NEC’s Research and Development

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Executive Vice President and
Chief Technology Officer
Executive Summary

Constantly create No.1 technologies that support NEC’s businesses
- Laboratories have established competitive edge that contributes to the company’s business in focus and other businesses
  e.g.) Face recognition technology which marked the world’s No.1 evaluation for four consecutive times\(^1\) and AI technologies which ranked 5th in the world\(^2\) in terms of the number of papers that were adopted at top-quality international academic conferences
  \(\Rightarrow\) **Further strengthen AI technologies** and focus on **social acceptance, expansion of human capacity and mutual cooperation between AI and human**

Continuously acquire global top researchers
- The source of technological advantage is human resources. Provided more than enough opportunities in activities and compensations to acquire top researchers
- Research Fellow positions without limits on incentive founded in 2015. Market-level compensation being offered at NEC Laboratories America
  \(\Rightarrow\) **Introduced ”Selective Compensation Program for Professional Researchers”** without limits on compensations for non-managerial researchers

A new strategy, “Ecosystem-oriented R&D with NEC’s cutting-edge technologies”
- Shift to a new form of R&D operations, anticipating new relationships between researchers and the company to address a drastic market change
  \(\Rightarrow\) **Inbound & Outbound fusion-type open innovation that involves external parties**
  \(\Rightarrow\) **Enhance speed of R&D** to prepare for a spurt in the next era

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\(^1\) At the international benchmark tests by the U.S. National Institute of Standards and Technology (NIST). Results shown from the Face Recognition Vendor Test by NIST do not constitute endorsement of any particular product by the U.S. Government.

Mission of NEC’s R&D

**Core Technologies**
- Develop core technologies for AI and ICT platforms
- Focus on research into cutting-edge AI technologies using its favorable location as a mecca for high-tech
- R&D and enhancement of AI and security through social implementation in the EU
- Central Research Labs (4 research div.)
- NEC Labs America
- NEC Labs Europe
- NEC Labs China

**Solutions**
- NEC Labs India
- Israel Research Center
- NEC Labs Singapore

**Business Innovation Unit**
Create new businesses with technological seeds as a core

**Digital Business Platform Unit**
Prepare a company-wide common technological package

**Cross-Industry Unit**
Differentiate various businesses

**R&D**
7 bases in the world  900 researchers

Constantly create No.1 technologies that lead to advantages in existing and future businesses

- Create No.1 technologies unparalleled by others and solid solutions comprising those technologies as a core
- Forecast disruptive technologies and develop technologies in preparation for social changes in the future (=business opportunities)
<table>
<thead>
<tr>
<th>R&amp;D’s Contribution to Entire NEC</th>
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<tbody>
<tr>
<td><strong>Marked the World’s No. 1 for 4 consecutive times</strong> in face recognition of still images and videos under various environments; applying for the 5th No. 1 evaluation. <strong>Adopted as a new boarding procedure, One ID, at Narita Airport</strong></td>
</tr>
<tr>
<td><strong>Outcome of NEC–RIKEN-AIST AI Cooperative Research Lab.</strong> Efficiently discover very rare faults with 100 millionth probability as AI repeats simulations while it learns. Support design of equipment by simulations</td>
</tr>
<tr>
<td><strong>AI automatically calculates prediction models. A non-professional can achieve in a day what it takes several months for a professional to achieve.</strong> <strong>Established dotData Inc., which has obtained more than 20 client companies</strong></td>
</tr>
<tr>
<td><strong>Outcome of NEC–AIST AI Cooperative Research Lab.</strong> Derive optimal solutions and their grounds speedily by narrowing down candidate solutions with logical reasoning and reinforcing learning using simulations. Support optimal operations at large-scale plants</td>
</tr>
<tr>
<td><strong>Analysis of medical treatment information detects 71% of signs of patients’ agitation 40 minutes before and finds out 87% of high-risk patients for aspiration pneumonia. Support hospital management reform at Kitahara Neurosurgical Institute (KNI)</strong></td>
</tr>
<tr>
<td><strong>Overwhelmingly accelerate a statistical mathematics-type machine learning used for recommendations and other functions, by way of a vector-type computer. Enable easy and real-time AI application by complying with the spreading Spark Framework</strong></td>
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<tr>
<td><strong>Recognize multiple objects placed in a disorderly manner, such as vegetables in indefinite shapes and similar packages, at the same time. Realize object recognition PoS systems with an error ratio of 0.1% or less for more than 10,000 goods, adopted by an operating company of Seven-Eleven convenience stores in Taiwan</strong></td>
</tr>
<tr>
<td><strong>Realize a tool that allows anyone to be able to develop systems using secure computing by automatic generation of necessary codes. Support the development of a medical data distribution platform which needs safe use of data</strong></td>
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<td><strong>Predict neoantigens unique to each patient by modeling experimental data and biochemical knowledge as a knowledge graph</strong> <strong>Started clinical trials for individualized neoantigen vaccines jointly with Transgene SA</strong></td>
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<td><strong>High-speed tampering detection which can be used for IoT equipment with insufficient performance. Detect tampering of IoT equipment by a cyber attack at a factory at an early stage. Contribute to preventing damages from spreading to the destruction of production lines</strong></td>
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<tr>
<td><strong>A structure comprising points and lines that connect them</strong></td>
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<tr>
<td><strong>Nonlinear compensation using AI for the first time in the world and demonstrate the world’s best performance in optical submarine cables. Outcome of an advanced joint study with Google</strong></td>
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Competitiveness of NEC’s Research in Academia

Good presence at top-quality academic conferences tells strength in technological advantages

- **AI**
  - Ranked 5th in terms of # of accepted papers at top-quality international academic conferences on machine learning*1 (since 2000, company survey)
  - Many papers accepted at top conferences also in other AI fields*2
    - *1 NeurIPS, ICML, KDD, ECML-PKDD and ICDM
    - *2 AI in general: IJCAI, AAAI, image recognition-related: ICCV, ECCV, CVPR, etc.

- **Security**
  - Many papers accepted at top-quality academic conferences on cyber security, incl. ACM CCS, Eurocrypt and IEEE S&P, etc.

- **Network**
  - Many papers accepted at top-quality academic conferences on optical communication (OFC/ECOC) for over 30 consecutive years

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

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<thead>
<tr>
<th>No. of Accepted Papers at Top-quality Int’l Conferences (machine learning)</th>
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<tbody>
<tr>
<td>1</td>
<td>Microsoft</td>
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<tr>
<td>2</td>
<td>IBM</td>
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<tr>
<td>3</td>
<td>Google</td>
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<td>4</td>
<td>Yahoo</td>
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<td>5</td>
<td>NEC</td>
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<tr>
<td>6</td>
<td>DeepMind</td>
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<td>7</td>
<td>Facebook</td>
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<td>8</td>
<td>AT&amp;T</td>
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<td>9</td>
<td>NTT</td>
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<tr>
<td>10</td>
<td>Baidu</td>
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Contribution of No.1 Technologies to Businesses: Face Recognition Technology

World’s No.1 face recognition technology contributes to various businesses from monitoring to customer service

Win the world’s No.1 evaluation for 4 consecutive times

- No.1 accuracy in any environment
  - Whether at gates or audience seats
- High accuracy irrespective of race, gender, age, etc.
  - No.1 result in each item
  - Posture change, change by aging, multiple races

Win the world’s No.1 evaluation for 4 consecutive times

Results of NIST accuracy benchmark tests

Contribution to Businesses

Creation of social value with face recognition technology

- Walkthrough entry by face recognition
- Empty-handed payment
  - Seven-Eleven Japan
- Accurate identification and speedy boarding

Narita International Airport

One ID, new boarding procedure adopted to Narita International Airport

Reliability for Security

"NEC Group AI and Human Rights Principles" enacted in April 2019

Good environment: Test at a passenger gate
Bad environment: Test at a stadium
Enter real medical treatment sites and find issues to be solved

Solutions derived from medical treatment sites

Value to Hospitals
- Reduce workload at hospitals
- Shorten hospitalized periods
- Improve QoL

Value to Patients
- Find 87% of high-risk patients for aspiration pneumonia at early hospitalization stages
- Detect 71% of signs of patients’ agitation 40 minutes before

Analysis with explanation to which those engaging in medical treatment understand

Real-time analysis of a large quantity of data

Case
Joint efforts with Kitahara Neurosurgical Institute (KNI)

Electronic medical records × Vital data

Data from medical treatment sites × AI

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Direction of NEC’s R&D

Design social foundation with AI to realize abundant society for all people

Secure AI’s safety and fairness to enhance social acceptance of AI

- Strengthens fairness and resistance to the environment
- Collectively recognizes many faces in a wide area
- Understand inside of people and things
- Reliable AI

Extend human ability with AI which people can understand and cooperate with

- Explainability for Analysts
- Explainability and Transparency Accepted by Anyone
- AI that gives a new insight
- Collaboration among AI systems

Provide AI foundation that is easily introduced and make AI spread all over human society

- Cloud-based Use
- Realize processing on Edge with low energy consumption, compact AI systems
- Integrate distributed AI systems
- Assure security from cloud to IoT
- Improve communication performance by AI

“abundant for all people”

Realize society

- Safety
- Security
- Efficiency
- Equality

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High-level Researchers Who Support Creation of No.1 Technologies

Attracting many distinguished researchers. Both people and laboratories appeal to researchers and foster them

Internationally Acclaimed NEC Researchers

- Hitoshi Imaoka
  World’s No.1 face recognition technology
  Youngest-ever NEC Fellow

- Kazue Sako
  President of the Japan Society for Industrial and Applied Mathematics (-June)

- Ting Wang
  Verification of the world’s Fastest AI optical communication

- Ghassan Karame
  High-speed blockchain

- Mathias Niepert
  Graph-based relational learning

- Hans Peter Graf
  Development of machine learning PF “Torch”

- Manmohan Chandraker
  Computer vision

Former distinguished NEC researchers

- Yann LeCun
  ACM A.M. Turing Award in 2018
  (Highest authority in computer science)

- Vladimir N. Vapnik
  Invention of support vector machine

- Thai Jaw Shen / Yasunobu Nakamura
  Pioneers of a practical use of quantum computer

- Ronan Collobert
  Jason Weston
  ICML Test of Time Award

- Kai Yu
  Horizon Robotics CEO

- Leon Bottou
  NeurIPS Test of Time Award

- Yidong Huang
  Prof., Chair of the Department of Electronic Engineering

Maintain consistent investments in basic research, and announced a target of “300 AI researchers” for FY2018 (at IR presentation for FY2016)

⇒ Achieved a far higher level of 470 researchers and planning to further strengthen peripheral areas

⇒ Introduced the Compensation Program for Research Fellows (posts for dedicated researchers) for managerial officers in FY2015 and created Research Fellow positions

⇒ Introduced the Selective Compensation Program for Professional Researchers without limits on incentive for non-managerial employees (younger researchers)
Ecosystem-oriented R&D with NEC’s Cutting-edge Technologies as a Core

Expand NEC’s technologies externally at an early phase, taking in technologies and funds from customers/startups/VC to speed up R&D. Open innovation of an Inbound/Outbound fusion type

NEC

**Cutting-edge Technologies**
- AI
- Network
- Security

Business Unit / Unit

**Business Opportunity**

- Spin In
  - New Startups
    - dotData
      - Established in 2018
      - Provide incentives to researchers

- Spin Out/Carve Out
  - Technologies
  - Talents
  - Academia
  - External Fund
  - Partners/Startups
  - Business Knowledge
  - Customers
  - Business Person

**Field of R&D For Real-World Usecase**

- Market Needs

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# Aim of Ecosystem-oriented R&D

- Strengthening resources incl. external funds, and raising new business creation ratio are required for large-scale outcomes
- Dare to introduce top-level technology and human resources to strengthen the capability of execution

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<thead>
<tr>
<th>Strengthen Resources</th>
<th>Raise New Business Creation Ratio</th>
<th>Speedy New Business Creation of Large-scale Outcomes</th>
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<tbody>
<tr>
<td>External funds (VC, Partners)</td>
<td>Co-creation with No.1 technology as a core</td>
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<tr>
<td>Various internal and external human resources</td>
<td>Various domain knowledge</td>
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**Management measures of Ecosystem-oriented R&D**

- **Cutting-edge Core technologies**: Invest on cutting-edge technologies that contribute to NEC’s core businesses
- **Top Researchers**: Appoint AI researchers, incl. Research Fellows, dedicated as a full-time coverage
- **Business Talents**: Inject professional business persons to reinforce new business creation
Agree on joint comprehensive research themes with a vision to solve social issues with AI. Promote creation of technological outcomes which is difficult to achieve alone.

**NEC/AIST**
AI Cooperative Research Lab. (Advanced research)

- Research of technologies which integrate simulations, which compensate for lack of real-world data on social issues, and AI.

**RIKEN AIP-NEC**
Collaboration Center (Basic research)

- Research on Brain-Morphic AI platform for an ultra low power AI processing.
- Investigation of ethics and legal systems and promotion of human resource development.

**NEC/University of Tokyo**
Partnership Agreement for Future AI Research and Education in the Field of Strategic AI

- Future AI vision: Future vision of society that supports co-creation of sustainable social value achieved by various people with AI.

- Rare event discovery technology (NEC-AIST)
  AI determines next conditions for simulation while it learns the results of previous simulations. **Shortened periods to detect a fault in an optical device with 100 millionth probability from one week to one day.**

- Logical Thinking AI (NEC-RIKEN-AIST)
  Shortened periods to find an optimal solution procedure for an abnormal situation at a plant from several years to **several days**, combining narrowing down a huge number of procedures by way of logical reasoning and reinforcement learning.

Create remarkable technological outcomes

Aimed vision of society with AI
Lecture on Ecosystem-oriented R&D Plan at Stanford University

“NEC’s New Strategy for Inbound/Outbound Open Innovation”

- On Stanford University’s request
- Approx. 100 people, incl. students and entrepreneurs, attended
- Row of questioners for an hour after the lecture
- Introduced the case of dotData

View lecture on YouTube
https://youtu.be/oW1zJ_dUBAk

Video: https://www.youtube.com/watch?v=oW1zJ_dUBAk
Summary

Constantly create No.1 core technologies that contribute to NEC’s businesses and social value creation

Provide more than enough opportunities and compensations for top researchers to maintain and strengthen the ability to create technologies

Speedily provide more technological outcomes and commercialized products by way of “Ecosystem-oriented R&D” with NEC’s cutting-edge technologies as a core

Establish business competitive advantages