

NEC's Business Model

R&D and Business Development

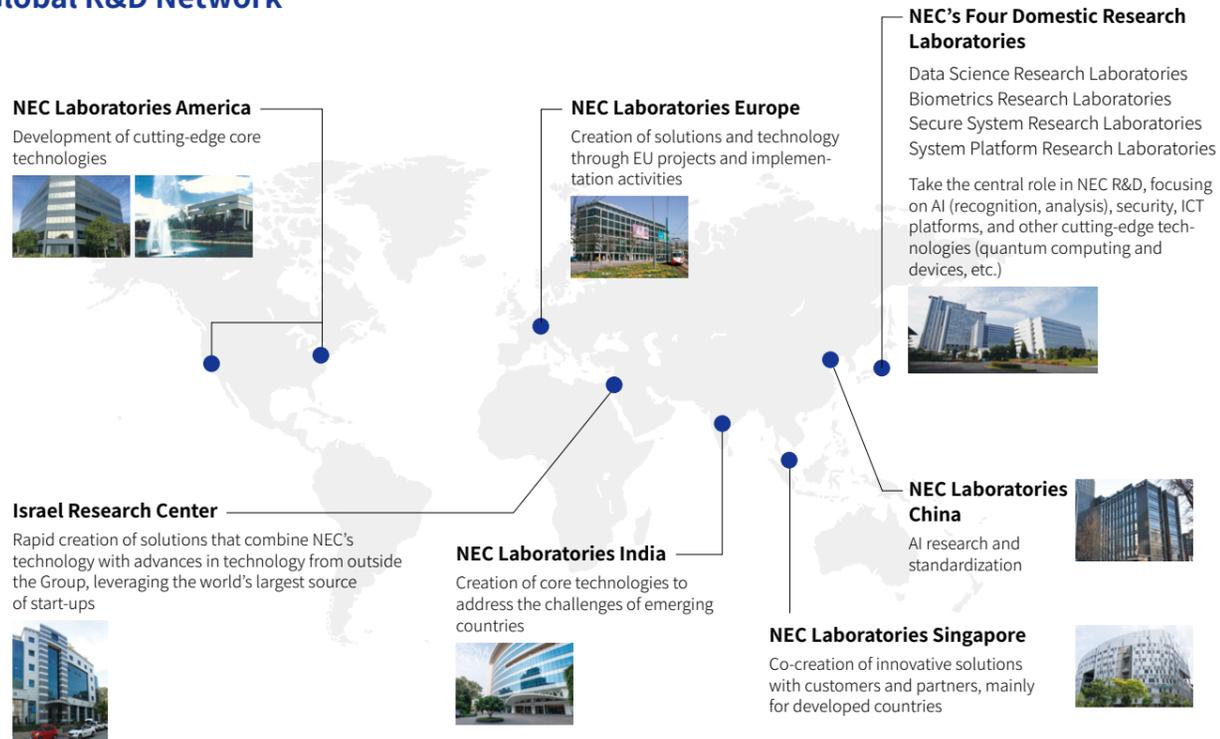
At NEC, we are aggregating the functions necessary for expediting the commercialization process and upgrading our R&D capabilities, in order to enhance results through co-creation with external business partners, realize faster commercialization, and generate technological synergies throughout the Group. With a focus on human resources, co-creation, synergy, and commercialization, we will continue to develop differentiated technologies and commercialize them in a timely manner, thereby steering the growth of NEC forward.

Major Areas of Research

Creating Social Value with Cutting-edge AI and ICT Platforms



Global R&D Network



Please refer to "AI Utilization with Respect for Human Rights as the Highest Priority" on page 61 for details on our policies regarding AI and human rights.

R&D Competitiveness

AI

- Ranked 7th in terms of the number of accepted papers at prestigious international academic conferences on machine learning*; ranked a strong 2nd after IBM among B2B enterprises; and ranked 1st among Japanese companies
- Similarly ranked among the top companies in the world for image- and video-related AI, retaining its position as the No. 1 company in Japan

*1 NeurIPS, ICML, KDD, ECML-PKDD, ICDM
*2 AI General: IJCAI, AAAI; image recognition systems: ICCV, ECCV, CVPR, etc.

Network / Security*

- A number of papers accepted at prestigious academic conferences on cyber security → Awarded CRYPTO 2019 Best Paper Award
- A number of papers accepted continuously at prestigious academic conferences on optical communication for over 30 consecutive years

* Security: ACM CCS, Eurocrypt, IEEE S&P, etc.
Network: OFC/ECOC, etc.

Patents*

- Ranked as a "Top 100 Global Innovator" for the 10th consecutive year in a global survey of the impact of corporate patents (2021)
- Ranked 5th in the world in terms of the number of AI-related patent applications (2019)
- No. 1 in terms of domestic patent capability in facial authentication (2019)

* Top 100: <https://clarivate.com/top-100-innovators/>
Number of AI patents: WIPO/WIPO Technology Trends 2019 - Artificial Intelligence
Facial authentication: Patent Result Press Release (2019) (Source)

Ranking among Companies for Accepted Papers at Prestigious International Conferences on Machine Learning

Rank	Company	No. of Accepted Papers
1	Microsoft	994
2	IBM	831
3	Google	830
4	Yahoo	336
5	DeepMind	267
6	Facebook	205
7	NEC	184
8	Alibaba	150
9	Amazon	132
10	Tencent	126

Source: Internal survey 2000-2020

An Example of NEC's Competitiveness: Biometrics

NEC's biometric solutions are ranked **No. 1 in the world.***

No. 1 in the World in Biometric Technology

Fingerprint Identification
No. 1
×8

Facial Authentication
No. 1
×6

Iris Recognition
No. 1
×2

* Latest survey from research company Frost & Sullivan

R&D Results

AI-powered Drug Discovery (graph-based relational learning)
Began trials of a cancer vaccine developed using AI in collaboration with biotech company Transgene

Newborn Children Fingerprint Identification
Recognized newborn fingerprints two hours after birth with 99.7% accuracy. Verified results in the Republic of Kenya together with Nagasaki University

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

Invariant Analysis, etc.
Analyzed a variety of data from satellites, etc., with AI in 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. On average, 25% of bandwidth expansion was verified over the course of 10,000km

AI-driven Endoscopic Image Analysis
Developed AI technology for endoscopic image analysis to detect neoplasia in patients with Barrett's esophagus, becoming the first technology of its kind to meet CE mark labeling requirements

Intellectual Property (IP) Strategy

Selected as a "Top 100 Global Innovator*" for the 10th Consecutive Year Based on IP Building an IP Network That Takes Advantage of Global Business While Ensuring Competitive R&D

Build a strong IP network by developing a group of patents necessary to conduct overseas business in line with our business plan, as opposed to relying on our core group of patents

Enhancing IP Business and 5G Standard Patents

Focus on creating new businesses that utilize intellectual property, accelerate R&D co-creation, and strengthen cooperation with partners, which includes leveraging intellectual property

* <https://clarivate.com/top-100-innovators/>

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Genealogy of Strengths

Technological strength is born from "the bonds between human talent."

- The bonds between human talent surpass time and location, creating superior technology.
- The following key players involved in the development of AI over the course of its history form the genealogy of NEC Laboratories' AI research:
Yann LeCun
Vladimir Vapnik
Leon Bottou
Hitoshi Imaoka

Photograph of Yann LeCun by J r my 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 CCBY 2.0.



Acquiring & Cultivating Talent to Continuously Strengthen Our Genealogy

Continuously investing in our talent via fair evaluations, the creation of an environment where everyone strives for their best

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

- Considering the market value of researchers, we did not cap their remuneration.
- The program began in 2019 in Japan. We also offered the program to applicable new graduates during recruitment activities in the U.S.

Young researchers participating in the program

Masafumi Oyamada Riki Eto

Continuously strengthening our acquisition of excellent talent from overseas, including from India

- We have been engaging in recruitment activities at India's prestigious institute IIT for the last eight years, and have successfully recruited 39 researchers.
- Nine percent of research personnel at our Japanese labs are foreign nationals, and we continue to strengthen our excellent talent acquisition from around the world.

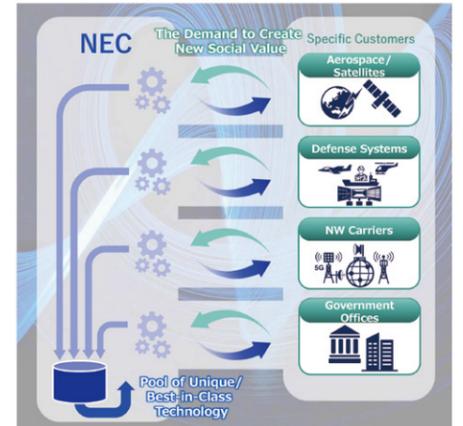
Researchers from IIT

Kanishka Khandelwal Prakash Chaki

Business Creation Initiative

Companywide Technology Synergies to Create Sources of New Strength

- Utilize the unique or best-in-class technology we have offered over many years to specific customers in social infrastructure fields to enhance other business domains
- Horizontal deployment of technology across business domains

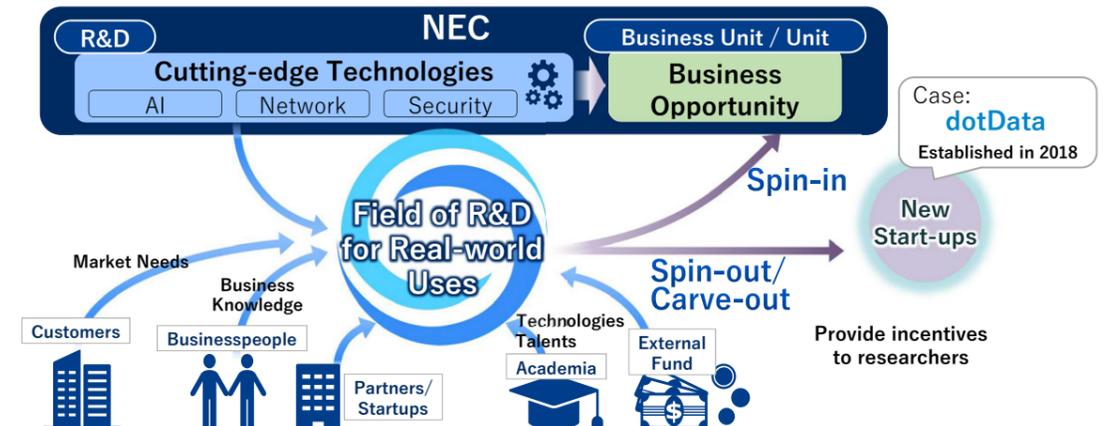


Examples of Business Development Promoted through Open Innovation

NEC X, Inc.	Business Incubator That Takes Advantage of Silicon Valley's Ecosystem Since its establishment in 2018, three out of its 23 projects have become established companies (Inguo, GAZIRU, and Metabob).
dotData	A Carve-out Company Specializing in Data Analysis Process Automation Established by World-class AI Researchers Highly capable products, peripheral businesses rooted in these products, and strong team creation
AI-driven Drug Discovery	Cases of Global Innovation in Drug Discovery Investment in, acquisition of, and joint clinical trials with biotechnology companies • Investment in BostonGene (U.S.) • Start of clinical trials with Transgene (France) • Joint development with VAXIMM (Switzerland) • Acquisition of Oncolmmunity (Norway)
CropScope Agricultural Support Solutions	Strategic Partnerships in the Food Processing Industry and Support for Producers Utilizing AI Technology and Ecosystems Worked with local manufacturers and producers through a strategic partnership with KAGOME to build a global ecosystem
Smart Wellness	Working with Leading Venture Capital Companies and Utilizing Crowdfunding to Verify Consumer Needs Engaged in open innovation targeting consumers through unique combinations of the capabilities of NEC, FiNC, and Makuake
BIRD INITIATIVE	A Joint Venture with Six Participants from Industry, Finance, and Academia for Collaborative R&D An unprecedented collaborative R&D business launched in Japan by six participants from different fields

Promotion of Eco System-type R&D

- Provide NEC's technologies externally at an early phase to involve external partners and speed up R&D
- Open innovation of inbound/outbound integration



Roundtable: Creating Social Value through NEC's R&D



Terumi Umematsu

Area of responsibility: Modeling human internal states (psychological and neurological) using biological signal analysis. Visiting researcher at the Massachusetts Institute of Technology (U.S.) from 2017 to 2019.

Masafumi Oyamada

Area of responsibility: R&D on data integration and machine learning systems. Principal researcher (alumnus of the first iteration of the Selective Compensation Program for Professional Researchers).

Yusuke Akamatsu

Area of responsibility: R&D related to biomedical signal processing. Joined the Company under the Selective Compensation Program for Professional Researchers.

The Strengths and Merits of R&D at NEC, from a Researcher's Perspective

Judging by your day-to-day R&D activities and your experience to date, what would you say are the characteristics of NEC?

Oyamada Speaking broadly, NEC is quite solid when it comes to basic research, and they apply this research to the real world, and these are both appealing points. Speaking of research, when it comes to my area of databases, machine learning, AI, and other similar fields, NEC is one of the best in the world. They are very aware of getting the basics right, and this is something that has been historically well-nurtured among researchers in Japan, of course, but also in North America and Europe. This has made the level of researchers quite high and has increased the appeal of NEC as a potential workplace for many top-level students.

NEC has customers in various fields both in Japan and abroad, so I think another appealing point is being able to look at a cross-section of data, discover universal issues, and produce research results to tackle those issues.

Umematsu I think one strength is that we get to feel a sense of responsibility for our research, from the beginning all the way to the end, when both we and the business divisions send our research out as business. I would also have to say that another major strength is NEC's connections to areas outside of Japan, universities, and other companies. Also, when I want to embark on a theme of research, the people at NEC are very sincere with their inquiries regarding it. If what you propose is logical and shows promise, you can take charge of your research on your own. This is a great amount of freedom. I can do the things I really want to do, and I can work with a dream in mind and see my efforts come to fruition in society. This is the driving force that gets me to do my best every day.

Do you come across any obstacles when you take on challenges?

Umematsu Even when you try but fail, people encourage you to try your best next time. I think this is a really positive thing. I am always taking on challenges, and my hope is that people like Mr. Akamatsu will see me try and fall short and realize that this is acceptable—and will feel like making an attempt themselves.

Akamatsu That's right. When I see someone senior to me with as much passion as Ms. Umematsu, I feel like I'm in a place that welcomes those who like taking on a challenge.

Mr. Akamatsu, you joined the Company in fiscal 2021, but what drew your attention to NEC as a student?

Akamatsu I was drawn in by NEC's unique social solutions, that is, the way they would work with other companies to identify issues and then apply technology to solve the issues. For me, this is what separates NEC's research laboratory from the rest. My goal was to be useful to the world and have people benefit from things I created, so I chose a company that would allow me to achieve this goal and see the fruits of my efforts in society.

Another characteristic of NEC that I have noticed since joining is that there are people working in a variety of fields, and being around so many different professionals, being able to ask them for advice and conduct research together with them is definitely appealing.

Oyamada One of the people who laid the foundation for deep learning belonged to NEC Laboratories America, and I think the reason that NEC is so well known among students as a research institution is because of its excellent and long-standing reputation.

Is there a divide between your image of NEC before joining and how you see it now?

Akamatsu The biggest gap for me was that I had imagined a place where you conduct research focused on creating technology—either developing technology or improving existing technology—but in reality, I have had many opportunities to think in terms of business. One example is an approach to research I learned regarding patents. I learned that, even if the patents and technology didn't exist, we could discuss hypotheticals with someone from one of the business divisions and begin research from there.

Oyamada About seven years ago, we started promoting the idea of thinking in terms of business needs. I think this has become part of the Company's culture.

Umematsu There are more and more opportunities for us to communicate research themes to the entire Company. This is partly due to communication reforms and this can lead to good discussions at the grassroots level where people can confirm as to whether such-and-such is possible and exchange with each other.

Oyamada Things are not in vertical silos and there is no real sense of "territory," so there are lots of discussions along the line of "why don't we work together to do this?" or "why don't we partner up to do that?" I think this sense of research as a holistic effort is something quite unique.

There has been mention of in-house collaboration, but is there much collaboration with research laboratories abroad?

Umematsu My impression is that there is quite a lot. There is no kind of threshold for us to pass through, and because of this, it is getting easier and easier to contact other researchers and have casual interactions to get information. The only difference is location, but to me, it only seems like the distance between the head office and the Tamagawa Plant. There has been a recent emphasis on speed, meaning that if it is faster to do something using assets from outside of the Company, versus sticking to in-house assets, we should choose the faster way. I feel like this is a change that has taken place over the last five years. It was not like that when we joined NEC, right?

Oyamada You're right. I feel like there used to be a belief that everything needed to be made by us.

What sparked this change?

Umematsu I think we have realized that in a time when there are complex problems all across society that need to be resolved—the SDGs are a good example—NEC cannot resolve them on its own. The Company mindset has changed to one that is more open and draws from outside sources to commercialize and contribute to society. I think the sense of urgency and a feeling of impending challenge have moved the Company in a more flexible direction.

Oyamada There is a sense of urgency, no doubt about it. Academic conferences are held online, software is becoming more open sourced, and the things that happen abroad can

reach us in real time. If your research capabilities in a certain technological field are not up to par with another group, that gap is apparent for all to see. Therefore, if things are opening up, we are best off taking advantage of the benefits.

Umematsu I was stationed abroad about two years ago, and the most shocking difference for me was that researchers were also entrepreneurs, business owners and managers, and they took care of people while establishing a vision for research. I was astonished to see these superhuman people who seemed to be able to do it all. I felt the difference in power. But with that shock out of the way, I feel that with NEC's lineup of a variety of professionals, we should all work to create something grand, instead of only trying to do things on our own.

Oyamada I had a similar experience about four years ago, working with people from top universities abroad, but I felt jealous every day. I felt disappointment in myself, seeing them organically flow between research, capital, and business. It made me want to play a bigger role in society. Speaking to that feeling, over these past three years NEC has figured out a process for researchers to commercialize their research outcomes. Also, the Company has created NEC Growth Careers, a horizontal work transfer system. While I think there is still a ways to go, the threshold is getting lower, and opportunities are increasing across the board.

Umematsu There are some examples of spin-out companies coming out of research laboratories, and having the frame of mind to step out of your comfort zone is a huge change psychologically and in many other ways.

What are your goals five to 10 years down the line?

Akamatsu First, I would like to focus on gaining some expertise. After that, I would like to propose my research, acquire a budget, and then work to be able to do something in another field, such as marketing, since I hope to build myself into one of these multi-faceted people we have been talking about.

Umematsu I would like to create solutions that are, of course, efficient and safe, but I also want them to be compassionate and close to the hearts of the people who utilize them in the end. To realize such a lofty goal, I hope to increase my own appeal, not just in terms of skills and technical capabilities, but also as a person, so that people will want to work with me and put their faith in me.

Oyamada Now that I am working on a business that I started myself, I would like to get it on track. Customers say that our service is very convenient, but convenience does not necessarily guarantee profit. I would like to solve this dilemma and create a system that will keep providing value in a sustainable way, both in terms of technology and business.