a framework (competition-type cloud sourcing data analysis platform) for cooperative data analysis by an unspecified large number of people to seek optimal solutions in a tolerance manner for unstable/inaccurate elements

→ Feasibility evaluation (Three centers/three institutions & industry-academia-government collaboration)

Collaboration with relevant companies, facilities, and local governments

- Data used:
  Service site data, dialogue data, speech data, and so on
- Demonstration environment used:
  Convenience store simulation environment (AIST)

Productivity

Infrastructure Technology Sectors That Support the Above

- AI security technology (secret technology/secret search technology/privacy protection technology, strengthening of cyber security, and so on)
- Large-scale AI development environment (middleware for applying advanced machine learning techniques such as deep learning to big data in a prompt manner with low delays, parallel computation, cluster construction technology, and so on)
- Research and development of schemes and the like for acquiring necessary data (annotation technology, applicability of AI to meta technology for data (semantic technology), noise cancelation technology for cleansing, and so on)
- Research and development of next-generation AI architecture (neuromorphic architecture, neuromorphic devices, and so on)
- General-purpose questions and answers/dialogues, research and development of general-purpose technology related to multilingual speech recognition/automatic translation/speech synthesis
- Research and development of brain information communication technology
- Acceleration of science and technology research (analysis of literature on science and technology, construction of a knowledge base, optimization of experimental designs, hypothesis generation/verification)
- Development of general-purpose infrastructure technology (incomplete information learning, optimization, causal inference, deep learning, search, mathematical science, and so on)
- Research of artificial intelligence related to humanities and social sciences (social impacts, legislation, social systems, ethics, privacy, and so on)

Further Advancement of Collaboration Among the 3 Centers

- Data sharing (Example: To avoid Copyright Act related problems, such as not being able to share Web data and the like, in other words, researchers who don't have the right to use Web data have to virtually share the data through concurrent posts, cross-appointments, and so on with the institution that own the data)
- Sharing of computer resources, middleware, and so on (Example: Joint use of AI bridge cloud infrastructure (ABCI: AIST)), sharing of tacit knowledge and know-how for data creation

Image of Research Objectives Based on Collaboration Among the 3 Centers

* Research issues, used data, and so on will be continuously examined in the future
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Legend: NICT / RIKEN / AIST / Other / Three centers

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Data infrastructure development
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- Health/medical data (FY2017 data platform business)

Common platform development
- Advanced module development
- AI middleware development
- General-purpose infrastructure technology development (Theoretical study/algorithm development)

• Early discovery of diseases including dementia/selection of optimal cure and treatment for them, and realization of related systems

Construction of a diagnostic support system based on medical images such as cell images and medical movies such as of ultrasound examinations and endoscopic examinations
Research related to support for selecting diagnostic/cure methods based on integrative analysis of electronic medical records and clinical information
Construction of a welfare service support system based on collection/analysis/modeling of big data on welfare
AI analysis of skilled technology for drug discovery in development of new pharmaceuticals by individuals/ stratification → Integration into a drug discovery robot system

Research and development of neuro feedback technology that supports discovery and curing of brain biomarkers by analyzing data on brain activity based on MRIs
Design and construction of a brain information database

Construction of a medical image analysis support system targeting image data such as MRIs and hemograms
Development of a complex AI diagnostic system for predicting the effects of pharmaceuticals beforehand on cancer
Construction of a disease risk prediction model based on extracting feature representation from large-scale cohorts
Development of conversation support technology founded on the co-imagination method, and utilization of AI in support technology
Evaluation of differentiation potency of iPS cells and tumorigenic transformation of transplanted cells

→ Feasibility evaluation of integrated system for support of medical care (Three centers/three institutions & industry-academia-government collaboration)

Collaboration with medical institutions and the like

- Data used:
  Health/medical data owned by research institutions (images, genome, medical records, medical prescriptions, medical examinations, and so on), Welfare data (verbal hearings, and so on), Pharmaceutical data, bio experiment data, and so on
- Demonstration environment used:
  Medical institutions, welfare facilities
  Bio experiment factories (AIST)
  Welfare simulation environment (AIST), and so on

Health, medical care/welfare

• Realization of a social system that curbs damages caused by immense natural disasters to a minimum and enables for prompt restoration

Research on damage suppression and prompt recovery in relation to natural disasters
Collection of damage data based on numerical simulations and model experiments using shaking tables, and development of damage prediction technology using these simulations and experiments → Development of damage suppression system/prompt recovery system and research on legislation and social systems related to recovery

Disaster natural language processing system that efficiently analyzes/collects broad disaster information, including grassroots information, and supports rescue activities → Feasibility evaluation

Research related to estimating damage conditions based on machine learning using satellite images and aerial images

Collaboration with SIP's "strengthening of resilient disaster prevention/disaster reduction functions" (National Research Institute for Earth Science and Disaster Resilience (NIED))

→ Feasibility evaluation of integrated system (Three centers/three institutions & industry-academia-government collaboration)

Collaboration with relevant companies and the like

- Data used:
  Natural disaster data, data related to damages
  Satellite data (AIST), and so on
  Web data, SNS data
- Demonstration environment used:
  E-Defense (NIED)

Safety/security

Infrastructure Technology Sectors That Support the Above

- AI security technology (secret technology/secret search technology/privacy protection technology, strengthening of cyber security, and so on)
- Large-scale AI development environment (middleware for applying advanced machine learning techniques such as deep learning to big data in a prompt manner with low delays, parallel computation, cluster construction technology, and so on)
- Research and development of schemes and the like for acquiring necessary data (annotation technology, applicability of AI to meta technology for data (semantic technology), noise cancelation technology for cleansing, and so on)
- Research and development of next-generation AI architecture (neuromorphic architecture, neuromorphic devices, and so on)
- General-purpose questions and answers/dialogues, research and development of general-purpose technology related to multilingual speech recognition/automatic translation/speech synthesis
- Research and development of brain information communication technology
- Acceleration of science and technology research (analysis of literature on science and technology, construction of a knowledge base, optimization of experimental designs, hypothesis generation/verification)
- Development of general-purpose infrastructure technology (incomplete information learning, optimization, causal inference, deep learning, search, mathematical science, and so on)
- Research of artificial intelligence related to humanities and social sciences (social impacts, legislation, social systems, ethics, privacy, and so on)

Further Advancement of Collaboration Among the 3 Centers

- Data sharing (Example: To avoid Copyright Act related problems, such as not being able to share Web data and the like, in other words, researchers who don't have the right to use Web data have to virtually share the data through concurrent posts, cross-appointments, and so on with the institution that own the data)
- Sharing of computer resources, middleware, and so on (Example: Joint use of AI bridge cloud infrastructure (ABCI: AIST)), sharing of tacit knowledge and know-how for data creation

Necessity of Fostering Human Resources Who Play a Role in R&D and Industrialization of AI [Attachment 3]

- As a shortage of AI personnel has been pointed out in realizing the research objectives and Industrialization Roadmap, **it has become a pressing need to foster top-level AI personnel as immediate assets, based on strong industry-academia-government collaboration**, particularly in Phase 1.
- As utilization of AI technology is anticipated in a broad variety of industries in Phases 2 and 3, it is also necessary to foster human resources who can disseminate the value created by AI technology as industries.

Future estimates for "leading IT human resources" (People)

	2016	2018	2020
Scale of potential human resources (a+b)	112,090	143,450	177,200
Number of human resources lacking as of the current point in time (b)	15,190	31,500	47,810
Current number of human resources (a)	96,900	111,950	129,390

* Source: Created by the secretariat based on Ministry of Economy, Trade and Industry "Results of Study of Recent Trends and Future Estimates Concerning IT Human Resources" (March 2016, commissioned to Mizuho Research & Information Institute) p.218, Figure 4-183

* "Leading IT human resources" refers to human resources engaged in big data, IoT, and AI (ibid., pp. 84 and 218)

Survey on needs for human resources in AI technology sector in the industrial world

With regard to AI human resources at various companies, the trend is that there are many companies that do not have any at all, companies that are unable to comprehend this, and companies that have not even examined this.

* Study commissioned to NEDO that was implemented at human resources fostering TF

Example of provisional calculation of the annual training scale at universities (People)

	Hokkaido University	Tohoku University	University of Tokyo	Tokyo Institute of Technology	Nagoya University	Kyoto University	Osaka University	Kyushu University	University of Tsukuba	Waseda University	Keio University	Total
Master's program (estimated) *2	54.5	50.9	118.0	116.0	51.0	81.7	90.6	56.4	98.4	83.0	63.3	863.8
Doctoral program (estimated) *3	9.0	13.6	19.3	23.0	6.0	20.5	19.1	12.6	16.9	9.0	6.4	155.4

*1 Strategic Council for AI Technology Council study at human resources fostering TF. For Tsukuba and Waseda, the numbers represent the number of new students in FY2015, and for all other universities, the number represent the number of people completing the programs in FY2015.

*2 The number of human resources engaged in AI technology were calculated for the graduate schools/specializations related to AI technology at each university based on "Number of new students or graduates for the corresponding graduate schools/specializations" × "percentage of research laboratories conducting research related to AI within the corresponding graduate schools/specializations" (If the actual number of students affiliated with a research laboratory engaged in AI technology is known, calculations are made based on this actual number).

* 3 The number of human resources in doctoral program s was also calculated using the same method as for those in master's programs.

In order to concretely realize research objectives and the Industrialization Roadmap, it is necessary to foster human resources who, as persons bearing responsibility, possess the three skills/knowledge below.

1) Solving the problems of AI technology
   (Various knowledge related to AI, ability to discover valuable problems, formularize them, and indicate a path towards solving such problems)
2) Realization of AI technology
   (Knowledge of computer science, programming techniques)
3) Utilization of AI technology
   (Capacity to apply AI technology to concrete social issues)

In addition, to exhibit the effects of fostering AI human resources, it is important to secure opportunities for AI human resources to participate actively, from the perspective of developing an environment to attract AI human resources.

Concrete Approaches to Foster Human Resources Responsible for R&D and Industrialization of AI

- As concrete measures oriented toward realizing research objectives and the Industrialization Roadmap, **it is necessary to progress with the following approaches to foster immediate assets in a concentrated manner, targeting Phase 1 in particular.**

(1) Conception and implementation of an educational program to foster immediate assets (new)

- Target members of society who are engaged in AI, and aim for them to acquire systematic knowledge on AI and cutting-edge knowledge on areas necessary for their work, and to improve their value creation strength through real common data learning

(2) Promotion of joint research and fostering of human resources by universities and the industrial world

- Creation of a mechanism for expanding individual approaches for joint research with universities and the industrial world, and for fostering human resources through OJT, from "point" to "aspect"
  (Measures for industry-academia collaboration related to dissemination of the abovementioned education programs, examination of enhancements to internships, and so on)

(3) Past approaches up to now by the government and research institutions, and further enhancements

- Industry-Academia-Government Collaboration Guideline (realize a "three-fold increase" in investments by companies towards universities and National Research and Development Agencies by 2025)
- Treatment of young researchers, welcoming of joint researchers and personnel exchange at NICT, RIKEN, and AIST,
- Fostering of human resources through NEDO special courses, TCP, research and development projects of NEDO activities.
- AIST's AI Technology Consortium
- Fostering of young human resources through JST funding
- AI challenge competitions
- Program for fostering data-related human resources
- Strengthening of education on mathematics/data science at universities and so on
- Formation of bases for fostering information technology human resources who support growth sectors (enPiT), and the like

With regard to fostering such human resources, there are issues such as development of an educational environment that corresponds to social needs, treatment at corporations, and matching, and it is necessary to advance with discussions related to these issues as well.

(Fourth Industrial Revolution Strategic Council for AI Technology Council, Industry-Academia-Government Collaborative Roundtable on Human Resources Development in Science and Technology, and so on)

(Reference) Knowledge and Skills of Human Resources Who Are Sought After

1) Solving the problems of AI technology

- Pioneering knowledge of AI technology
  - Intelligence informatics (machine learning, natural language processing) — Think
  - Perception informatics (computer vision, speech information processing) — Watch/listen
  - Intelligent robotics — Move
- Basic knowledge/relevant knowledge on AI technology
  - Inferences, searches, knowledge representation, ontology, agents, and so on
  - Cognitive science, neuroscience, sensitivity/psychology
- Generic capabilities
  - Ability to discover (forge) valuable problems
  - Ability to formularize problems that they discover, and indicate a route for problem-solving

2) Realization of AI technology

- Knowledge of computer science
  - Algorithm and data structure, databases
  - Architecture, networks, IoT, and so on
- Programming techniques

3) Utilization of AI technology

- Domain knowledge, knowledge on target sectors
  - *Monozukuri* manufacturing, mobility, health/medical care/welfare, infrastructure, agriculture, science, disaster prevention/crime prevention, smart communication/energy, learning, cross-sectional issues (information security, Web, services, and so on)

Policies Regarding Environmental Development of Data and Tools Owned by Industry, Academia, and Government [Attachment 4]

Policy proposal	Needs, problem consciousness	Image of concrete actions that are anticipated (examples)
1. Strengthening of data preparation in priority focus areas	・For priority areas (productivity and so on) in the Industrialization Roadmap, preparation should be implemented by acquiring new data.	(1) Strengthening of data preparation in research linked to ministries (2) Data preparation for AI performance evaluation, such as of standard images (3) Development of data sets for learning for research and fostering of human resources
2. Strengthening of institutions responsible for data management/provision	・It is necessary to strengthen support for data management that is more plain and continuous than research itself.	(1) Strengthening of dedicated institutions responsible for data management and provision
3. Development of simulation environments and demonstration environments for accelerating data acquisition and verification of tools	・As there are hindrances to data acquisition, such as personal information, it is necessary to secure a special environment in which data can be acquired.	(1) Development of simulation environments that mimic actual structures, such as factories, stores, and hospitals (2) Securing of sites to use in verification of AI products and services
4. Virtuous cycle of collecting data and tools through industry-academia collaboration	・A framework for a virtuous cycle in Japan that does not rely on foreign AI clouds is necessary.	(1) Provision of AI cloud that enables for a virtuous cycle of provision of data analysis strength and data provision by industry, academia, and government (2) Support for development of open tools through provision of AI cloud
5. Technological development and system development for accelerating preparation of data sets	・Streamlining is necessary for forming data sets such as cleansing and tagging, which are labor-intensive tactics.	(1) Development of technology for accelerating data preparation, such as technology that carries out automatic association using AI, and technology for anonymization/secret calculations/secret searches (2) System development for promoting automatic registration (accumulation) of data
6. Development of open data for data generated from national projects	・The national government should take the initiative and provide open data.	(1) Management and provision of data acquired through national projects (2) Development of national projects that have the objective of data acquisition itself
7. Listing of resources related to data and tools	・An environment that can be easily used by users, such as URL lists, should be developed.	(1) Promotion of provision and utilization of URL lists for open data/open tools, computer resources, environment for data acquisition itself (demonstration/simulation environment) (including the three research institutions)
8. Sharing and cross-sectional utilization of data owned by the private sector, and so on	・Movements surrounding data distribution should be applied actively to AI	(1) Use of frameworks of private-sector entities, such as information banks, data transaction rules, and so on (2) Improvement in data linkage/compatibility, such as API publication (IT headquarters and the like)

Policies on Revitalization of AI-Related Start-ups, such as Support for Launching Start-ups and Support for Matching Start-ups with Large Corporations/Financial Institutions

[Attachment 5]

Policy proposal	Needs, problem consciousness	Image of concrete actions that are anticipated (examples)
1. Formation of communities and networks surrounding AI (promotion of open innovation)	・A “place” where research and commercialization can be promoted easily by AI start-ups specializing in individual specialized fields is necessary based on linkage between start-up corporations and with large corporations and universities.	(1) Formation of places for all-Japan AI start-up communities (2) Opportunism for exchange with AI start-ups and large corporations (3) Hosting of start-up pitches (linkage with finance) in the AI sector (4) Hosting of AI symposiums based on industry, academia, and government that are mixed with AI start-ups (5) Formation of human resources network of coordinators and assessors surrounding AI
2. Development of environment that promotes research and commercialization of AI start-ups	・It is necessary to provide public resources that can be easily used by AI start-ups that have difficulty owning large-scale facilities.	(1) Establishment/expansion of open labs and incubation labs at the three AI research institutions (2) Provision of governmental computer resources for data analysis and so on (3) Provision of an environment for hardware/software prototyping (4) Provision of simulation environment for data acquisition and PoC (Proof of Concept) environment for products and services
3. Development of an environment where comparison (benchmark) of AI performance is possible	・For start-up corporations that are not well known, an environment where the performance of AI technology that they own can be appealed objectively to outsiders is necessary.	(1) Implementation of AI competitions (competition formation and so on) (2) Implementation of AI awards (3) Development of AI performance evaluation indicators (standardization of standard images and so on)
4. Promotion of the use of AI for public welfare objectives (problem-solving)	・Initial market creation of AI products and services is necessary.	(1) Strengthening of coordination with exit ministries for cultivating AI demand (2) Expansion of AI products and services for administration
5. Harmonization of AI and regulations	・Establishment of appropriate regulation levels is important for marketization of AI products and services.	(1) Ideals for regulations that match the latest technological levels for AI and so on
6. Expansion of data and tools that can be utilized	<Reviewed in data maintenance/provision and open tools TF	<Reviewed in data maintenance/provision and open tools TF
7. Expansion of training opportunities	<Reviewed in human resources fostering TF	<Reviewed in human resources fostering TF>
8. Other	Visualization (listing) of measures that can be expected to be used by AI start-ups	(1) Featuring of a list of measures on the AI portal