NEC’s R&D to Drive Future Business

December 16, 2016

NEC Corporation
Motoo Nishihara, Senior Vice President
NEC brings together and integrates technology and expertise to create the ICT-enabled society of tomorrow.

We collaborate closely with partners and customers around the world, orchestrating each project to ensure all its parts are fine-tuned to local needs.

Every day, our innovative solutions for society contribute to greater safety, security, efficiency and equality, and enable people to live brighter lives.
Table of Contents

1. Research Activity Policies for Social Value Creation
2. R&D of AI/ICT Platforms to Drive Future Business
3. R&D of Security Technologies to Drive Future Business
4. Providing “Solutions for Society” for Value Enhancement
5. Summary
Research Activity Policies for Social Value Creation
Orchestrating a brighter world

Sustainable Earth

Safer Cities & Public Services

Quality of Life

Lifeline Infrastructure

Work Style

Communication

Social value creation + Digital

Industry Eco-System
Creating social values through co-creation with customers

To drive NEC’s growth, we will
1. Focus on delivering high value solutions
2. Focus on developing and refining No.1/Only 1 technologies
3. Co-create strong solutions with our partners and customers
Our R&D policies are to pursue competitive superiority on 3 axes, supported by investigations into technology visions, expansion of global locations, open innovation, and HR management.

1. Future technology vision
2. Global R&D
3. Open innovation
4. HR management
1. Future technology vision: Linking social issues with business and technology

Exploring NEC’s future business opportunities and focus technologies by “backcasting” from social issues and technology vision

**Predicted social issues of 2030**
- Increasing threats to safety and security
- Transportation and logistics problems in expanding cities
- Increasing medical expenses owing to aging and shrinking population

**Backcasting**

**Business opportunities (solutions for society)**
- Prevention of serious crimes
- New transportation and logistics systems
- Pre-illness management

**5 axes of technological evolution**
- Insightful Sensing
- Collaborative Wisdom
- Brain-Inspired Computing
- Cloud to Edge
- Holistic Security
2. Global R&D: New organizational structure for specific objectives

1. New branch locations to engage tech talents and leading customers
2. Optimize R&D organization and promote solution developments to meet local needs

- Control tower for open innovation
- Establish technology visions

Value Co-creation Center

NEC Labs China
Security Research Labs (solution development)

NEC Labs Europe
Core technologies through standardization and EU Projects

NEC Labs America
Leveraging high-tech areas

NEC Labs Singapore
Co-creation with local government and customers

Security operation research

Create high value solutions

Refine core technologies

Japanese Research Labs
Reorganizing labs by technology areas

New global branches

- Solution Branches – where leading customers are
- Research Branches – where innovation happens

Strengthen

Strengthen

NEW

Leveraging high-tech areas

心底

Security operation research

Leveraging high-tech areas

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2. Global R&D: Further expansion through external collaboration

1. Expanding R&D ecosystems: collaborating with universities and startup investments
2. Use external funding and HR to accelerate commercialization of our technologies

Utilize and expand global labs and branches

- Top researchers
- Leading customers

R&D acceleration including M&A

- Universities and startups
- External funds and resources

External funds and resources

- External funds

Global branches

- Europe
- Singapore
- Japan
- China
- North America

- Global research labs
- Global research branches
3. Open innovation: Universities and startups

Deepen open innovation through extensive collaborative research + startup investments

Investments in open innovation

Capital investments

- To acquire technologies that NEC does not possess
- To expand collaborative research

→ Create new ecosystems including collaborations with startups

Collaborative research/BU-funded projects

- Early acquisition of future technologies
  - Found collaborative research labs
- Select areas of focus and make large investments in them

Past example

Collaborative development with an encryption technology startup realized R&D within 1 year that would normally take 3 years or more.

⇒ Apply this model to all areas

1/3 of all R&D expenses

3x compared to 2016

2015 2016 2018

1/3 of all R&D expenses

3x compared to 2016

2015 2016 2018

3x compared to 2016

2015 2016 2018
3. Open innovation: Examples of extensive collaborations on next-gen AI

NEC has begun extensive collaborations with top institutions to complement technologies that NEC does not possess. We will also leverage overseas channels and triple the scale of collaborative research.

**NEC-AIST AI Cooperative Research Laboratory**
- Combine simulations and AI to support advanced decision-making by humans even where there is little data to examine.

**NEC Brain-Inspired Computing Research Alliance Laboratories**
- Establish brain-inspired information processing architecture to achieve “post deep learning” AI processing.

**NEC/University of Tokyo Partnership Agreement for Future AI Research and Education in the Field of Strategic Artificial Intelligence (AI)**
- Research ultra-low power consumption AI processing platforms modeled after the brain and nerve system.
- Study ethical/legal systems and HR development for social implementation of AI.
4. Human resource management: AI/security fields

1. Move up the plan and push forward with cultivation of HR in the AI field
2. Explore HR in pursuit of resolving ethical/legal issues related to social implementation of AI

- **Progressing ahead of plan**
  - **2015:** 150
  - **Oct. 2016:** 220
  - **2018:** 300

- **Hiring diverse talent** (in the fields such as humanities and law)

- **Specific measures to make AI acceptable by the society**
  - Efficiency, equality, transparency
  - Clear identification of responsibilities
  - Prevention of loss of control over AI
  - Comfort sense of people’s aversion
  - Protection of privacy
  - ...
4. Human resource management: Global talent

Compensate researchers based on global standards whether they are located in Japan or overseas.

Approximately 40% of new hires have global backgrounds:

- Strengthen recruitment from globally renowned universities (e.g. Indian Institutes of Technology)
- Place top talent in our worldwide branches

Break down the border between Japanese and overseas NEC laboratories, hire top global talent and get the right people in the right places.
<table>
<thead>
<tr>
<th>Seven themes for social value creation</th>
<th>Major contributions</th>
<th>No.1/Only 1 technologies</th>
<th>Partners/customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainable Earth</td>
<td>• Released a system to detect signs of landslides in advance.</td>
<td>Landslide risk prediction</td>
<td>Local governments, etc.</td>
</tr>
<tr>
<td>Safer Cities &amp; Public Services</td>
<td>• Released AI software capable of analyzing video images of security cameras and identifying specific individuals at high speed and high precision.</td>
<td>High detail</td>
<td>Government institutions, public facilities, etc.</td>
</tr>
</tbody>
</table>
| Lifeline Infrastructure               | • Provided a biometric authentication system to a government institution in Australia.  
  • Delivered a face recognition system to a major US airport for border control.                                                           | Face recognition                                                                          | Government of Australia  
  JFK Int. Airport, U.S.                                                                                 |
| Communication                         | • Delivered an E-gate system to an immigration bureau that automatically recognizes infants as individuals and detects facial disguises.                                                                               | Liveness detection                                                                        | An Asian Immigration Bureau                                                                             |
| Industry Eco-System                  | • Started a joint business program to operate support services for thermal power plants.                                                                                                                             | Invariant analysis                                                                        | Chubu Electric Power                                                                                  |
| Work Style                           | • Started construction of the world’s first optical submarine cable crossing the South Atlantic Ocean.                                                                                                                  | Beyond-100 Gbps optical transmission                                                       | Angola Cables                                                                                         |
| Quality of Life                      | • Engaged in cooperative business with ALSOK to explore new security services.  
  • Provided cloud-based security camera services to Seven-Eleven Japan.                                                                           | Face recognition                                                                          | ALSOK  
  Seven-Eleven Japan                                                                                    |
|                                      | • Released Auto-response Solution to renovate contact center business.                                                                                                                                                  | Lightweight block cipher                                                                  | Contact center operations, etc.                                                                       |
|                                      | • Registrations in India’s unique ID system (Aadhaar Program) exceeded 1 billion people.                                                                                                                             | Recognizing textual entailment                                                             | Government of India                                                                                   |
R&D of AI/ICT Platforms to Drive Future Business
Application areas of AI/ICT on which NEC focuses

**Customers from governments/municipalities/companies**

**Real world**
A world with insufficient digitization

- Solutions for society
  (safety and infrastructure management)

**Cyber world**
A world that has been fully digitalized

- Digitalized Businesses

**Consumers**

- Consumer devices & services
- Consumer Web services
Application areas of AI/ICT on which NEC focuses

NEC will provide solutions on social issues in the real world by utilizing AI and ICT.

Real world
A world with insufficient digitization

Cyber world
A world that has been fully digitalized

Customers from governments/municipalities/companies

Consumers

NEC’s focus area: Solutions for society

Global ICT vendors

Internet Service companies
Creating social values with AI, platforms, and security

NEC’s technological platforms

Real world
- People
- Things
- Environment

Cyber world
- Visualization
- Analysis
- Prescription
- Data Science

AI and supporting platforms

ICT platforms
- Computing
- Networking

Security

Social values
- Safety
- Security
- Efficiency
- Equality

Orchestrating a brighter world
Issues with AI in creating solutions for society

Previous AI does not meet specific requirements of solutions for society

<table>
<thead>
<tr>
<th>Specific requirements of solutions for society</th>
<th>Previous AI technology</th>
</tr>
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<tbody>
<tr>
<td>Deep understanding of the real world</td>
<td>Applicable to organized digital information</td>
</tr>
<tr>
<td>Diverse and complex domain knowledge</td>
<td>Dependent on the experience of domain experts and analysts</td>
</tr>
<tr>
<td>Response to unknown or rare cases (small data)</td>
<td>Requires big data</td>
</tr>
<tr>
<td>Real-time and on-site processing</td>
<td>Requiring high-performance/high-power cloud</td>
</tr>
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Inference from raw data such as images, video, and sensor data

Deep domain knowledge on how to make specific social systems work

Flexible handling of abnormal cases or natural disasters with few examples

Power limitation in IoT, real-time requirement
Issues with AI in creating solutions for society

Previous AI does not meet specific requirements of solutions for society

Specific requirements of solutions for society

- **Deep understanding of the real world**
  - Inference from raw data such as images, video, and sensor data

- **Diverse and complex domain knowledge**
  - Deep domain knowledge on how to make specific social systems work

- **Response to unknown or rare cases (small data)**
  - Flexible handling of abnormal cases or natural disasters with few examples

- **Real-time and on-site processing**
  - Power limitation in IoT, real-time requirement

**NEC’s AI technology**

- **Video/speech recognition**
- **Automatic feature extraction without needing a specialist**
- **Machine learning even from small data**
- **AI processors running only at several tens of watts**
Evolution of NEC’s AI technology for supporting solutions for society

Take a commanding lead with AI for creating solutions for society based on real-world understanding

Social value

NEC’s AI technology

Video/speech recognition

Automatic feature extraction without needing a specialist

Machine learning even from small data

AI processors running only at several tens of watts

Organized digital information

Analysis requiring involvement of specialists

Machine learning based on big data

Centralized processing on cloud

Areas that can be achieved by current AI

Cyber world

Real world
Breakthrough technologies covered in today’s presentation

Creating social values with AI, platforms, and security

1. Predictive analytics automation technology
2. Brain-inspired computing

Social values: Safety, Security, Efficiency, Equality
1. Predictive analytics automation technology: Data analysis issues

Previously, heavy involvement of domain experts has been required to perform analysis.

**Dependent on analysis expertise**

Specialized analysts are needed to relate complex data.

**Significant time required for analysis**

Need to analyze a large amount of data over a long period of time.

**Specialists are needed for each solution for society**

Increasing analysis costs.
By automating the trial-and-error process performed by specialists, the analysis period of 2 to 3 months can be shortened to 1 day.

Analysis process

Data organization

Non-specialists

Feature extraction

Specialists

Model generation and analysis

Y = a₁x₁ + … + kₙxₙ

Y = b₁x₂ + … + hₙxₙ

Y = c₁x₄ + … + fₙxₙ

Interview on issues

(1) Automatic feature extraction design

Automatically search for features from large amounts of diverse data without relying on the experience and intuition of specialists.

Predictive analytics automation technology

(2) Automatic prediction model design

Search various models of different types, and automatically generate a model able to make predictions with best accuracy.
1. Substantial improvement in efficiency of managed service businesses
2. Competitive superiority in the rapidly-growing self-service analysis market*

Predictive analytics automation: Transforming the data analysis business

Managed services

Overwhelming reduction of analysis lead time
(substantial improvement in productivity)

Self-service analysis (new)

Analysis is made easy even for non-specialists

Predictive analytics automation technology

*5 times greater growth rate than general data analysis markets (Gartner)
2. Brain-inspired computing: Reducing power consumption for AI processing

Dramatically reduces power consumption, enabling AI processing even on edge devices for various solutions for society.

- **Large-scale cloud**: Several hundred kW or more
- **Human brain**: 20W
- **Brain-inspired computing**: Reducing power consumption for AI processing
Use of analog circuits imitating cerebral electrical activity improves the power efficiency of AI processing by over 10,000 times.

**Current approach**

- Artificial neural net model
- Software processing on many general-purpose CPUs
- Large-scale cloud

**New architecture NEC is working on**

- Shift to models based on the structure of the human brain
- Nerve cell connections (synapses)
- Nerve cells (neurons)
- "Brain-morphic" model
- Hardware processing using specialized analog circuits

Power consumption for AI processing:

- > several hundred kW
- Power consumption roughly equivalent to that of 100 households

Power consumption:

- < 20W
- Power consumption equivalent to that of 1 light bulb

Collaboration with U. Tokyo
R&D of Security Technologies to Drive Future Business
NEC’s technological platforms

Creating social values with AI, platforms, and security
1. System defense from both physical and cyber attacks
2. Data protection with robust encryption technology
Breakthrough technologies covered in today’s presentation

Creating social values with AI, platforms, and security

Real world

People  Things  Environment

Cyber world

Visualization   Analysis   Prescription

AI (data science)

ICT platforms

Computing   Networking

Social values

Safety   Security

Efficiency   Equality

1. Secure computation
1. Secure computation: Robust prevention against data breaches

Eliminating the risk of data breaches by processing encrypted data without decryption

Data lifecycle

Create → Transmit → Record → Aggregate → Analyze → Store/Discard

Secure computation

- Encrypted data processed without being decrypted
- IoT devices
  - Lightweight block cipher*
  - Data robustly encrypted even with less powerful devices
- Cloud
  - Statistical processing
  - Analysis results
  - Data analysts
  - Previous issues:
    - Slow processing speed
    - Less versatility

*Under study at NIST
1. Secure computation: Exceptionally high speed calculation

1. Completed high-speed multi-party computation technology development
2. Comparisons show it is 10x faster than competitors (best in the world)

**Multi-party computation**

Encrypt data and store as fragments

- Encrypt data and store as fragments
- Processed without decryption

**Achievement of extraordinarily high speeds**

- Other companies
- NEC

<table>
<thead>
<tr>
<th>Frequency of secure computations (AES)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>1,000,000</td>
</tr>
<tr>
<td>2,000,000</td>
</tr>
</tbody>
</table>

More than 10x faster

Can be applied to authentication and big data processing

**Eliminate data breach risks**

- Data remain encrypted while being processed
- Even if data is stolen, it cannot be decoded

Store and process confidential information
Providing “Solutions for Society” for Value Enhancement
Major solution co-creation activities in 2016

Creating solutions for NEC’s future businesses through global co-creation activities

59 projects launched globally and more than 10 high value solutions created

- **Southeast Asia: International airport**
  Airport monitoring

- **North America: Stadium**
  Stadium entry monitoring

- **Japan: Major drugstore**
  Next-generation retail IT service

- **Japan: Kitahara International Hospital**
  Hospital operation optimization

- **Singapore: SMRT**
  Public transportation operation optimization

- **Japan: Sumitomo Mitsui Trust Bank**
  Blockchain verification for liquidation of receivables
Solution R&D currently being tested

Enhance values in NEC’s focused business areas and new business areas to drive NEC’s mid to long term growth.

- **Safety**: Criminal investigation assistance
- **Retail**: Store operation support
- **Smart transportation**: Transportation operation support
- **Large-scale plants**: Facility maintenance support
- **Infrastructure maintenance management**: Remote internal deterioration diagnosis
- **Healthcare**: Resource operation optimization

- **Early resolution of criminal investigations**
- **Rapid initial response**
- **Crime prevention**
- **Floor operation support**
- **Backyard operation support**
- **Automation of store management**
- **Bus operation optimization**
- **Optimization of hybrid transportation**
- **Stable plant operation**
- **Operation optimization**
- **Deterioration prediction**
- **Automatic maintenance planning**
- **Recurrence prevention and pre-illness management**
Safety solutions for crime prevention

Enhance solution values by realizing earlier concluding of investigations, quicker response to crimes, and crime prevention

~2016
- Earlier concluding of investigations
  - List comparison
- Face recognition

~2018
- Quicker response to crimes
  - Detection of suspicious sounds and abnormal crowd behavior
- Specific behavior recognition
- Crowd behavior analysis

2020
- Crime prevention
  - Detection of suspicious behavior
- Psychological inference
- Integration with background and other related cyber information
- NIST’s next challenge
  - No.1: Ranked as the 1st place in three consecutive times in benchmark tests held by the National Institute of Standards and Technology (NIST) in the U.S.
  - No.2: Ranked as the 1st place at “DCASE2016”, an international contest in sound event detection (2016).

Enhancement of solution values by realizing earlier concluding of investigations, quicker response to crimes, and crime prevention

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For quicker response to crimes

Contribute to many businesses through solutions for criminal investigations - now targeting to identify situations where crimes might occur and improve response to them.

Earlier concluding of investigations (up to 2016)

- Identification of specified people or objects
  - Prevention of entry into countries by criminals
  - Determining face authenticity
    - Masked
    - Real
  - Prevention of entry into countries by criminals

Quicker response to crimes (up to 2018)

- Understanding the situations where crimes might occur
  - Detection of suspicious sounds
  - Detection of abnormal crowd behavior
  - Detection of abnormal crowd behavior

Border control system
- Adopted by international airports around the world, including airports in 14 cities in Brazil, and JFK International Airport in the U.S.

Face recognition
- No.1 Commercialized

e-Gate system
- Adopted by immigration bureau of an Asian country

Liveness detection

Ee acoustic situation recognition
- Detection of screams or jeers, sounds of glass shattering, gunfire, etc.

Detection of abnormal crowd behavior
- Prediction of abnormal movement of people accurately and at high speed, even in crowds numbering several tens of thousands.
Crime prevention

Understand and speculate backgrounds, plans, and psychology of criminals that could trigger crimes before they actually happen

**Crime prevention (by 2020)**

- **Detection of specified situations**
- **Remote gaze detection**
- **Face Recognition (non-frontal)**
- **Recognizing textual entailment**
- **Specified situations** (placement of suspicious objects, etc.)
- **Behavioral and psychological states** (behavior toward surroundings)
- **Suspicious behavior** (loitering, reconnaissance)
- **Background of incidents that have occurred**
- **Integration**
  - Understanding of backgrounds/plans/psychology of criminals
  - Predict risk
  - Prescribe actions

**Successful case**

Automobile thefts: reduced by **80%**
(Tigre, Argentina)

*Comparison from 2013 to 2014*
Core technologies for safety businesses

**Video image face recognition, Remote gaze detection**

Find multiple registered individuals from a distance

Detect the gaze of people accurately in real time

**Crowd behavior analysis**

Predict crowd conditions that will occur 20 to 30 minutes later, and prevent abnormal crowding with guidance appropriate to the situation

Predict the flow of movement on a scale of tens of thousands of people with high accuracy

**Acoustic situation recognition**

Accurately detect the occurrence of abnormal situations or incidents that cannot be detected by cameras

Ranked 1st at "DCASE2016", an international sound event detection contest

**Adaptive video delivery technology**

Transmits smooth, high-resolution video images even in communication environments of extremely poor quality

Adaptive video delivery technology that supports security, relief activities, and disaster prevention
Summary

Trinity of R&D management for the co-creation of social values

1. Technology visions and R&D to drive future business
2. No.1 AI/security technology to support future business
3. Creating solutions for society that are one notch above the rest

Global and open R&D strategies will contribute to the creation of new solutions for society businesses
Cautionary Statement with Respect to Forward-Looking Statements

This material contains forward-looking statements regarding estimations, forecasts, targets and plans in relation to the results of operations, financial conditions and other overall management of the NEC Group (the “forward-looking statements”). The forward-looking statements are made based on information currently available to NEC and certain assumptions considered reasonable as of the date of this material. These determinations and assumptions are inherently subjective and uncertain. These forward-looking statements are not guarantees of future performance, and actual operating results may differ substantially due to a number of factors.

The factors that may influence the operating results include, but are not limited to, the following:

- Effects of economic conditions, volatility in the markets generally, and fluctuations in foreign currency exchange and interest rate
- Trends and factors beyond the NEC Group’s control and fluctuations in financial conditions and profits of the NEC Group that are caused by external factors
- Risks arising from acquisitions, business combinations and reorganizations, including the possibility that the expected benefits cannot be realized or that the transactions may result in unanticipated adverse consequences
- Developments in the NEC Group’s alliances with strategic partners
- Effects of expanding the NEC Group’s global business
- Risk that the NEC Group may fail to keep pace with rapid technological developments and changes in customer preferences
- Risk that the NEC Group may lose sales due to problems with the production process or due to its failure to adapt to demand fluctuations
- Defects in products and services
- Shortcomings in material procurement and increases in delivery cost
- Acquisition and protection of intellectual property rights necessary for the operation of business
- Risk that intellectual property licenses owned by third parties cannot be obtained and/or are discontinued
- Risk that the NEC Group may be exposed to unfavorable pricing environment due to intensified competition
- Risk that a major customer changes investment targets, reduces capital investment and/or reduces the value of transactions with the NEC Group
- Risk that the NEC Group may be unable to provide or facilitate payment arrangements (such as vendor financing) to its customers on terms acceptable to them or at all, or risk that the NEC Group’s customers are unable to make payments on time, due to the customers’ financial difficulties or otherwise
- Risk that the NEC Group may experience a substantial loss of, or an inability to attract, talented personnel
- Risk that the NEC Group’s ability to access the commercial paper market or other debt markets are adversely affected due to a downgrade in its credit rating
- Risk that the NEC Group may incur large costs and/or liabilities in relation to internal control, legal proceedings, laws and governmental policies, environmental laws and regulations, tax practice, information management, and human rights and working environment
- Consequences of natural and fire disasters
- Changes in methods, estimates and judgments that the NEC Group uses in applying its accounting policies
- Risk that the NEC Group may incur liabilities and losses in relation to its retirement benefit obligations

The forward-looking statements contained in this material are based on information that NEC possesses as of the date hereof. New risks and uncertainties come up from time to time, and it is impossible for NEC to predict these events or how they may affect the NEC Group. NEC does not intend to update or revise any forward-looking statements, whether as a result of new information, future events or otherwise.

Note: In this presentation, the accounting periods of the fiscal years for March 31, 2015 and 16 were referred as FY15/3 and FY16/3 respectively. Any other fiscal years would be referred similarly.