NEC’s R&D to Drive Future Business

December 16, 2016

NEC Corporation
Motoo Nishihara, Senior Vice President
Orchestrating a brighter world

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
- Industry Eco-System

Social value creation + Digital
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

Seven Themes for Social Value Creation

- Customer challenges
- Core competency
- Competitor analysis/NEC’s strategy
- Focus Solutions
- Partners (Technical cooperation)
- Solution prototyping
- Validate value with partners and leading customers
- Customers (knowledge/validation)

Create Solutions for Society

- Safety
- Security
- Efficiency
- Equality
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

- NEC Labs China
  - Security Research Labs (solution development)
  - Security operation research

- 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

- NEC Research Labs
  - Reform
  - Reorganizing labs by technology areas

- Value Co-creation Center
  - Control tower for open innovation
  - Establish technology visions

- New global branches
  - Solution Branches – where leading customers are
  - Research Branches – where innovation happens

- Top research institutes
  - Leading start-ups

- Local customers and partners
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

Global branches
- Europe
- Japan
- China
- North America
- Singapore

Global research labs
- Global research branches

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3. Open innovation: Universities and startups

Deepen open innovation through extensive collaborative research + startup investments

**Investments in open innovation**

- 3x compared to 2016
- 1/3 of all R&D expenses

**Collaborative research/BU-funded projects**
- Early acquisition of future technologies
  - Found **collaborative research labs**
- Select areas of focus and make large investments in them

**Capital investments**

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

→ **Create new ecosystems including collaborations with startups**

**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**
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

- **Number of AI researchers**
  - 2015: 150
  - Oct. 2016: 220
  - 2018: 300

- **Progressing ahead of plan**

- **Strive to resolve potential issues related to social implementation of AI by**
  
  - **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.
## Major business contributions (2016)

<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></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>Profiling across spatio-temporal data</td>
<td>Government institutions, public facilities, etc.</td>
</tr>
<tr>
<td>Safer Cities &amp; Public Services</td>
<td>Provided a biometric authentication system to a government institution in Australia.</td>
<td>Face recognition</td>
<td>Government of Australia</td>
</tr>
<tr>
<td></td>
<td>Delivered a face recognition system to a major US airport for border control.</td>
<td></td>
<td>JFK Int. Airport, U.S.</td>
</tr>
<tr>
<td>Lifeline Infrastructure</td>
<td>Delivered an E-gate system to an immigration bureau that automatically recognizes infants as individuals and detects facial disguises.</td>
<td>Liveness detection</td>
<td>An Asian Immigration Bureau</td>
</tr>
<tr>
<td>Communication</td>
<td>Started a joint business program to operate support services for thermal power plants.</td>
<td>Invariant analysis</td>
<td>Chubu Electric Power</td>
</tr>
<tr>
<td>Industry Eco-System</td>
<td>Started construction of the world’s first optical submarine cable crossing the South Atlantic Ocean.</td>
<td>Beyond-100 Gbps optical transmission</td>
<td>Angola Cables</td>
</tr>
<tr>
<td>Work Style</td>
<td>Engaged in cooperative business with ALSOK to explore new security services.</td>
<td>Face recognition</td>
<td>ALSOK</td>
</tr>
<tr>
<td></td>
<td>Provided cloud-based security camera services to Seven-Eleven Japan.</td>
<td>Lightweight block cipher</td>
<td>Seven-Eleven Japan</td>
</tr>
<tr>
<td>Quality of Life</td>
<td>Released Auto-response Solution to renovate contact center business.</td>
<td>Recognizing textual entailment</td>
<td>Contact center operations, etc.</td>
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<tr>
<td></td>
<td>Registrations in India’s unique ID system (Aadhaar Program) exceeded 1 billion people.</td>
<td>Fingerprint and face recognition</td>
<td>Government of India</td>
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</tbody>
</table>
R&D of AI/ICT Platforms to Drive Future Business
Application areas of AI/ICT on which NEC focuses

<table>
<thead>
<tr>
<th>Real world</th>
<th>Cyber world</th>
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<tr>
<td>A world with insufficient digitization</td>
<td>A world that has been fully digitalized</td>
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</tbody>
</table>

**Customers from governments/municipalities/companies**

**Solutions for society**

(safety and infrastructure management)

**Cyber world**

**Digitalized Businesses**

**Consumers**

**Consumer devices & services**

**Consumer Web services**

- A world with insufficient digitization
- Solutions for society (safety and infrastructure management)
- A world that has been fully digitalized
- Digitalized Businesses
- 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

Customers from governments/municipalities/companies

Real world
A world with insufficient digitization

Solutions for society
NEC’s focus area

Internet Service companies

Cyber world
A world that has been fully digitalized

Global ICT vendors

Consumers

Internet Service companies

Customers from governments/municipalities/companies

Real world
A world with insufficient digitization

Solutions for society
NEC’s focus area

Internet Service companies

Cyber world
A world that has been fully digitalized

Global ICT vendors

Consumers
Creating social values with AI, platforms, and security
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

Previous AI technology

- Applicable to organized digital information
- Dependent on the experience of domain experts and analysts
- Requires big data
- Requiring high-performance/high-power cloud
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**
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**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

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

Social value

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
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.
1. Predictive analytics automation: Transforming the data analysis business

1. Substantial improvement in efficiency of managed service businesses
2. Competitive superiority in the rapidly-growing self-service analysis market*

**Managed services**

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

**Self-service analysis (new)**

Analysis is made easy even for non-specialists

---

*5 times greater growth rate than general data analysis markets (Gartner)*
Dramatically reduces power consumption, enabling AI processing even on edge devices for various solutions for society.
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

Power consumption for AI processing: > several hundred kW

Power consumption roughly equivalent to that of 100 households

**New architecture NEC is working on**

Shift to models based on the structure of the human brain

Nerve cell connections (synapses) → Hardware processing using specialized analog circuits → Devices/terminals

Power consumption: < 20W

Power consumption equivalent to that of 1 light bulb

Collaboration with U. Tokyo

2. Brain-inspired computing: Ultra-efficient AI processing
R&D of Security Technologies to Drive Future Business
Creating social values with AI, platforms, and security

NEC’s technological platforms

Cyber world
- Visualization
- Analysis
- Prescription

AI (data science)

ICT platforms
- Computing
- Networking

Security platforms

Real world
- People
- Things
- Environment

Social values
Security technology to support solutions for society

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
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

Data robustly encrypted even with less powerful devices

Encrypted data processed without being decrypted

Lightweight block cipher*

Previous issues:
• Slow processing speed
• Less versatility

IoT devices

*Under study at NIST

Cloud

Statistical processing

Analysis results

Data analysts

1. Secure computation: Robust prevention against data breaches
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)

Achievement of extraordinarily high speeds

- Can be applied to authentication and big data processing

Encrypt data and store as fragments

- Multi-party computation
- Frequency of secure computations (AES)
- More than 10x faster

Eliminate data breach risks

- Store and process confidential information
- Even if data is stolen, it cannot be decoded
- Data remain encrypted while being processed

Multi-party computation

- Encrypt data and store as fragments
- Fragment 1
- Fragment 2
- Fragment 3

Encryption data and store as fragments

- Frequency of secure computations (AES)
- Other companies
- NEC
- More than 10x faster

Frequency of secure computations (AES)
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

<table>
<thead>
<tr>
<th>Safety</th>
<th>Criminal investigation assistance</th>
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</thead>
<tbody>
<tr>
<td>Retail</td>
<td>Store operation support</td>
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<tr>
<td>Smart transportation</td>
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<tr>
<td>Safety</td>
<td>Large-scale plants</td>
</tr>
<tr>
<td>Safety</td>
<td>Infrastructure maintenance management</td>
</tr>
<tr>
<td>Healthcare</td>
<td></td>
</tr>
</tbody>
</table>

- **Early resolution of criminal investigations**
- **Rapid initial response**
- **Crime prevention**
- **Floor operation support**
- **Backyard operation support**
- **Optimization of hybrid transportation**
- **Transportation operation support**
- **Bus operation optimization**
- **Optimization of hybrid transportation**
- **Facility maintenance support**
- **Stable plant operation**
- **Operation optimization**
- **Remote internal deterioration diagnosis**
- **Deterioration prediction**
- **Automatic maintenance planning**
- **Resource operation optimization**
- **Treatment support**
- **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
- Quicker response to crimes
  - Detection of suspicious sounds and abnormal crowd behavior

~2018
- Quicker response to crimes
  - Detection of suspicious behavior

2020
- Crime prevention
  - Psychological inference
  - Integration with background and other related cyber information

NIST’s next challenge
- Face recognition
- Specific behavior recognition
- Crowd behavior analysis
- Remote gaze detection
- Recognizing textual entailment
- Profiling across spatio-temporal data

New
- Low-resolution recognition
- Acoustic situation recognition
- Only

Only
- 1

*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.
*2: Ranked as the 1st place at “DCASE2016”, an international contest in sound event detection (2016).
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
    - Commercialized
    - 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.
  - Determining face authenticity
    - Commercialized
    - e-Gate system
      - Adopted by immigration bureau of an Asian country

Quicker response to crimes (up to 2018)
- Understanding the situations where crimes might occur
  - Detection of suspicious sounds
    - Presentation today
    - 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.

Identification of specified people or objects
- Face recognition
  - No. 1 Face recognition
  - Commercialized
  - Border control system

Liveness detection
- Determining face authenticity
  - Commercialized
  - e-Gate system

Acoustic situation recognition
- Detection of suspicious sounds
  - Presentation today
  - Detection of screams or jeers, sounds of glass shattering, gunfire, etc.

Crowd behavior analysis
- Detection of abnormal crowd behavior
  - Only
  - Presentation today
  - 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)**

- **Real world information**
  - Camera video images, etc.
- **NEC’s powerful recognition AI**
  - Detection of specified situations
  - Remote gaze detection
  - Face Recognition (non-frontal)
  - Profiling across spatio-temporal data
- **Cyber information**
  - SNS, e-mail
- **Visualization**
  - Specified situations (placement of suspicious objects, etc.)
  - Behavioral and psychological states (behavior toward surroundings)
  - Suspicious behavior (loitering, reconnaissance)
- **Analysis and prescription**
  - Background of incidents that have occurred
  - Understanding of backgrounds/plans/psychology of criminals
  - Predict risk
  - Prescribe actions

**Integration**

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 that supports security, relief activities, and disaster prevention

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

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

Technology visions and R&D to drive future business

No.1 AI/security technology to support future business

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
Orchestrating a brighter world

NEC
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.