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.

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Research Activity Policies for Social Value Creation

NEC

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Sustainable Earth

Safer Cities & Public Services

Quality of Life

Lifeline Infrastructure

Social value creation
+
Digital

Work Style

Communication
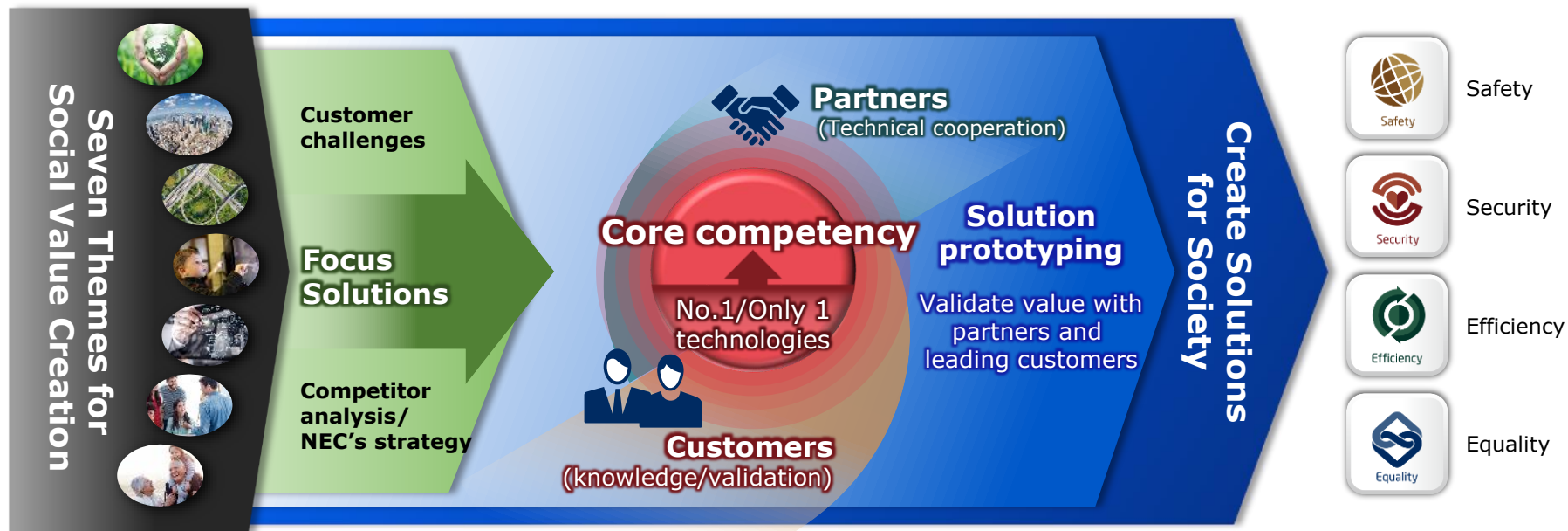
Industry Eco-System

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Creating social values through co-creation with customers
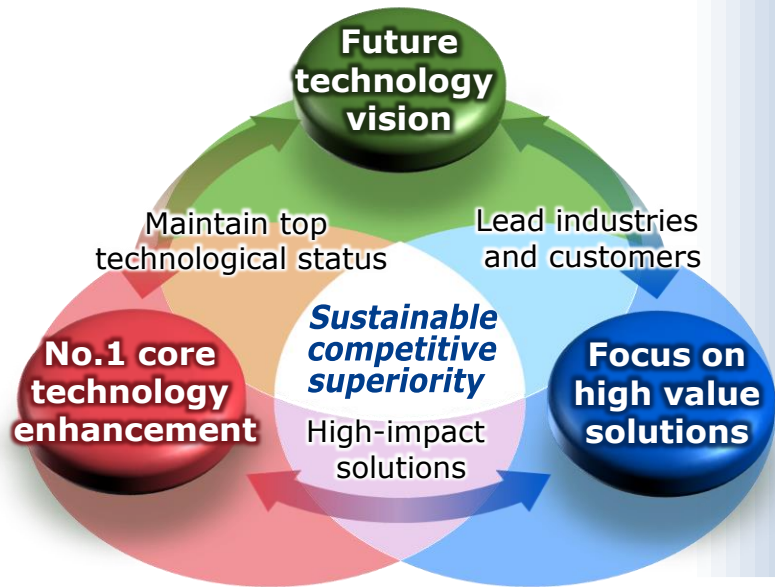
To drive NEC's growth, we will
1. Focus on delivering high value solutions
2. Focus on developing and refining No.1/Only 1 technologies
3. Co-create strong solutions with our partners and customers

Seven Themes for Social Value Creation

Customer challenges

Focus Solutions

Competitor analysis/ NEC's strategy

Partners
(Technical cooperation)

Core competency

No.1/Only 1 technologies

Solution prototyping

Validate value with partners and leading customers

Customers
(knowledge/validation)

Create Solutions for Society

Safety

Security

Efficiency

Equality

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R&D policies and actions

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

Policies

- Future technology vision
- Maintain top technological status
- Lead industries and customers
- No.1 core technology enhancement
- *Sustainable competitive superiority*
- Focus on high value solutions
- High-impact solutions

Actions

1. Future technology vision
2. Global R&D
3. Open innovation
4. HR management

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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

Back casting

Business opportunities (solutions for society)

Prevention of serious crimes

New transportation and logistics systems

Pre-illness management

...

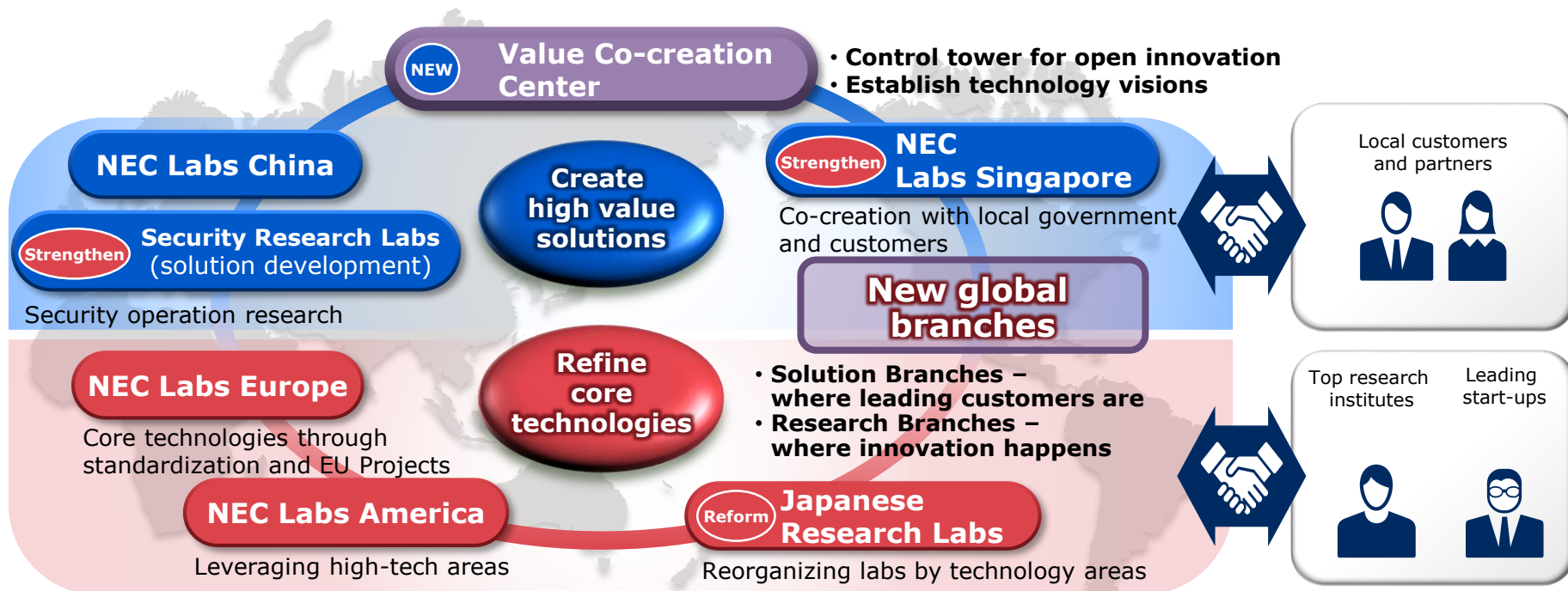## 5 axes of technological evolution

Insightful Sensing

Collaborative Wisdom
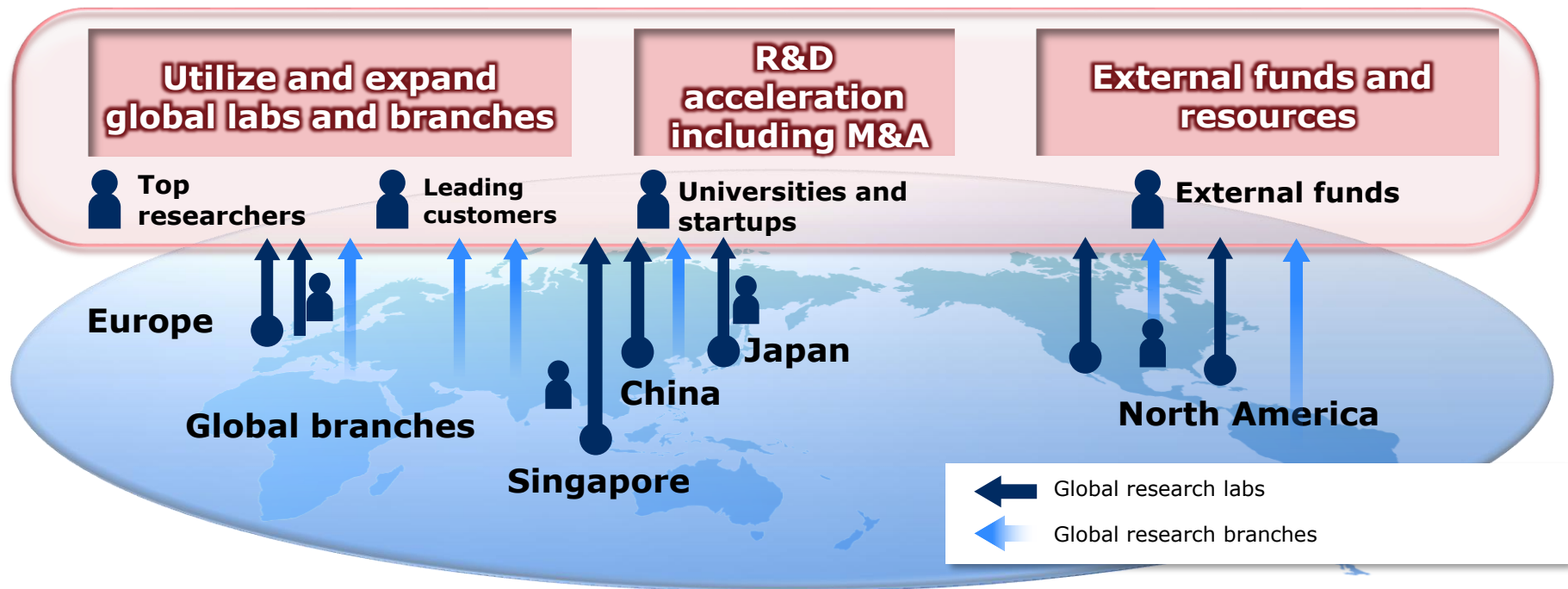
Brain-Inspired Computing

Cloud to Edge

Holistic Security

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

NEW **Value Co-creation Center**

- **Control tower for open innovation**
- **Establish technology visions**

NEC Labs China

Strengthen **Security Research Labs** (solution development)

Security operation research

Create high value solutions

Strengthen **NEC Labs Singapore**

Co-creation with local government and customers

New global branches

Local customers and partners

Refine core technologies

NEC Labs Europe

Core technologies through standardization and EU Projects

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

Top research institutes

Leading start-ups

NEC Labs America

Leveraging high-tech areas

Reform **Japanese Research Labs**

Reorganizing labs by technology areas

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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

R&D acceleration including M&A

External funds and resources

Top researchers

Leading customers

Universities and startups

External funds

Europe

Global branches

Singapore

China

Japan

North America

Global research labs

Global research branches

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Deepen open innovation through extensive collaborative research + startup investments

Investments in open innovation

1/3 of all R&D expenses

3x compared to 2016

2015 2016 2018
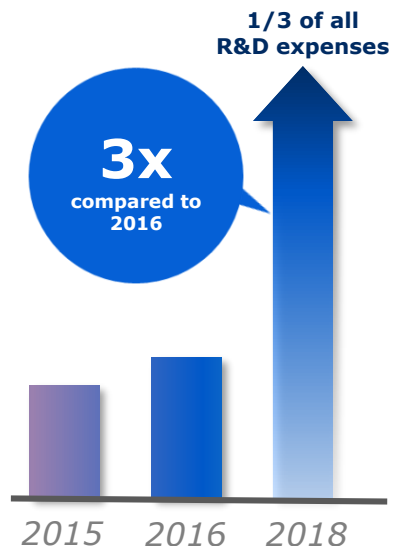
Collaborative research/ BU-funded projects

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

Universities

Research institutions

Capital investments

- To acquire technologies that NEC does not possess
- To expand collaborative research
→ **Create new ecosystems including collaborations with startups**

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Startup companies

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**

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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

AIST
National Institute of Advanced Industrial Science and Technology

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

大阪大学 OSAKA UNIVERSITY

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

東京大学 THE UNIVERSITY OF TOKYO

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

Scale of collaborative research

3x

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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

Progressing ahead of plan

2015: **150**

Oct. 2016: **220**

2018: **300**
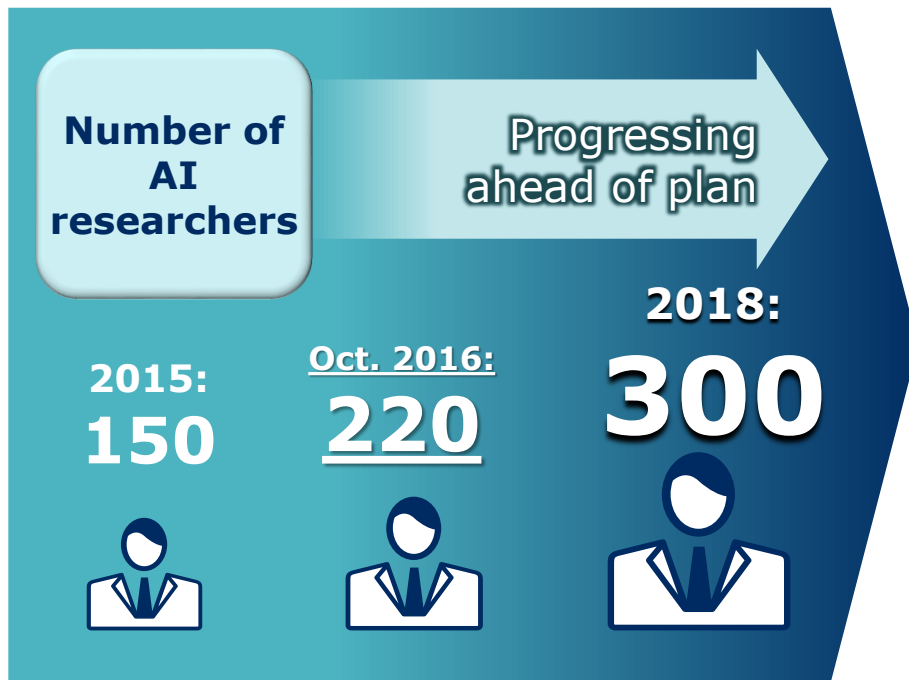
Strive to resolve potential issues related to social implementation of AI by

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	...

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

Global talents

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

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Major business contributions (2016)

Seven themes for social value creation	Major contributions	No.1/Only 1 technologies	Partners/customers
Sustainable Earth	• Released a system to detect signs of landslides in advance.	Landslide risk prediction	Local governments, etc.
	• Released AI software capable of analyzing video images of security cameras and identifying specific individuals at high speed and high precision.	High speed — Profiling across spatio-temporal data	Government institutions, public facilities, etc.
Safer Cities & Public Services	• Provided a biometric authentication system to a government institution in Australia. • Delivered a face recognition system to a major US airport for border control.	No.1 — Face recognition	Government of Australia / JFK Int. Airport, U.S.
Lifeline Infrastructure	• 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
	• Started a joint business program to operate support services for thermal power plants.	Only 1 — Invariant analysis	Chubu Electric Power
Communication	• Started construction of the world's first optical submarine cable crossing the South Atlantic Ocean.	World's first — Beyond-100 Gbps optical transmission	Angola Cables
Industry Eco-System	• Engaged in cooperative business with ALSOK to explore new security services.	No.1 — Face recognition	ALSOK
	• Provided cloud-based security camera services to Seven-Eleven Japan.	Lightweight block cipher	Seven-Eleven Japan
Work Style	• Released Auto-response Solution to renovate contact center business.	No.1 — Recognizing textual entailment	Contact center operations, etc.
Quality of Life	• Registrations in India's unique ID system (Aadhaar Program) exceeded 1 billion people.	No.1 — Fingerprint and face recognition	Government of India

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R&D of AI/ICT Platforms to Drive Future Business

Application areas of AI/ICT on which NEC focuses

	Customers from governments/ municipalities/companies	**Consumers**
Real world A world with insufficient digitization	**Solutions for society** (safety and infrastructure management)	**Consumer devices & services**
Cyber world A world that has been fully digitalized	**Digitalized Businesses**	**Consumer Web services**

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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
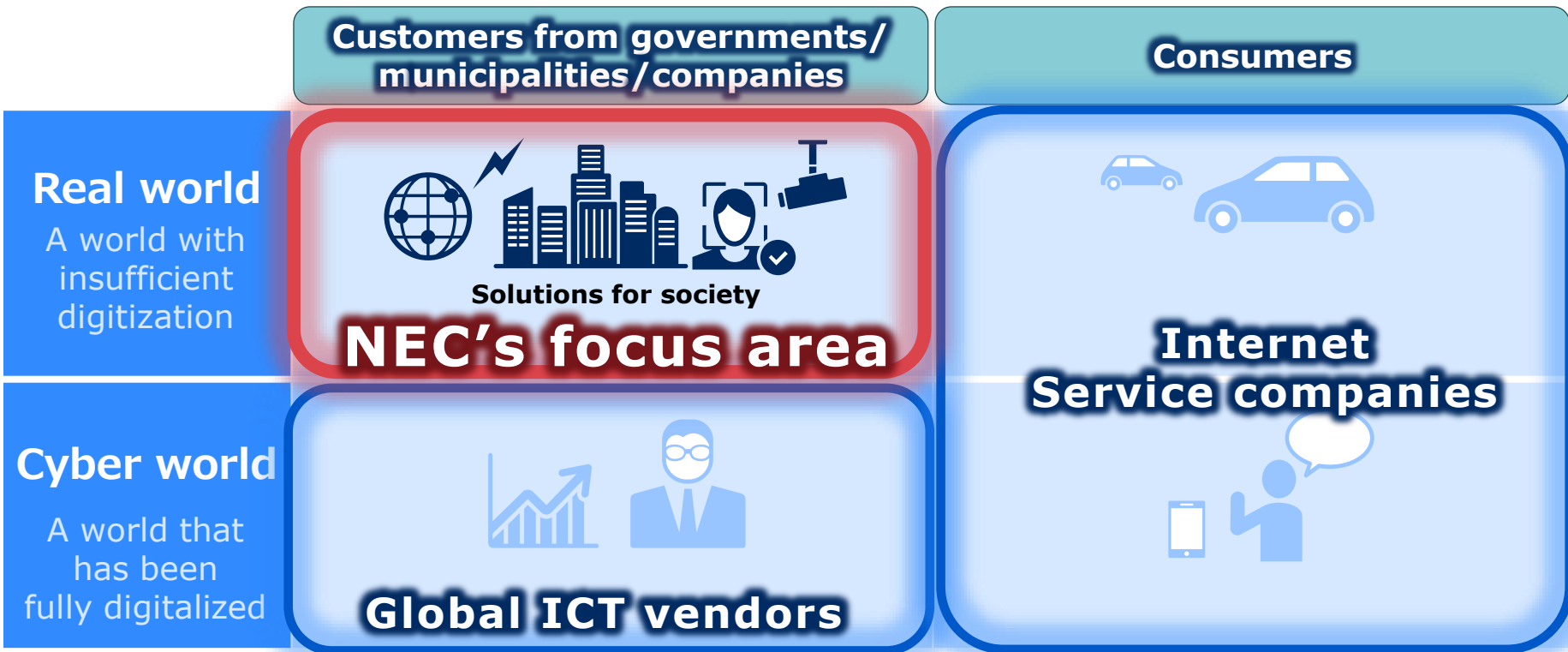
	Customers from governments/ municipalities/companies	Consumers
Real world A world with insufficient digitization	**Solutions for society** **NEC's focus area**	**Internet Service companies**
Cyber world A world that has been fully digitalized	**Global ICT vendors**	

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Creating social values with AI, platforms, and security

Real world

People

Things

Environment

Social values

Safety

Security

Efficiency

Equality

Cyber world

Visualization

Analysis

Prescription

AI and supporting platforms

AI (data service)

ICT platforms

Computing

Networking

Security

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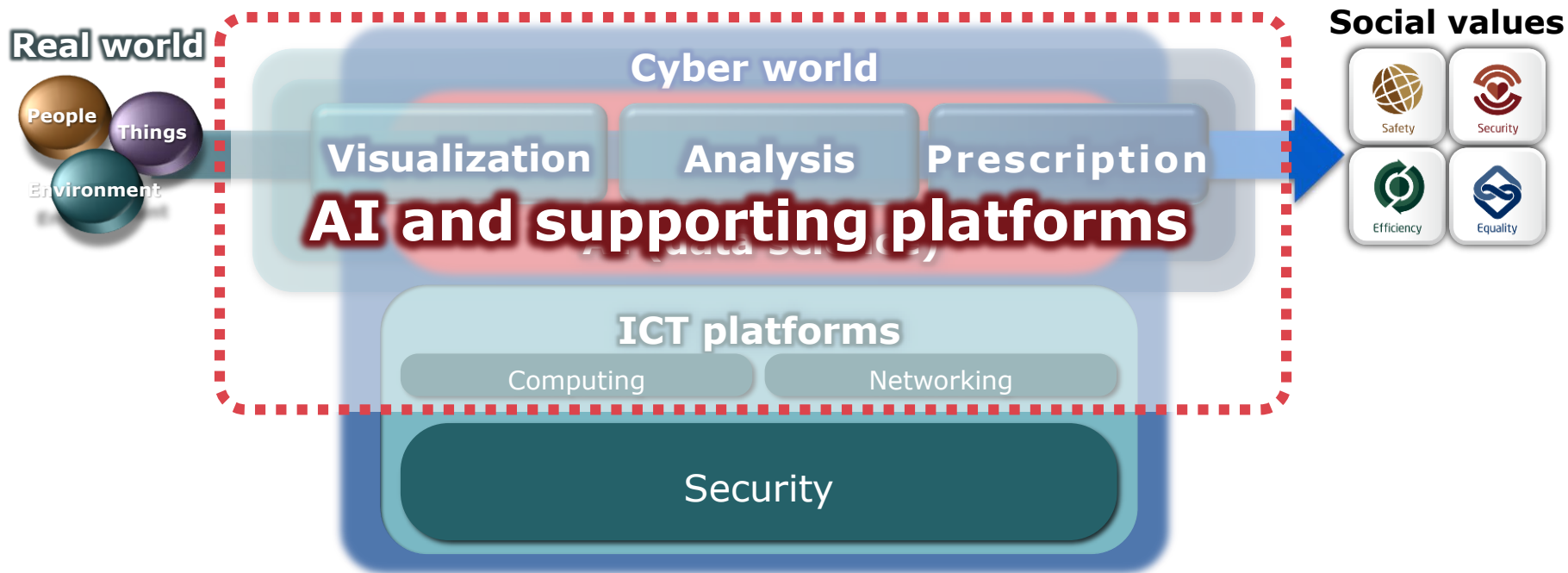
Issues with AI in creating solutions for society

Previous AI does not meet specific requirements of solutions for society

Specific requirements of solutions for society

Previous AI technology

Deep understanding of the real world	Inference from raw data such as images, video, and sensor data	✗	Applicable to organized digital information
Diverse and complex domain knowledge	Deep domain knowledge on how to make specific social systems work	✗	Dependent on the experience of domain experts and analysts
Response to unknown or rare cases (small data)	Flexible handling of abnormal cases or natural disasters with few examples	✗	Requires big data
Real-time and on-site processing	Power limitation in IoT, real-time requirement	✗	Requiring high-performance/ high-power cloud

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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

NEC's AI technology

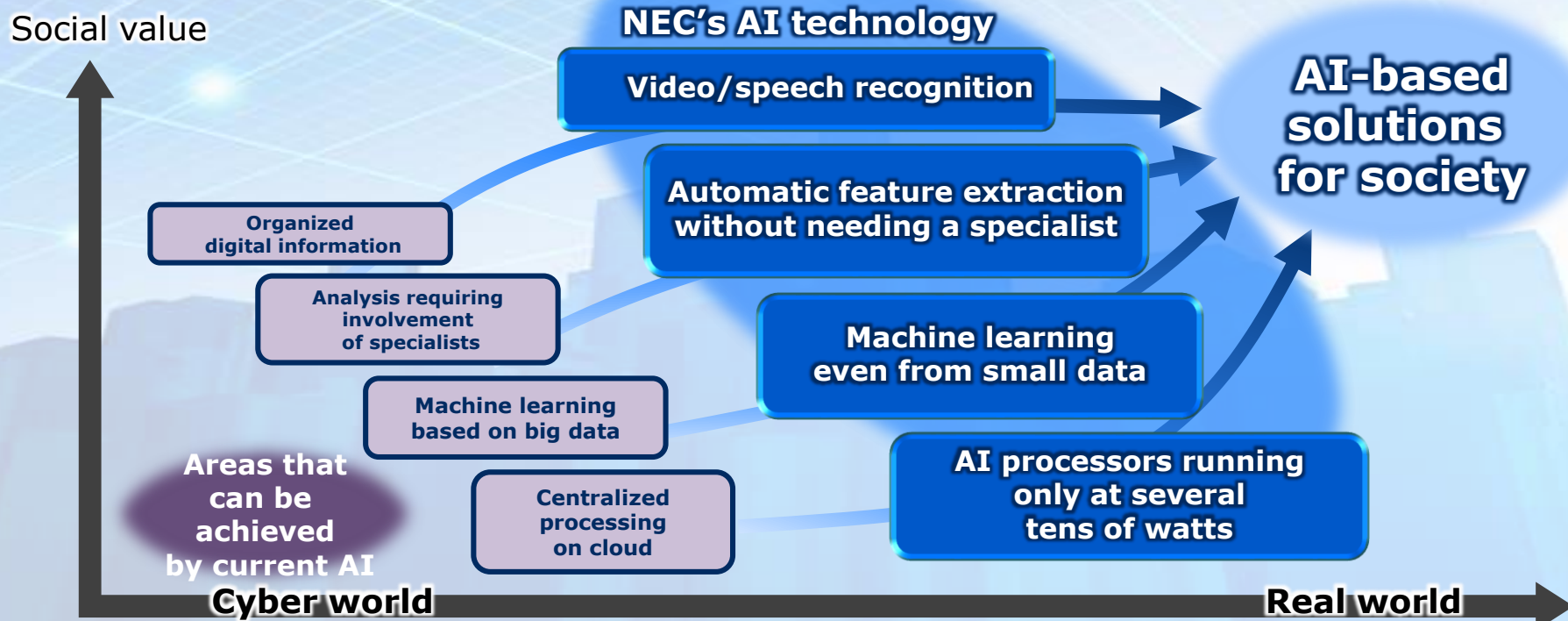| Requirement	Description	NEC's AI technology
Deep understanding of the real world	Inference from raw data such as images, video, and sensor data	**Video/speech recognition**
Diverse and complex domain knowledge	Deep domain knowledge on how to make specific social systems work	**Automatic feature extraction without needing a specialist**
Response to unknown or rare cases (small data)	Flexible handling of abnormal cases or natural disasters with few examples	**Machine learning even from small data**
Real-time and on-site processing	Power limitation in IoT, real-time requirement	**AI processors running only at several tens of watts**

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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

AI-based solutions for society

Video/speech recognition

Automatic feature extraction without needing a specialist

Organized digital information

Analysis requiring involvement of specialists

Machine learning even from small data

Machine learning based on big data

Areas that can be achieved by current AI

Centralized processing on cloud

AI processors running only at several tens of watts

Cyber world

Real world

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Breakthrough technologies covered in today's presentation

Creating social values with AI, platforms, and security

Real world

People

Things

Environment

Cyber world

Social values

Safety

Security

Efficiency

Equality

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

Computing

Networking

Security

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Previously, heavy involvement of domain experts has been required to perform analysis
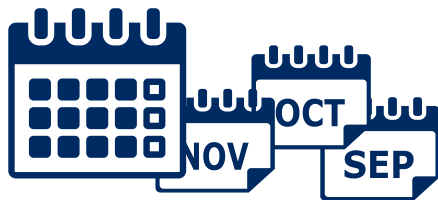
Dependent on analysis expertise

Specialized analysts are needed to relate complex data
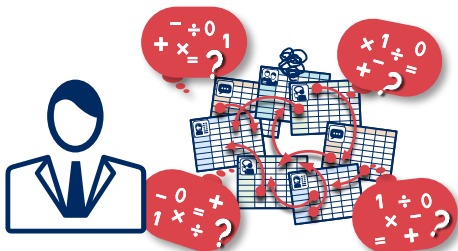
Significant time required for analysis

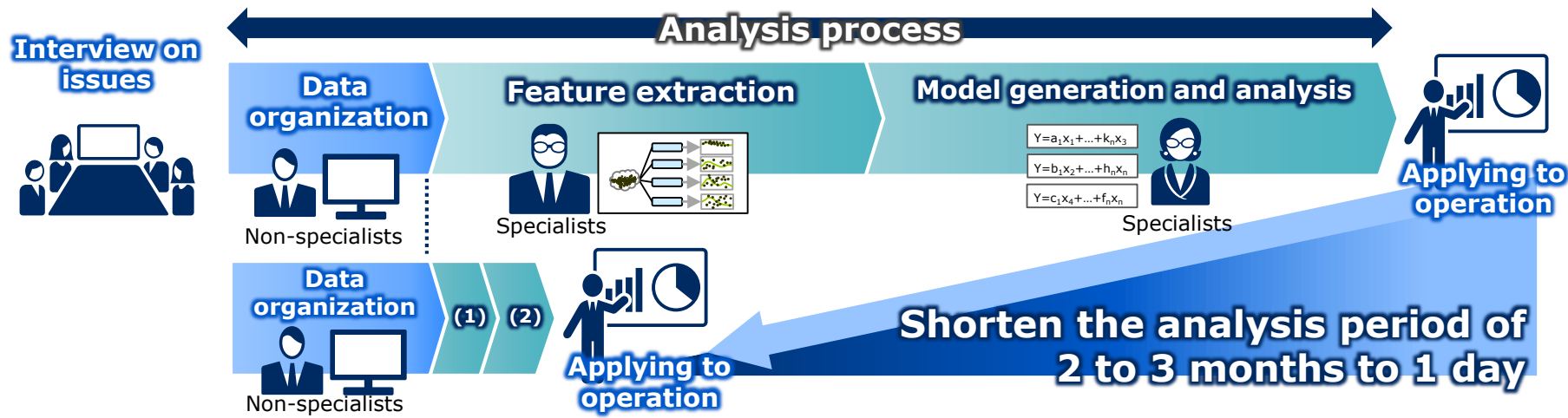Need to analyze a large amount of data over a long period of time

Specialists are needed for each solution for society

Increasing analysis costs

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

Interview on issues

Analysis process

Data organization

Non-specialists

Feature extraction

Specialists

Model generation and analysis

$Y=a_1x_1+...+k_nx_3$

$Y=b_1x_2+...+h_nx_n$

$Y=c_1x_4+...+f_nx_n$

Specialists

Applying to operation

Data organization

Non-specialists

(1) (2)

Applying to operation

Shorten the analysis period of 2 to 3 months to 1 day

Predictive analytics automation technology

(1) Automatic feature extraction design

World's first

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

(2) Automatic prediction model design

Only 1

Heterogeneous mixture learning

Search various models of different types, and automatically generate a model able to make predictions with best accuracy.

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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

Predictive analytics automation technology

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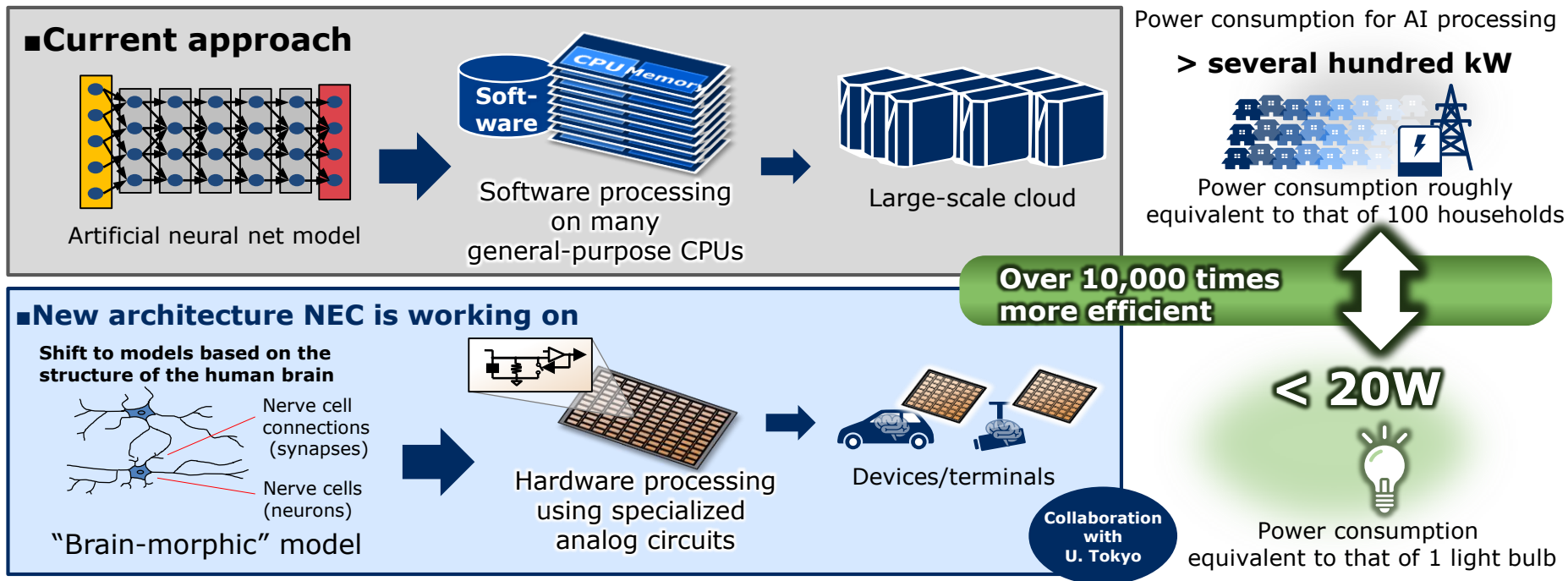
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Dramatically reduces power consumption, enabling AI processing even on edge devices for various solutions for society

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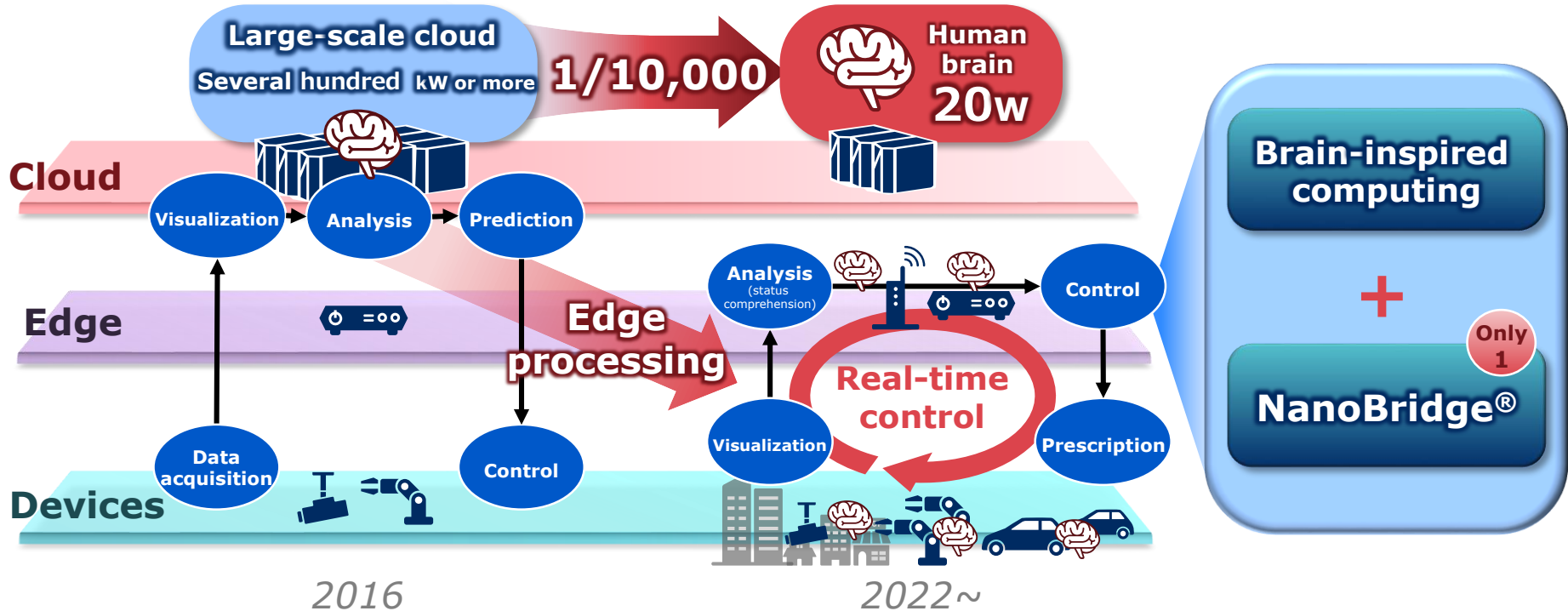
Use of analog circuits imitating cerebral electrical activity improves the power efficiency of AI processing by over 10,000 times

■**Current approach**
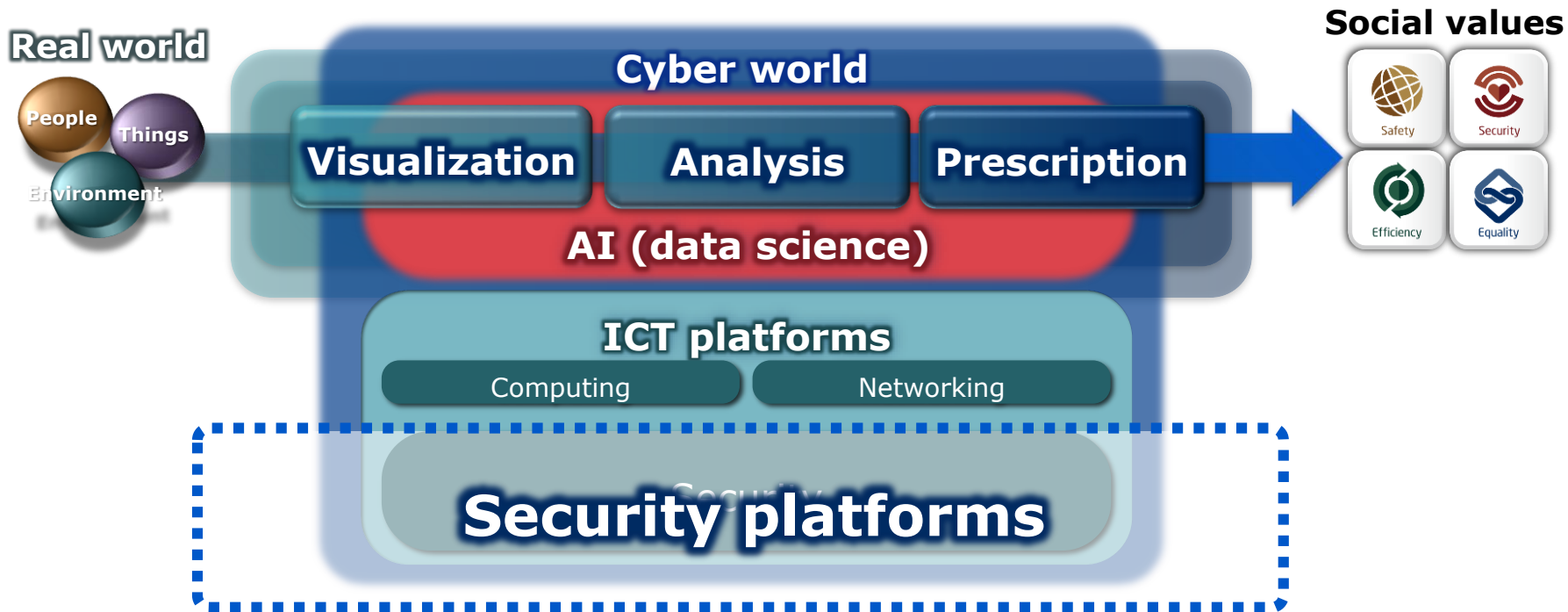
Artificial neural net model

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)

Nerve cells (neurons)

"Brain-morphic" model

Hardware processing using specialized analog circuits

Devices/terminals

Collaboration with U. Tokyo

Over 10,000 times more efficient

< 20W

Power consumption equivalent to that of 1 light bulb

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R&D of Security Technologies to Drive Future Business

Creating social values with AI, platforms, and security

Real world

People

Things

Environment

Cyber world

AI (data science)

Visualization

Analysis

Prescription

ICT platforms

Computing

Networking

Security platforms

Social values

Safety

Security

Efficiency

Equality

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Security technology to support solutions for society
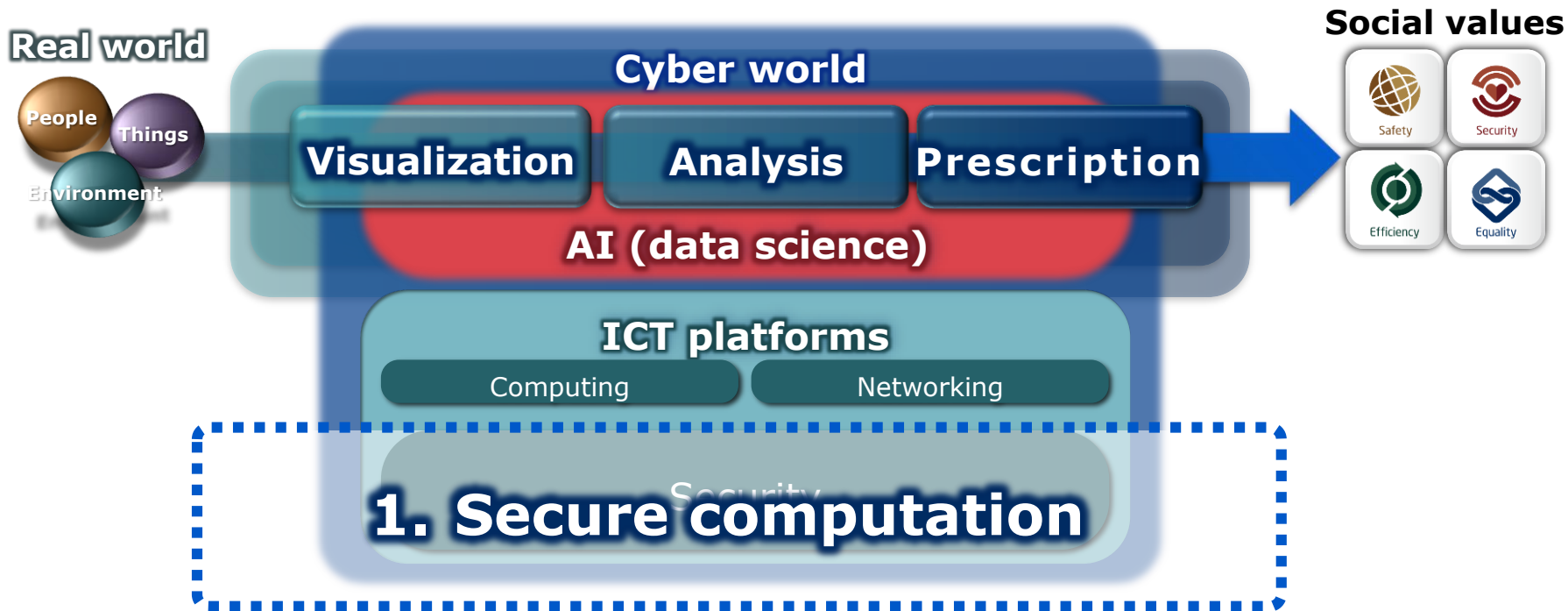
1. System defense from both physical and cyber attacks
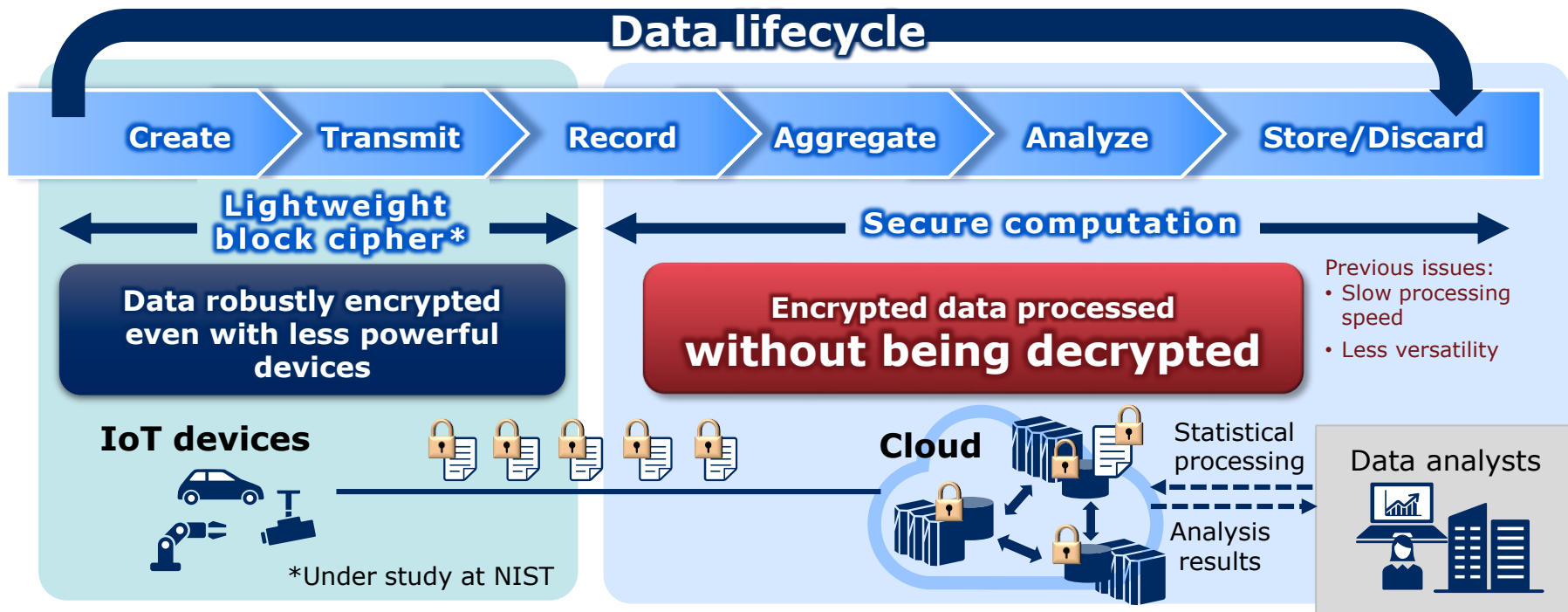2. Data protection with robust encryption technology

Malicious devices

Intruders

Cyber attacks

IoT system

Device authentication → Monitoring of Spoofing devices → Detection of unauthorized software use → Prevention of device hijacking

OT* system

User authentication → Behavioral analysis → Internal crime prevention → Internal crime

IT systems

AI analysis → Automated Security Intelligence

Thorough analysis of attacks

Detect and respond to equipment failures

*Operational Technology

Lightweight block cipher → Communications protection

Secure computation → Prevention of data breaches

Data security

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Creating social values with AI, platforms, and security

Social values

Real world

People
Things
Environment

Cyber world

Visualization **Analysis** **Prescription**

AI (data science)

ICT platforms

Computing Networking

Security

1. Secure computation

Safety Security Efficiency Equality

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

Data lifecycle

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

Lightweight block cipher*

Secure computation

Previous issues:
- Slow processing speed
- Less versatility

Data robustly encrypted even with less powerful devices

Encrypted data processed without being decrypted

IoT devices

Cloud

Statistical processing

Analysis results

Data analysts

*Under study at NIST

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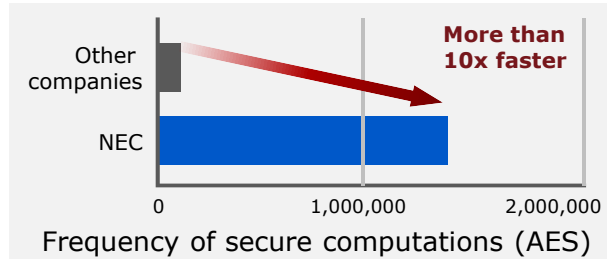
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1. Completed high-speed multi-party computation technology development
2. Comparisons show it is 10x faster than competitors (best in the world)

Multi-party computation

Encrypt data and store as fragments

Fragment 1

Encrypted fragments processed without decryption

Fragment 2

Fragment 3
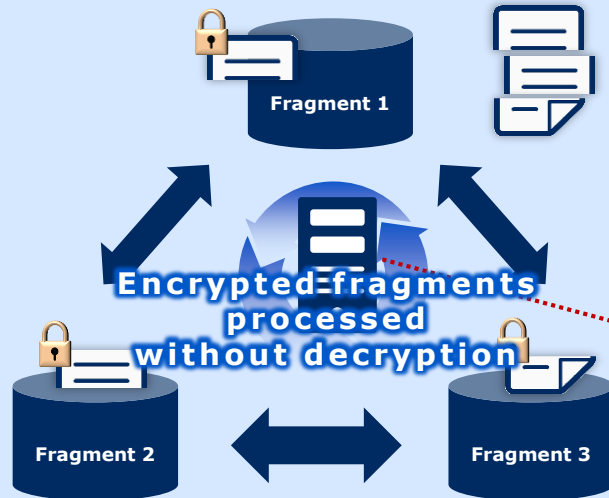
Achievement of extraordinarily high speeds

Other companies

NEC

More than 10x faster

0   1,000,000   2,000,000

Frequency of secure computations (AES)

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

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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:
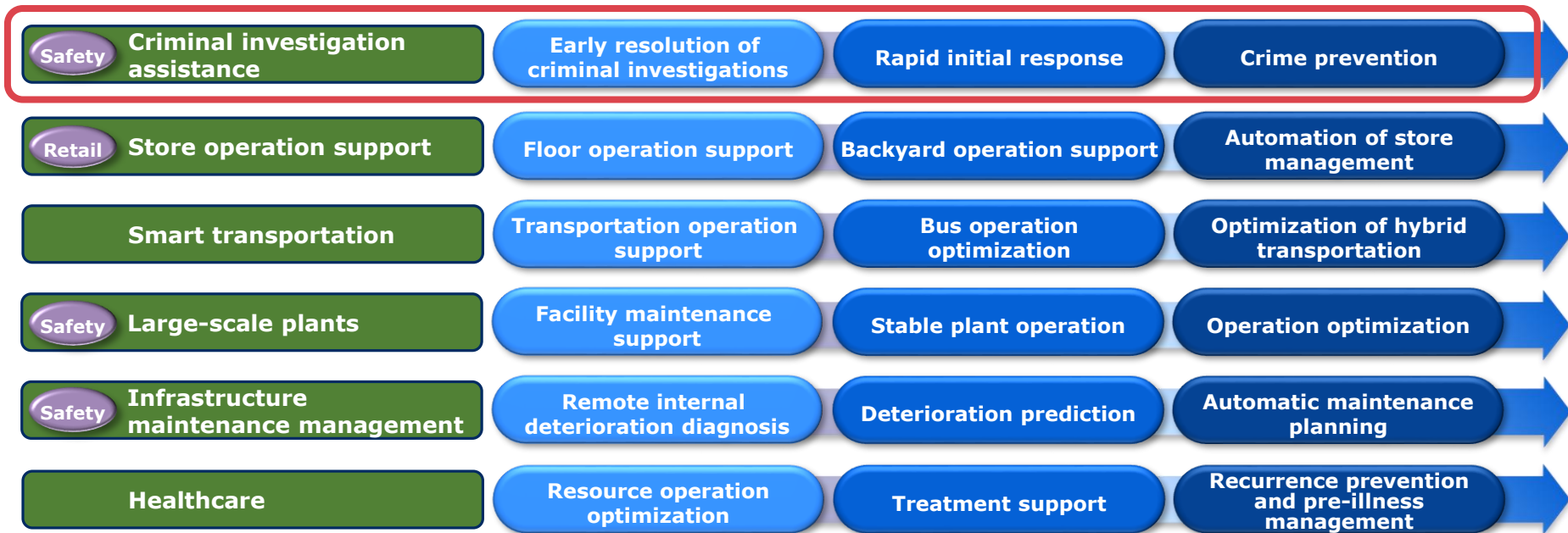Kitahara International Hospital**
Hospital operation optimization

Singapore: SMRT
Public transportation operation optimization

Japan: Sumitomo Mitsui Trust Bank
Blockchain verification for liquidation of receivables

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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	Early resolution of criminal investigations	Rapid initial response	Crime prevention
Retail	Store operation support	Floor operation support	Backyard operation support	Automation of store management
	Smart transportation	Transportation operation support	Bus operation optimization	Optimization of hybrid transportation
Safety	Large-scale plants	Facility maintenance support	Stable plant operation	Operation optimization
Safety	Infrastructure maintenance management	Remote internal deterioration diagnosis	Deterioration prediction	Automatic maintenance planning
	Healthcare	Resource operation optimization	Treatment support	Recurrence prevention and pre-illness management

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For quicker response to crimes

Safety

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)

Quicker response to crimes
(up to 2018)

Identification of specified people or objects

Understanding the situations where crimes might occur

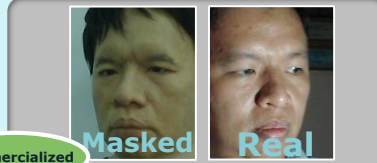### Prevention of entry into countries by criminals

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.

No.1 Face recognition

Determining face authenticity

Masked | Real

Commercialized

e-Gate system

Adopted by immigration bureau of an Asian country

Liveness detection
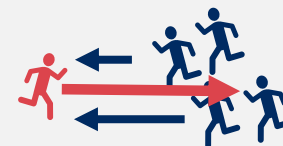
Detection of suspicious sounds

Presented today

Detection of screams or jeers, sounds of glass shattering, gunfire, etc.

New Acoustic situation recognition

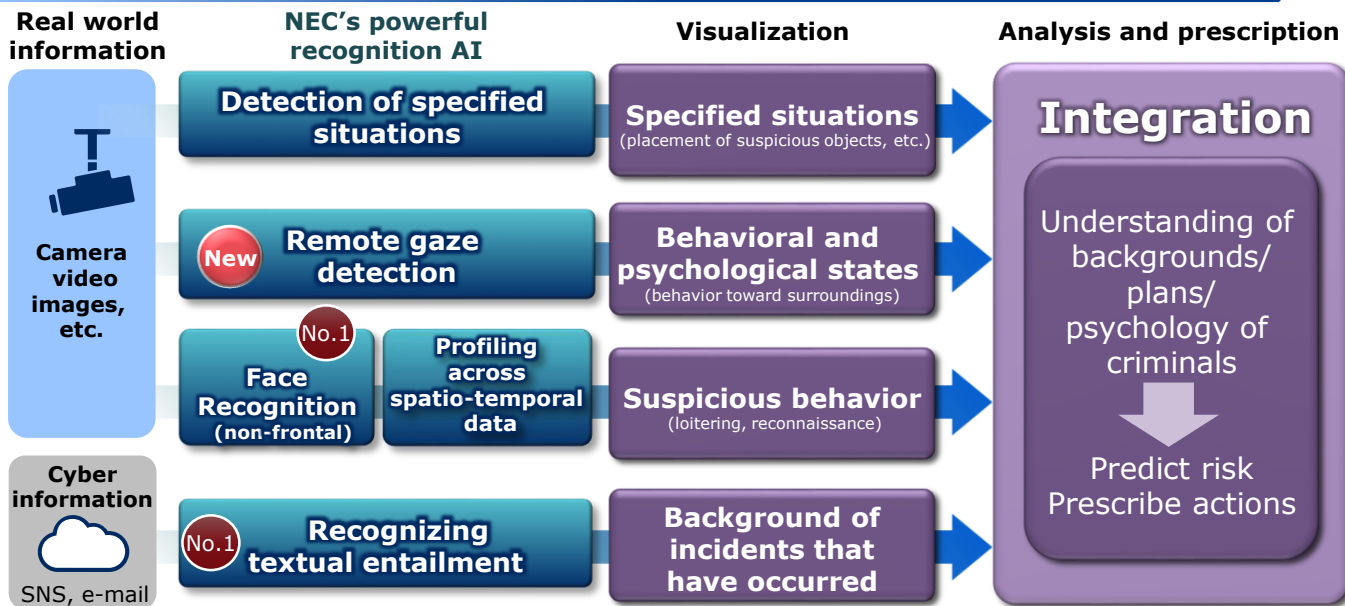### Detection of abnormal crowd behavior

Presented today

Prediction of abnormal movement of people accurately and at high speed, even in crowds numbering several tens of thousands.

Only 1 Crowd behavior analysis

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

Crime prevention (by 2020)

Real world information

NEC's powerful recognition AI

Visualization

Analysis and prescription

Successful case

Camera video images, etc.

Detection of specified situations

Specified situations
(placement of suspicious objects, etc.)

Integration

New **Remote gaze detection**

Behavioral and psychological states
(behavior toward surroundings)

Understanding of backgrounds/ plans/ psychology of criminals

No.1

Face Recognition
(non-frontal)

Profiling across spatio-temporal data

Suspicious behavior
(loitering, reconnaissance)

Predict risk
Prescribe actions

Cyber information

SNS, e-mail

No.1 **Recognizing textual entailment**

Background of incidents that have occurred

Disasters

Dangerous objects

Quarrels

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

Demonstrations

Crimes

*Comparison from 2013 to 2014

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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
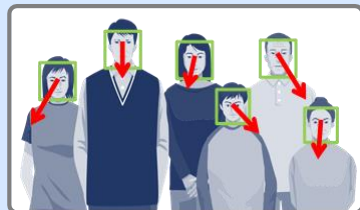
Crowd behavior analysis

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

No.1 Acoustic situation recognition

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

Screams   Jeers   Glass shattering

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

Security personnel
Instructions
Video
LTE/Wi-Fi
Communications network
Headquarters
Face recognition

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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**

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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.

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