

Further Improvement of R&D Capability and Challenge to Speed

Motoo Nishihara,
Executive Vice President, Member of the Board, and CTO

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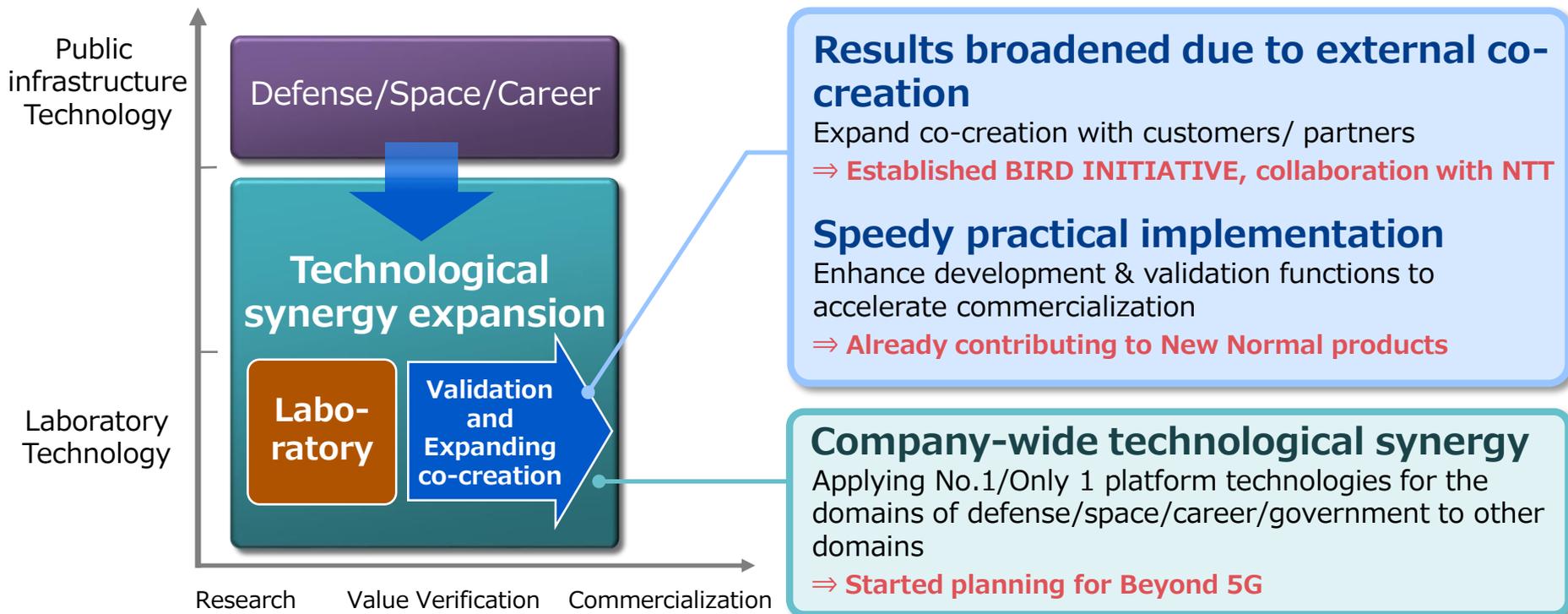
■ No. 1 Cutting-edge Technology to Support Future Business

■ Summary

Establishment of R&D Unit

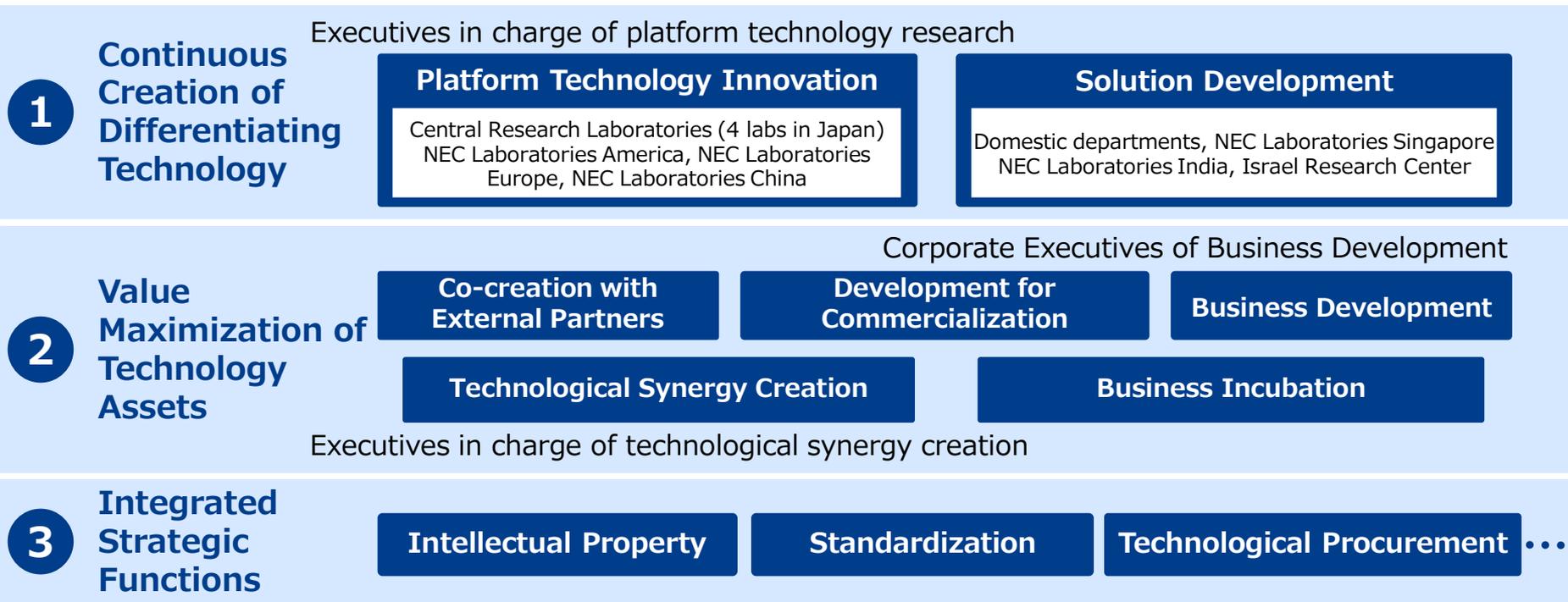
Purpose of Re-organization (April 2020)

Enhanced output through co-creation, accelerating commercialization, company-wide technological synergy



Integrate All R&D Functions

Organized all R&D functions which had been scattered between Central Research Laboratories and Corporate, aggregating them into a new unit. Assign company executives to relevant functions.

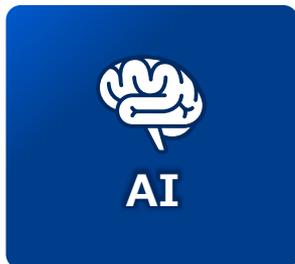


Further Improvement of R&D Capability

“Technological Genealogy and the Technology Value Chain,” Leading to NEC's Technological Prowess

NEC Research Competitiveness

Maintain global competitiveness in the fields of AI, security, and network



- **Ranked 6th in terms of # of accepted papers at top-quality international academic conferences on machine learning*¹; ranked solidly 2nd after IBM among B2B enterprises** (since 2000, internal survey)
- **A number of Papers accepted at top conferences also in other AI fields*²**

*1 NeurIPS, ICML, KDD, ECML-PKDD, ICDM

*2 AI General: IJCAI, AAAI, image recognition systems: ICCV, ECCV, CVPR etc.



- **A number of papers accepted at top-quality academic conferences on cyber security (CRYPTO, ACM CCS etc.)**
 - Awarded CRYPTO 2019 best paper award



- **A number of papers accepted continuously at top-quality academic conferences on optical communication (OFC, ECOC etc.) for over 30 consecutive years**



- **Ranked 5th in the world in terms of # of AI-related patent applications (2019)**

Source: WIPO / WIPO Technology Trends 2019 - AI

https://www.wipo.int/edocs/pubdocs/en/wipo_pub_1055.pdf

- **The very best in terms of domestic patent capability in facial authentication (2019)**

Source: Patent Result Press Release (2019)

<https://www.patentresult.co.jp/news/2019/01/faceauth.html>

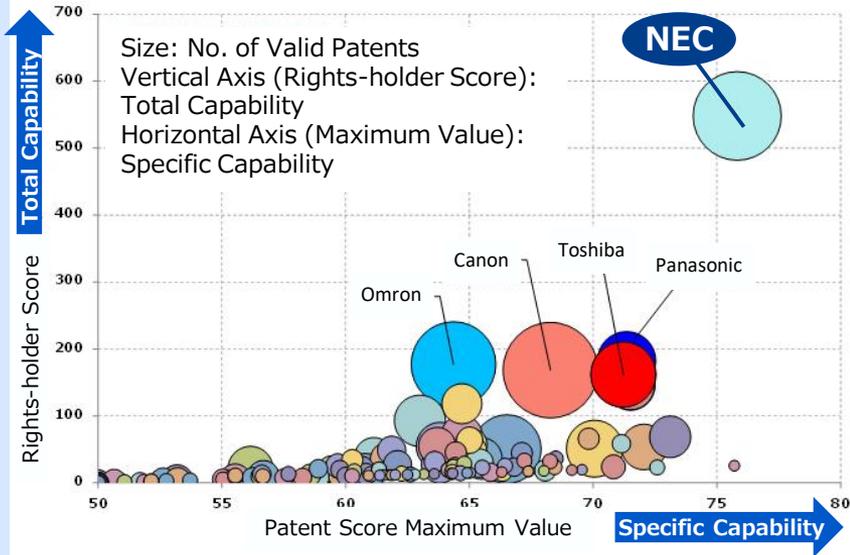
No. of Accepted Papers at Top-quality Int'l Conferences (machine learning)		
1	Microsoft	816
2	IBM	732
3	Google	570
4	Yahoo	320
5	DeepMind	194
6	NEC	168
7	Facebook	122
8	Siemens	93
9	Tencent	77
10	Baidu	76

Company Ranking (internal survey 2000-2018)

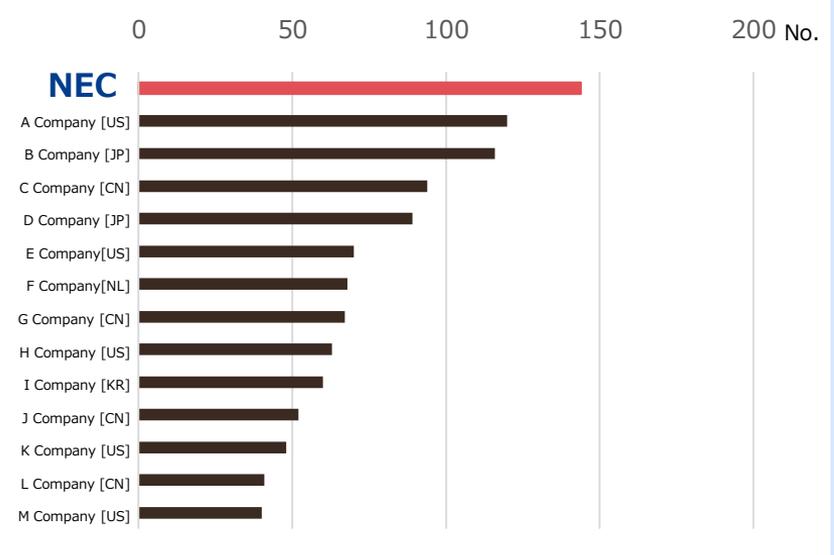
Technology Patent Portfolio of Facial Authentication

Our patent portfolio of facial authentication is the best in terms of total patent capability (Japan) and the number of international patent applications (global)

Evaluation of Total Patent Capability (Japanese)



No. of International Patent Applications (Global)



(Internal survey, accumulated no. of applications since 2001)

Source: Patent Result Press Release (2019)

<https://www.patentresult.co.jp/news/2019/01/faceauth.html>

R&D Results – Cases (1/2)



AI-powered Drug Discovery (graph-based relational learning)

Began trials of a cancer vaccine developed using AI with Transgene



Insight Marketing

Launched service business together with MACROMILL, utilizing recognition AI and analytical AI



Newborn Children Fingerprint Identification

Recognized newborn fingerprints 2 hours after birth with 99.7% accuracy. Verified it in the Republic of Kenya together with Nagasaki University.



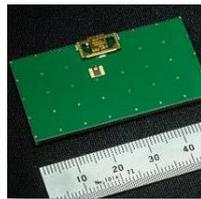
Integration of Simulation and Machine Learning

Conducted R&D together with AIST. Structured digital twins of factories and production sites to prove optimization and streamlining



Optical Fiber Sensing

Began trials with Verizon. Successfully obtained traffic data using existing optical fiber networks as sensors



Antennae using Metamaterial

Brought the world's smallest class of high-functioning antennae into service by combining JAE's precision engineering technology

R&D Results – Cases (2/2)



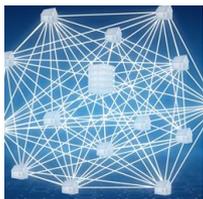
Invariant Analysis, etc.

Analyzed variety of data from satellites etc. with AI under partnership with Lockheed Martin Space in the satellite/outer space field.



High Bandwidth Optical Transport Systems

Developed technology of transport bandwidth expansion of optical submarine cable system. In average, 25% of bandwidth expansion was verified in 10,000km



Quantum Computing

Launched "Quantum Computing Application Service" in June. Collaborating with D-Wave to accelerate development.



Secure 5G

Began co-operation with Cisco. Aiming to provide a secure network platform with blockchain technology in the core



Digital Healthcare (Gait analysis)

Collaborated with FiNC to accelerate commercialization using cloud funding. Received international design awards etc.



Next-Gen. Heat management

Proved 50% reduction in air conditioning power consumption at a data center using a new coolant. Worked together with NTT Communications.

Genealogy of NEC's Strengths

Technological strength is born from "the bonds between human talent".
Why was facial authentication invented?

■ The bonds between human talent surpass time and location, creating strong technology

■ Key players in AI history form the genealogy of NEC Laboratory's AI Research

Yann LeCun

Vladimir Vapnik

Leon Bottou

Hitoshi Imaoka

■ Our story is also introduced in an article on R&D talent in the field of AI

Received ACM Turing Award (2018)

"The Three AI Giants"



"The Godfather of AI"
Geoffrey Hinton



Yoshua Bengio

LeCun School



Yann LeCun

AT&T Bell Lab
→NEC Labs America
→Facebook AI Lab Director

@NEC
Labs
America

Central Research Labs



Hitoshi Imaoka

World No.1 in
Facial Authentication



Keiji Yamada

Introduced machine learning
to pattern recognition



Atsushi Sato

Discovered and utilized
generalized learning
vector quantization

Pioneers in
Pattern Recognition

Advising
Research
Direction



Vladimir Vapnik

Joint Inventor of Support Vector Machine
Received C&C Award (2013)



Leon Bottou

Won Test of Time Award* for works
during his tenure at NEC (ICML 2018)



Ronan Collobert

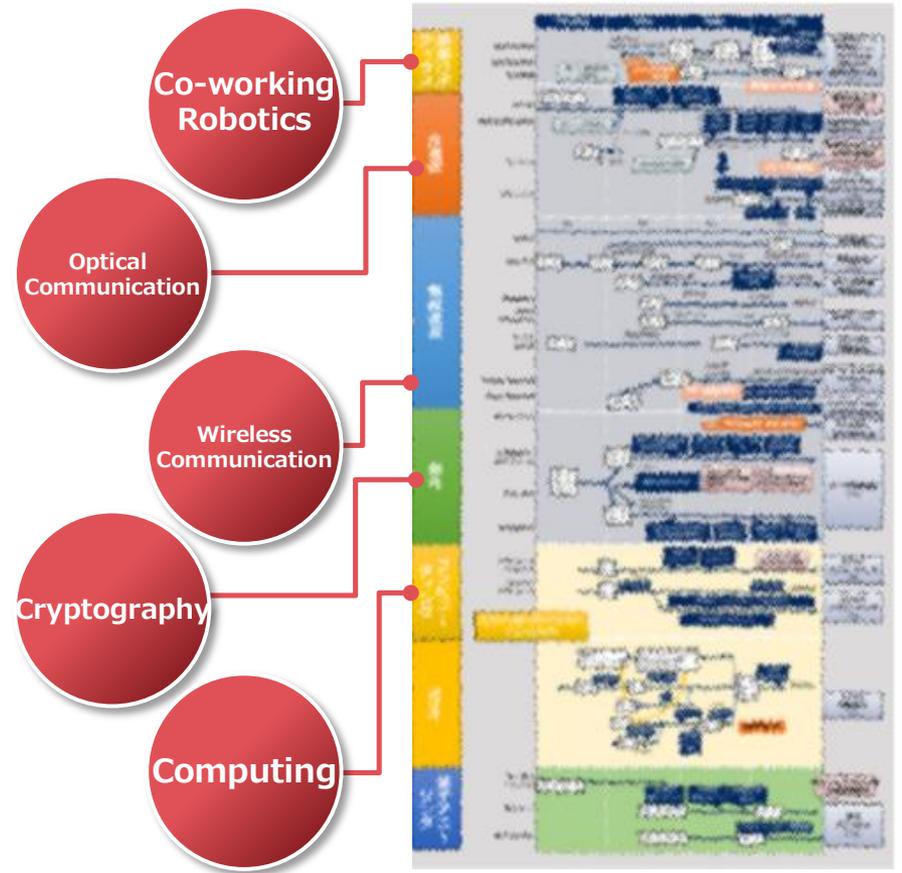
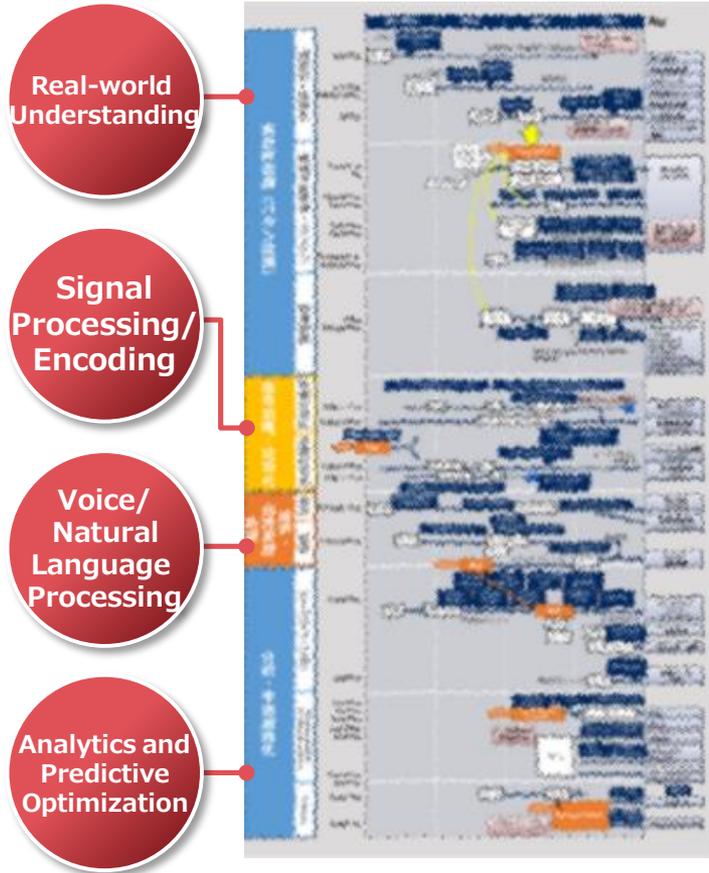
&
Jason Weston

Awarded the Test of Time Award*
for works during his tenure at NEC
(NeurIPS 2018)

*Test of Time Award:
An award for the most important papers which have
pioneered new paradigms in the last decade

Photograph of Yann LeCun by [Jérémy Barande "Yann LeCun \(41208595340\)"](#), photographs of Geoff Hinton & Yoshua Bengio by [Steve Jurvetson "Deep Thinkers on Deep Learning"](#), licenses for all three photographs are based on [CC BY 2.0](#)

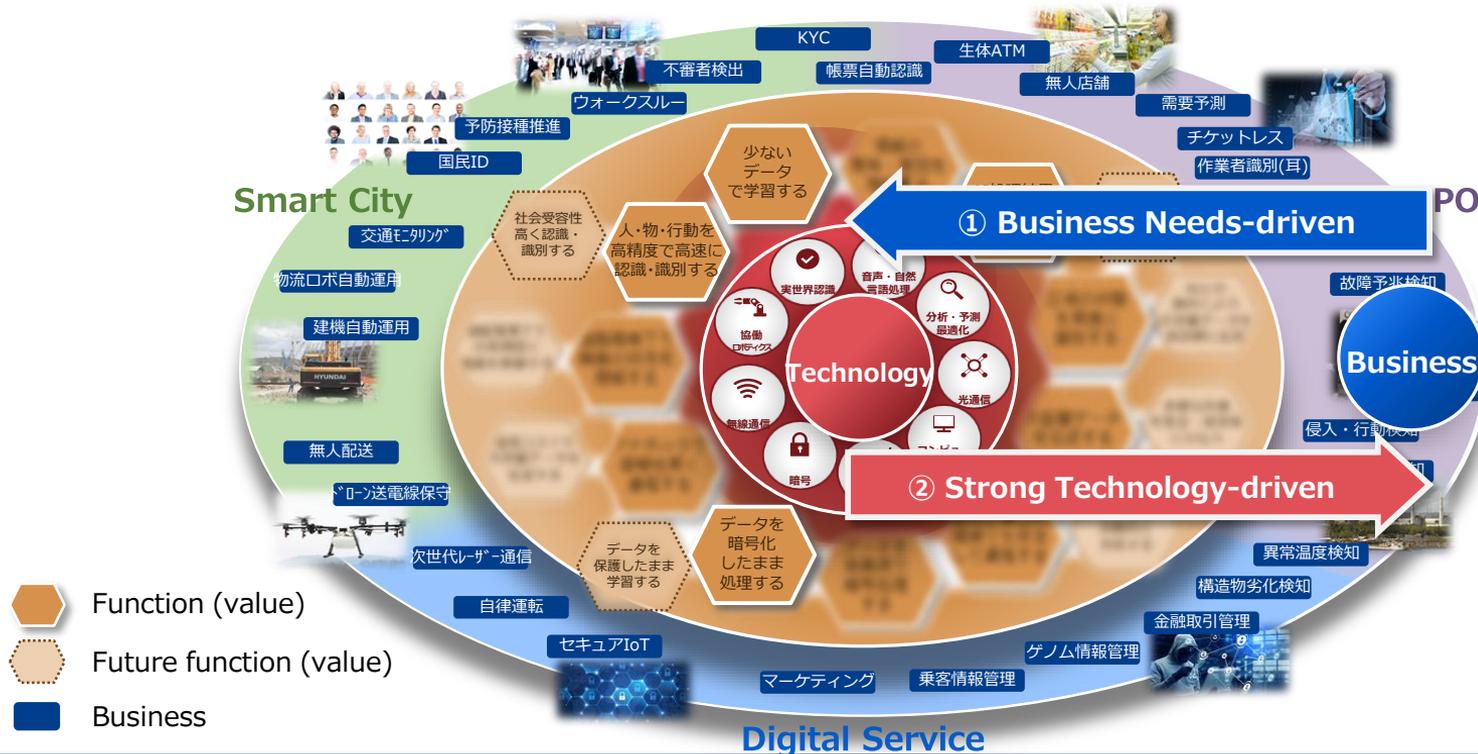
Genealogy of NEC's Technology over 30 Years



Development of Technology Value Chain

～Finding Strong Technology and Pioneering Business Opportunities～

Launching company-wide movements to create new business opportunities by finding strong core technology from our technological genealogy, and by generating value from it



Continuously invest in our human talent via fair evaluations, creation of an environment where everyone strives for their best, etc.

■ In 2019, we introduced the "Selective Compensation Program for Professional Researchers" for top young researchers

- Considering the market value of researchers, we did not cap their remuneration
- The program began in 2019 with 9 researchers in Japan.
During recruitment activities in the US, **we gave an offer to new graduates applicable to the program**

■ Continuously strengthening our acquisition of excellent talent from overseas, such as India

- We have been engaging in recruitment activities at India's prestigious institute, IIT, for the last 8 years, and have recruited 38 researchers
- 8.5% of research staff at our Japanese labs have foreign background, and we continue to strengthen our global excellent talent acquisition

Young researchers using the program



Masafumi Oyamada



Riki Eto

Researchers from IIT



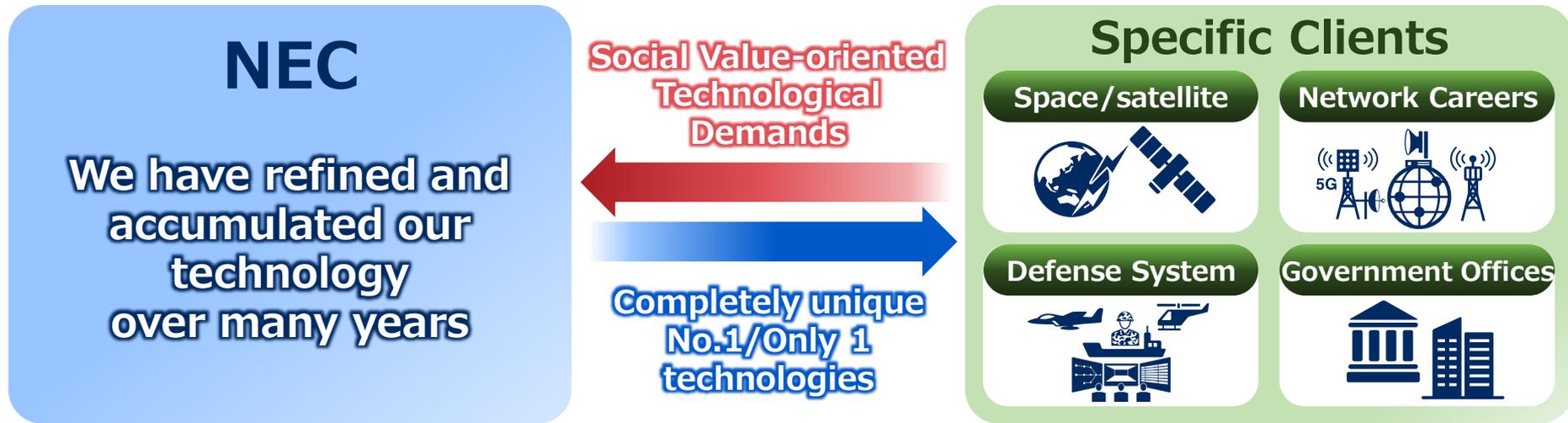
Kanishka Khandelwal



Chaki Prakash

“Source of New Strength” through Company-wide Technological Synergy

NEC is executing various public infrastructure businesses over the long-term, and has plenty of No.1/Only 1 technologies that are unique to NEC. The technologies will be utilized as company-wide strength for other businesses



Strong public infrastructure technologies to be cultivated into NEC’s shared strengths and launch on other markets

⇒ Promoted in newly established **“Technology Synergy Creation Division”**

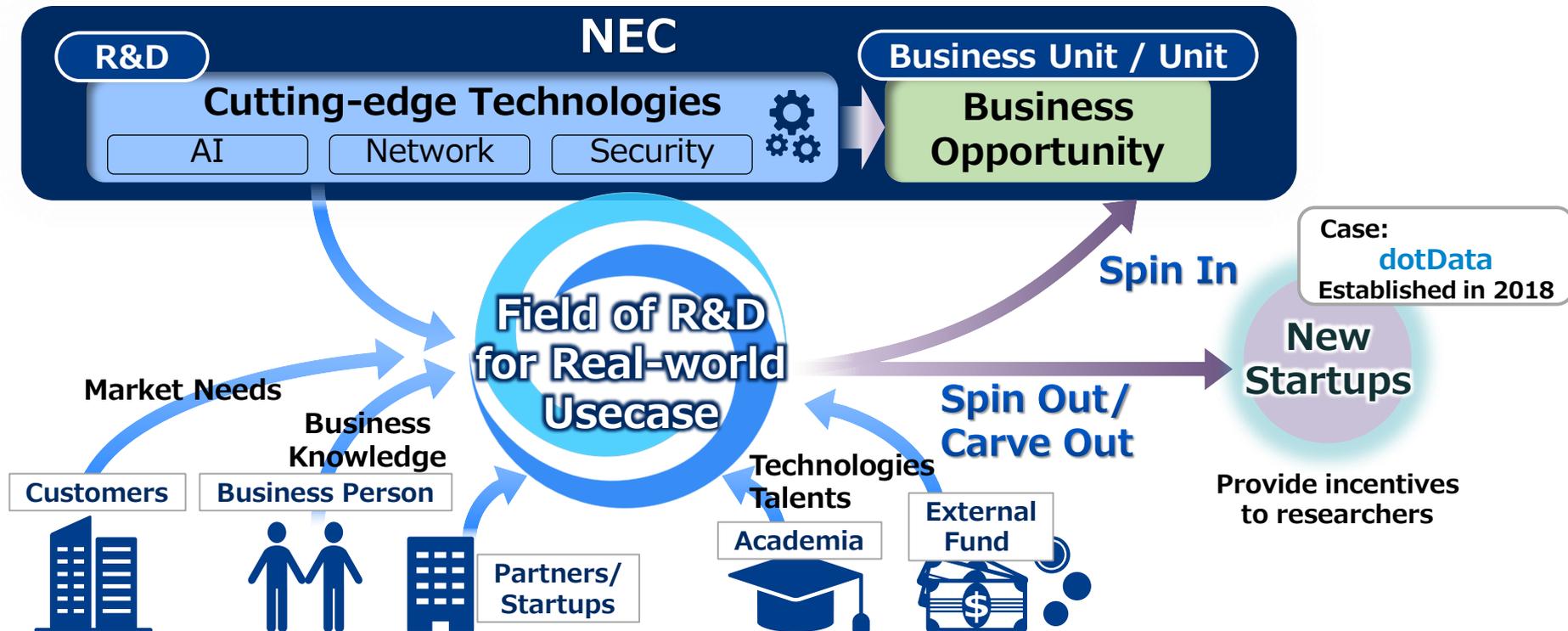
Further Improvement of R&D Capability

Record of Co-creation & Further Activity Expansion

Promotion of Eco-system Type R&D (from Previous Year's IR Day Materials)

Provide NEC's technologies externally at an early phase to involve external partners and speed up R&D.

Open innovation of an Inbound/Outbound integration.



Outcome of Eco-system Type R&D (with Business Innovation Unit)

Created new business that exceeds the existing framework, with NEC's technology at the core

Business Expansion of dotData

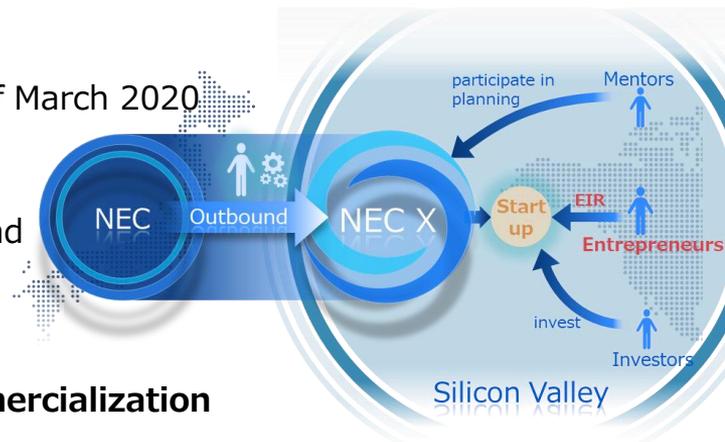
- Completed the large financing round of \$23m for dotData
- Acknowledged as a 'Leader' enterprise in machine learning automation SL market in a US market research report
 - Forrester New Wave Report (The Forrester New Wave™: Automation-Focused Machine Learning (AutoML) Solutions, Q2 2019)
- Providing commercial services to over 50 customers as of the end of March 2020

Creating new business with NEC X

- Established an organization together with local venture capitalists and accelerators in Silicon Valley
- Since its establishment in 2018, it has examined over 30 advanced technology projects.
Approx. 10 projects of which have been moving towards commercialization

Earnest participation in advanced AI-powered drug discovery

Began trials for a cancer vaccine in January 2020



Mutually driving medium-to-long term R&D as well as development of O-RAN and compact optical IC (DSP). Launching business globally with Japanese revolutionary technologies and products



Overview of Medium-to-Long Term Joint R&D

- Joint development of revolutionary optical/wireless devices needed for the IOWN
- Transforming the submarine cable system to a high bandwidth, high function, and low-cost system
- Transforming space communications to a high bandwidth, low delay, automated/autonomous system
- Enhancing technologies to ensure the security of infrastructure networks

New Structure of collaborative R&D: BIRD INITIATIVE, Inc.

Announcement on September 10th

6 companies from different industries launch an unprecedented research and development business from Japan

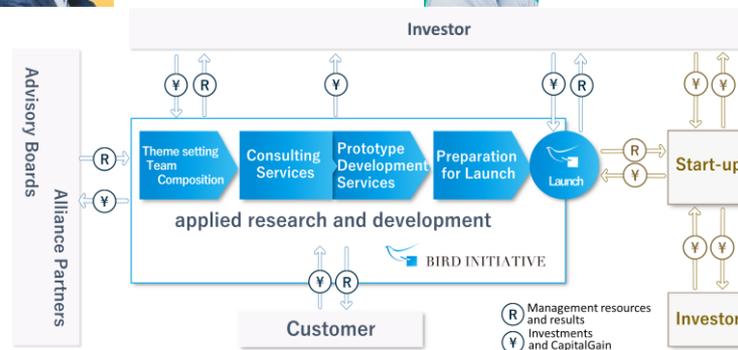
- Technology: Advanced AI technologies (Intelligent Simulation and Automation) from NEC-AIST AI Cooperative Research Laboratory
- Business: Provides consulting and prototype development to realize customer DX
- Success: Create 6 new businesses by 2025 through carve-outs.



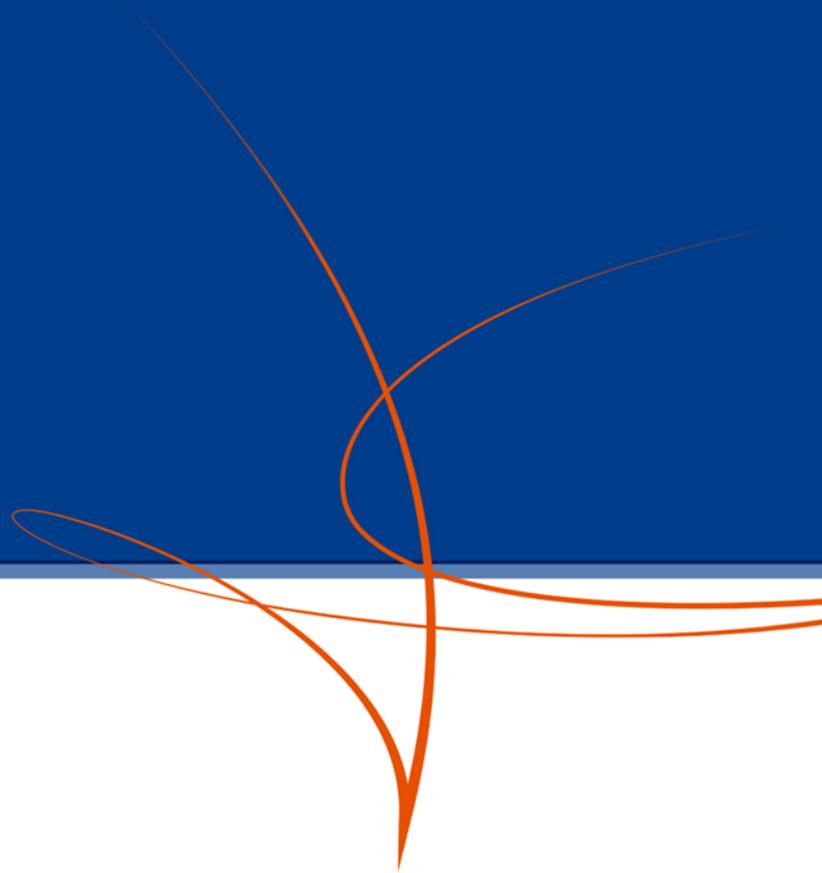
Masamitsu Kitase,
CEO at BIRD



Satoshi Morinaga,
CDO at BIRD



Challenges to Speed



Increasing Development Speed for Faster Commercialization

Improving development speed driven by newly established Technology Value Creation Division.

We are already accomplishing a number of results.

Organization for Practical Development

Technology Value Creation Division

NEC Laboratories Singapore

Israel Research Center

NEC Laboratories India

■ Infection control solution platform [NEC Laboratories Singapore]

- Expand the image analysis platform for safety, building a prototype in a very short time
⇒ Technology Value Creation Division is working together with the Sales division to achieve commercialization **within 3 months** (Announcements on July 2nd and 17th)

■ Visualization of Social Distancing [Biometrics Lab]

- Development & testing were completed very quickly based on underlying image analysis technologies developed over many years. Reached to the usable level **in 2 months**

■ Advanced facial authentication for people wearing face-masks [Biometrics Lab]

- Achieved enhanced face mask compatibility immediately, precision was improved and verified **in 2 months**

■ Contributions to development of vaccines against COVID-19 [NEC Laboratories Europe]

- Researchers of AI-powered drug for cancer proposed to contributing to the vaccine architecture. Working together with Oncolmunity, which we acquired, and our AI Drug Development Division, we completed a genetic analysis of COVID-19 and published the results **within 1 month**

Cases of Speedy Practical Implementation

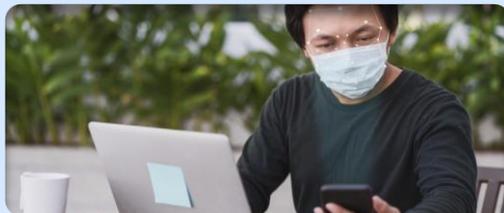
Since March, development of visualization technology of social distancing and facial authentication for people wearing face-masks was completed, and supported the commercialization of infection control solutions.

Social Distancing for Infection Control



Automatically detects the distance between people using camera imaging and displays the risk level

Facial Authentication for People Wearing Masks



Highly precise facial authentication using only the parts not covered by the mask

Vaccine Development Support for COVID-19



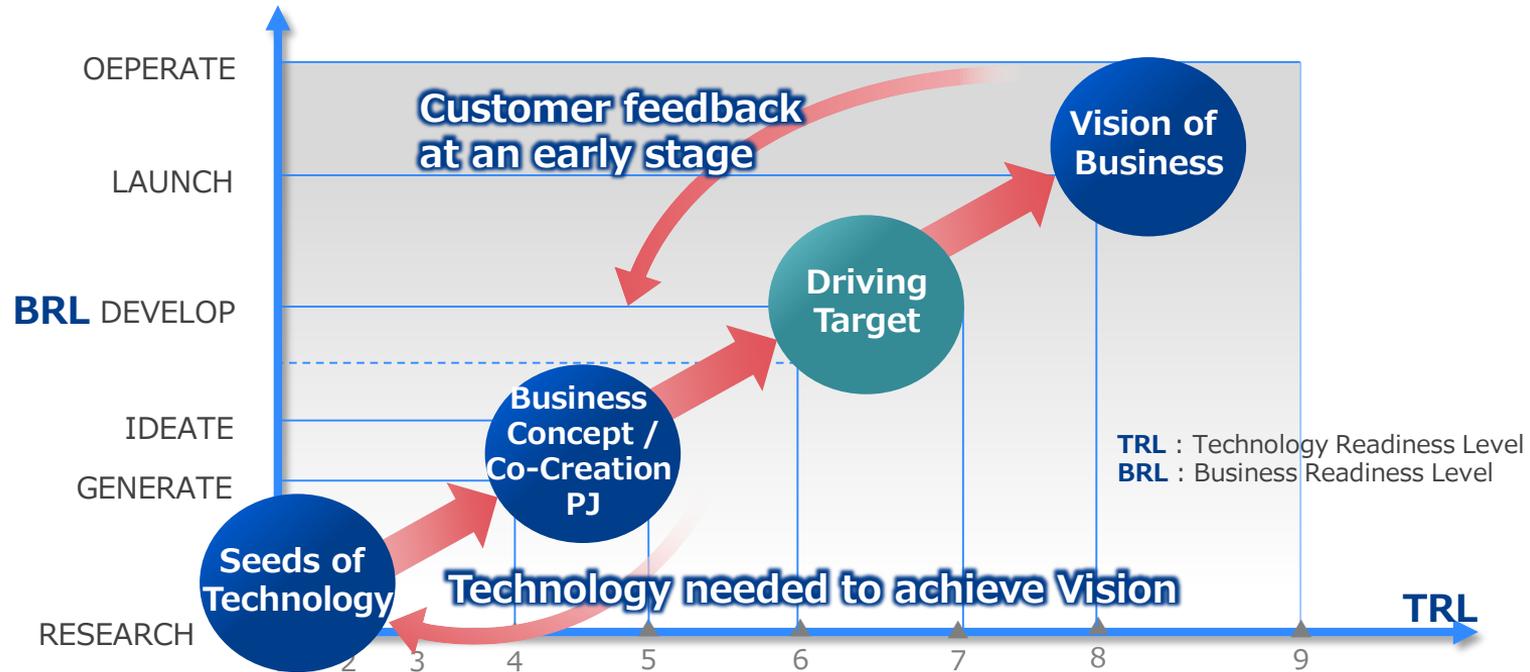
Graph-based Relational Learning

Published COVID-19 genetic analysis results within approx. 1 month after using AI-powered drug discovery methods

▲ **Contributing to New Normal Products** ▲

Research Activity Management and Accelerating Commercialization using TRL/BRL

Accelerate establishment of a technology needed for the vision of business by presenting the technology at an early stage to communicate with the market. Improve the speed for commercialization through bilateral approaches from technology seeds and by business development



Promoting Business Incubation Activities

Promoting and accelerating incubation of business with an advanced technology

Quantum Computing Promotion Office (since January 2020)

Accelerating application development, technology development and market creation using co-creation, in addition to chip development

Understand market needs
Develop the market

Accelerate development
of software/application

Accelerate service provision
(Verification, Education etc.)

Collaboration with D-Wave

Accelerate the market
creation with industry-
leading companies

Development of quantum
annealing simulation

Expand applied areas
Respond to unprecedented
large-scale issues with practical speed

Launch of co-creation service

Develop quantum technology
applications with customers

Comprehensive support for
commercial use
(Service launched on June 30, 2020)

No. 1 Cutting-edge Technology to Support Future Business

A decorative graphic consisting of several overlapping, flowing orange lines that originate from the top right and curve downwards and to the left, crossing the horizontal line that separates the blue header from the white body.

No. 1 Cutting-edge Technology to Support Future Business

DX Business

Data Business

Network Business

Acquire higher-level insight

- From efficiency to business sustainability, from stable operations to handling of unknown issues
- Constantly renewing and growing system with instant adaptation to environmental changes

Support High-level Human Judgements

High-level Real-world Recognition

Common Data Platform

- Secure Data Use & Management
- Acquire insights through inter-industry data sharing and utilization

Secure Data Management

Data Collection Platform

ICT Platform

- Technological differentiation
- Harmony with eco-systems

Revolutionary Network Technology

Sensor/Computing Technology

Support High-level Human Judgements

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Sensor/Computing Technology

AI Supporting Complex and High-level Judgments with Human

Provide analytical results of complex issues of realworld that human can understand and trust

Can communicate with human and understanding each other



Accountability and transparency that anyone can accept

Can make high-level judgments for public infrastructure operation etc.



Analysis in complex and large-scale environments



Graph-based Relational Learning



Retrieval based time series analysis

Logical thinking AI



Discovery of rare critical events



Working together with human to solve diverse and complex issues



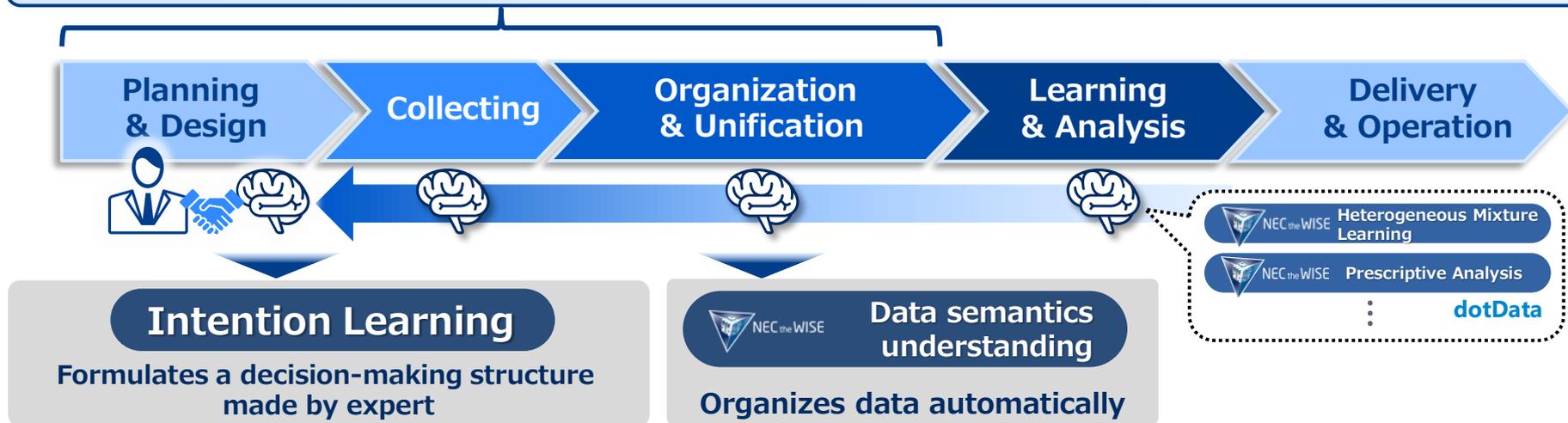
Automation of Data Scientists' Work

Targets for AI automation are advancing from analytical processes to upstream processes

As a result of development of new learning & analysis technology...

More than 80%* of total man-power are spent for data preparation and design planning

* The New York Times (Aug. 17, 2014) <https://www.nytimes.com/2014/08/18/technology/for-big-data-scientists-hurdle-to-insights-is-janitor-work.html>



Expand automation scope and quickly provide analysis of indisputable value

High-level Real-world Recognition

Acquire higher-level insight

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Sensor/Computing Technology

Strengthen Real-world Understanding based on Strong Biometrics



Facial
Authentication



Iris
Authentication

Facial Authentication **x** **Iris** Authentication



Maintain No.1 in Biometric Authentication

Continual improvement of precision of person authentication using multimodal recognition



Understanding the relationship between people and things



Expand strength to real-world understanding

Correct understanding of the on-site situation is becoming critical requirement

Authentication Technology with High Precision and Safety

Covered the world population with an error rate of less than 1 in 10 thousand million (theoretical figure)

Ranked World No.1 **5 times**
No.1



Facial Authentication

MBGC (2009)
MBE (2010)
FRVT (2013)
FIVE (2017)

FRVT (2019)

×

Iris
No.1



Iris Authentication

IREX IX (2018)
Iris Exchange IX



Error Rate
< 10⁻¹⁰



Face & Iris
Multimodal

Image showing the use of Multimodal Biometric Authentication Terminal (Press Release on May 14th)

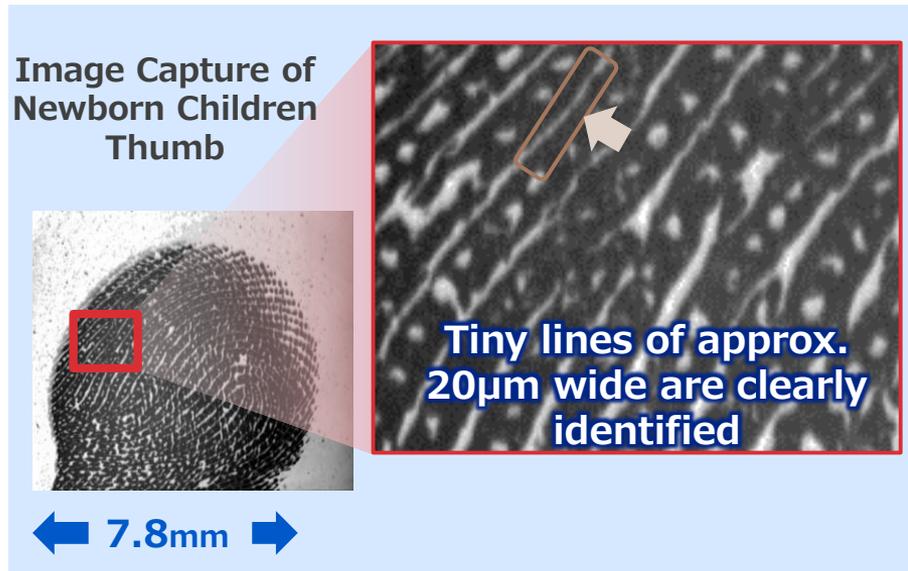


1 / 10,000,000,000 = World Population Coverage

Expanding the use of this technology for ATM user identification and payment which requires strict identification

※ NIST contest results have been obtained for the recognition of Face&Iris (https://jpn.nec.com/press/201910/20191003_01.html) (https://jpn.nec.com/press/201804/20180427_02.html)
※ Results proposed by NIST does not imply the recommendation of specific system, service, or company by US government

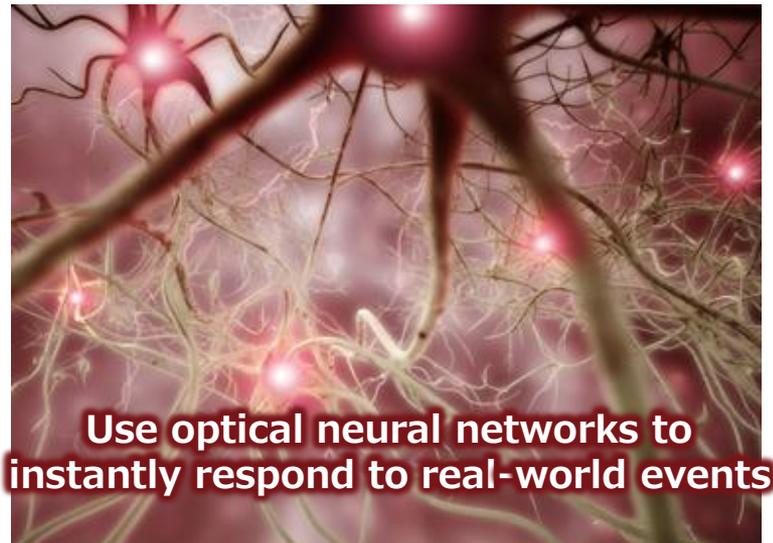
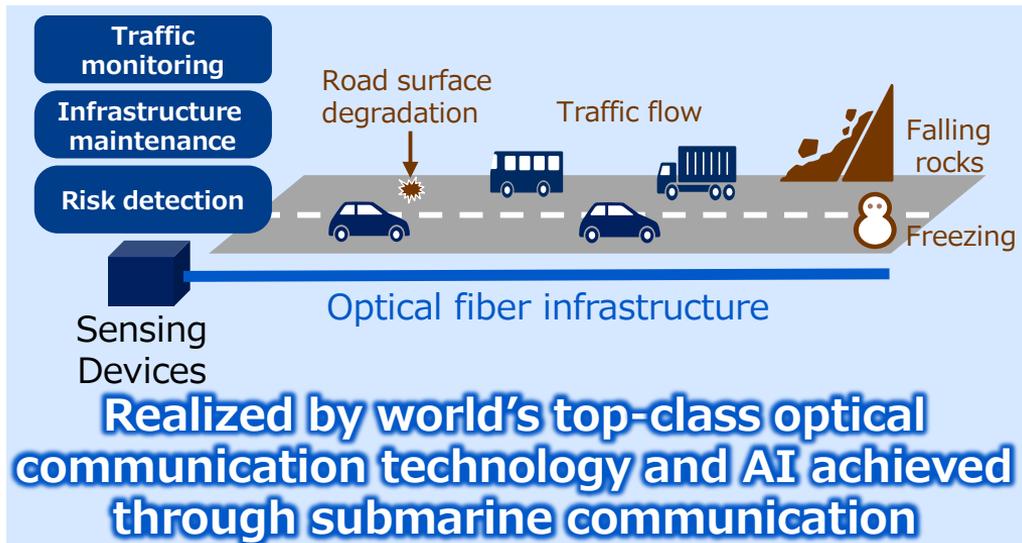
Recognized fingerprints of newborn children 2 hours after birth with 99.7% accuracy for the first time in the world



Can be used to issue a proof of birth, a personal verification, or a vaccine record after birth, even in places where mothers and babies are left from hospitals mere hours after birth

Optical Fiber Sensing Technology

Use existing wide-spectrum optical fiber infrastructure to automate traffic monitoring, the maintenance of communication/road network, and the risk detection of falling rocks/freeze



Successfully verified the technology with existing fiber in Dallas, US with Verizon. Currently co-operating towards commercialization

Secure Data Management / Data Collection Platform

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Revolutionary Network Technology

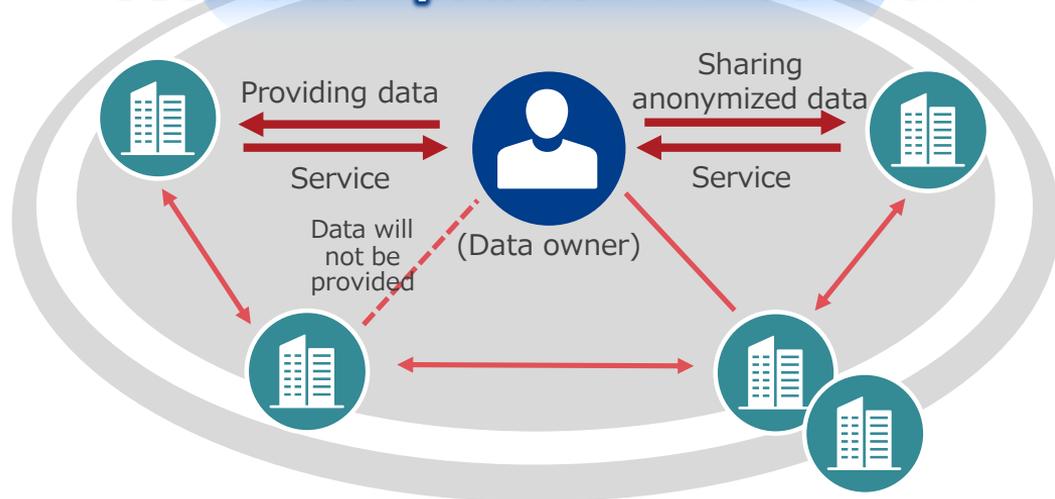
Sensor/Computing Technology

Enabling "Protecting Data x Collecting Data"

Sharing valuable data
in which individuals
cannot be identified



Secure Computation + Blockchain



Person Authentication **No.1** (incl. product/system performance)

Secure Computation **No.1** (Academic, POC performance)

Blockchain **No.1** (Academic, POC performance)

Secure Storage **Partially commercialized**

FIWARE **Leading the OSS community**

AI Security **New security in the AI era**

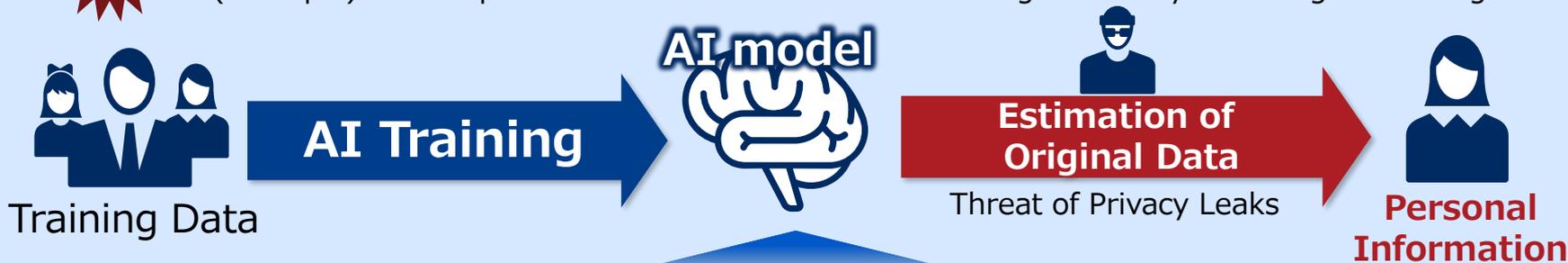
NEC owns the top technology needed for the major functions of data management & collection platform. The new unit will accelerate commercialization from now on.

Along with the popularization of AI, vulnerability of AI learning models and threats of information leaks by exploiting it are exposed. We will focus on security technologies to minimize privacy leaks.



Threats in the AI Era: Estimating training data from the AI model

(Example) Leak of personal information such as face images used by AI during its training



AI Security Technology to protect personal information from the threat of leaks



- Technology which extracts only the data necessary for training and input it to AI
- AI training technology which makes it difficult to estimate the original data from the AI model

Revolutionary Network Technology

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Revolutionary Network Technology

Sensor/Computing Technology

Boundless Social Value from 5G to Beyond 5G

Expand from the value for individual, to the value for company/city, and to the value for the entire Earth. We are co-creating with NTT on 5G to develop revolutionary O-RAN & security technology

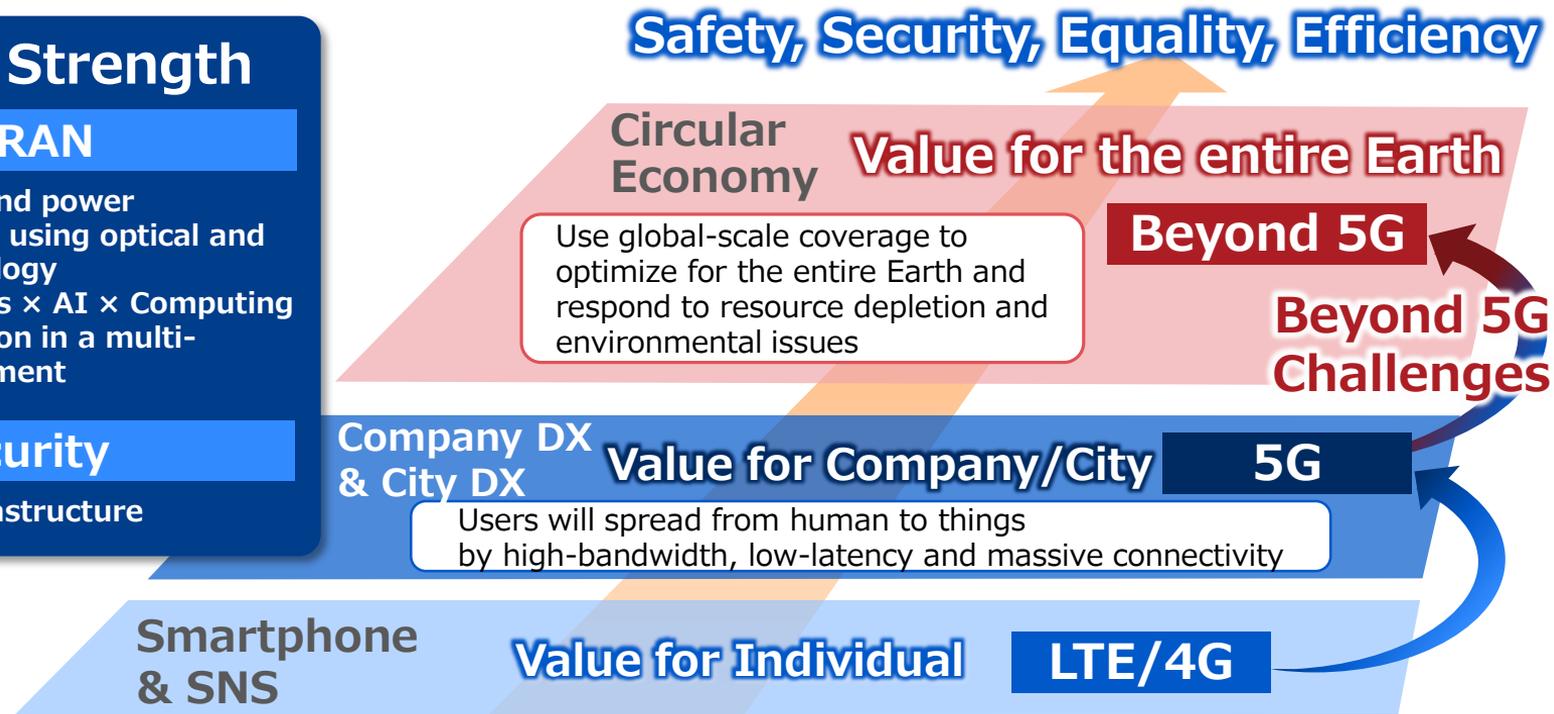
NEC 5G Strength

O-RAN

- Reducing size and power consumption by using optical and wireless technology
- Communications × AI × Computing
- Optimal operation in a multi-vendor environment

Security

- Security as infrastructure



Leading Earth-level Infrastructure through Synergy of Technologies (Beyond 5G)

High-bandwidth & Low-latency 5G Technology

Standardization

+

Network Service BU Technology

×

Public Infrastructure BU
Space & Wireless Technology

Research Labs Technology

×

Public Infrastructure BU
Technology

Using "mobile communication technology" with Earth-wide coverage, we will accelerate DX of the entire Earth



Current

5G

Local 5G

Public Wireless/Satellite Communication

Future

Beyond 5G

Beyond 5G Solutions

User Management

Ultra Large Number of Connections

E2E Connections

High-speed Wireless Communication

Ultra High Bandwidth

>100Gbps

Mission Critical

Ultra High Reliability

High security

Wide Area Communication

Coverage expansion

National Area Coverage

Networking Control

Ultra low latency / Traffic optimization

Unmanned & Labor-saving advancements

High-speed Optical Communication

Low-cost

Anywhere and everywhere Gbps

Summary

Summary

Integrate functions needed to improve R&D capability and accelerate commercialization by establishing R&D unit as a company-wide technological organization

Further improvement of R&D capability

- Acquire & develop excellent human talent for continuous development of our technological genealogy **Human talent**
- Promote ecosystem-type R&D via large-scale co-creation with external partners **Co-creation**
- Business division technology (public infrastructure, etc.) as the source of new strengths for the whole company **Synergy**

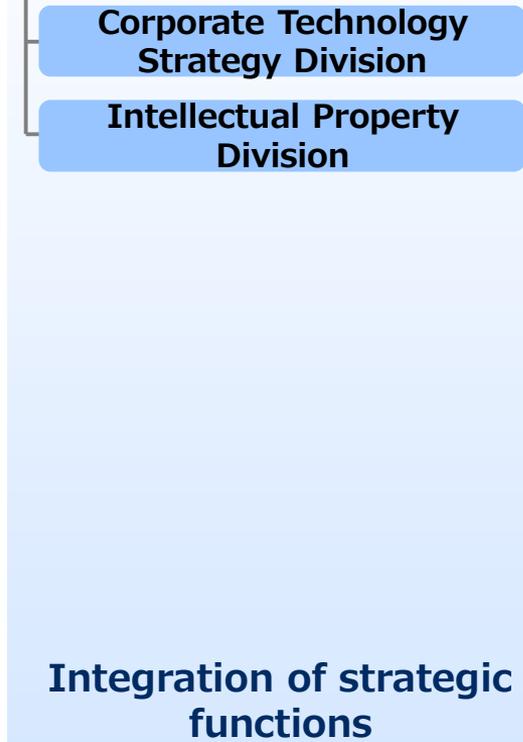
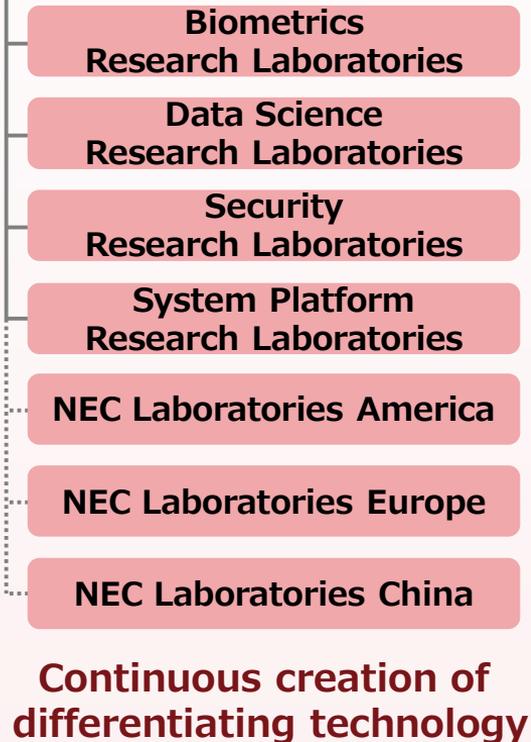
Challenges to accelerate commercialization

- Largely shorten the time for commercialization of a core technology by creating an engineering division

Commercialization

Lead NEC's growth via continuous creation of differentiating technologies and accelerating their commercialization

R&D Unit



 **Orchestrating** a brighter world

NEC