NEC's Business Model

Innovation: R&D and Business Development

We believe that a key component to realizing the NEC 2030VISION in a VUCA* world, that is both complex and difficult to predict, is the idea of "seizing the future together," multiplied by "technology."

To this end, it is important to implement technology in society, which requires a scheme for market intelligence, development of technology, development of business, and acceptance within society.

Therefore, NEC is working toward R&D co-creation, expanding open innovation, and venturing into new domains to create businesses that can impact society.

* Acronym for volatile, uncertain, complex, and ambiguous

In Search of Social Value Creation—The NEC Technology Vision

Social Issues →

Digital twins for co-creation and trials of the future
Providing a foundation to support the convergence of the real and cyber worlds

AI that works with people and permeates society
AI that people can trust, AI that people can accept

Platform to support environmental friendliness, high reliability, and high efficiency
Integrated apps / IT / network, security, and secure data platforms

→ **Social Value**

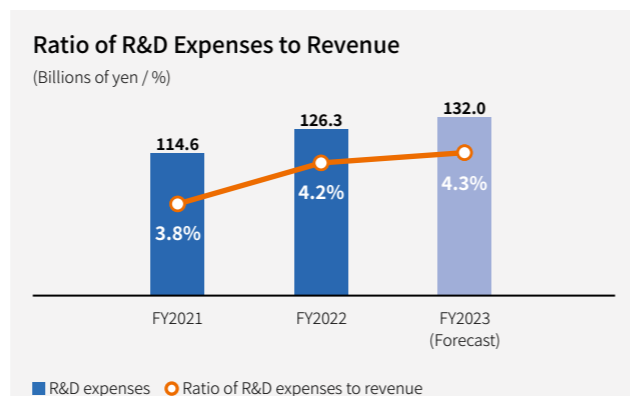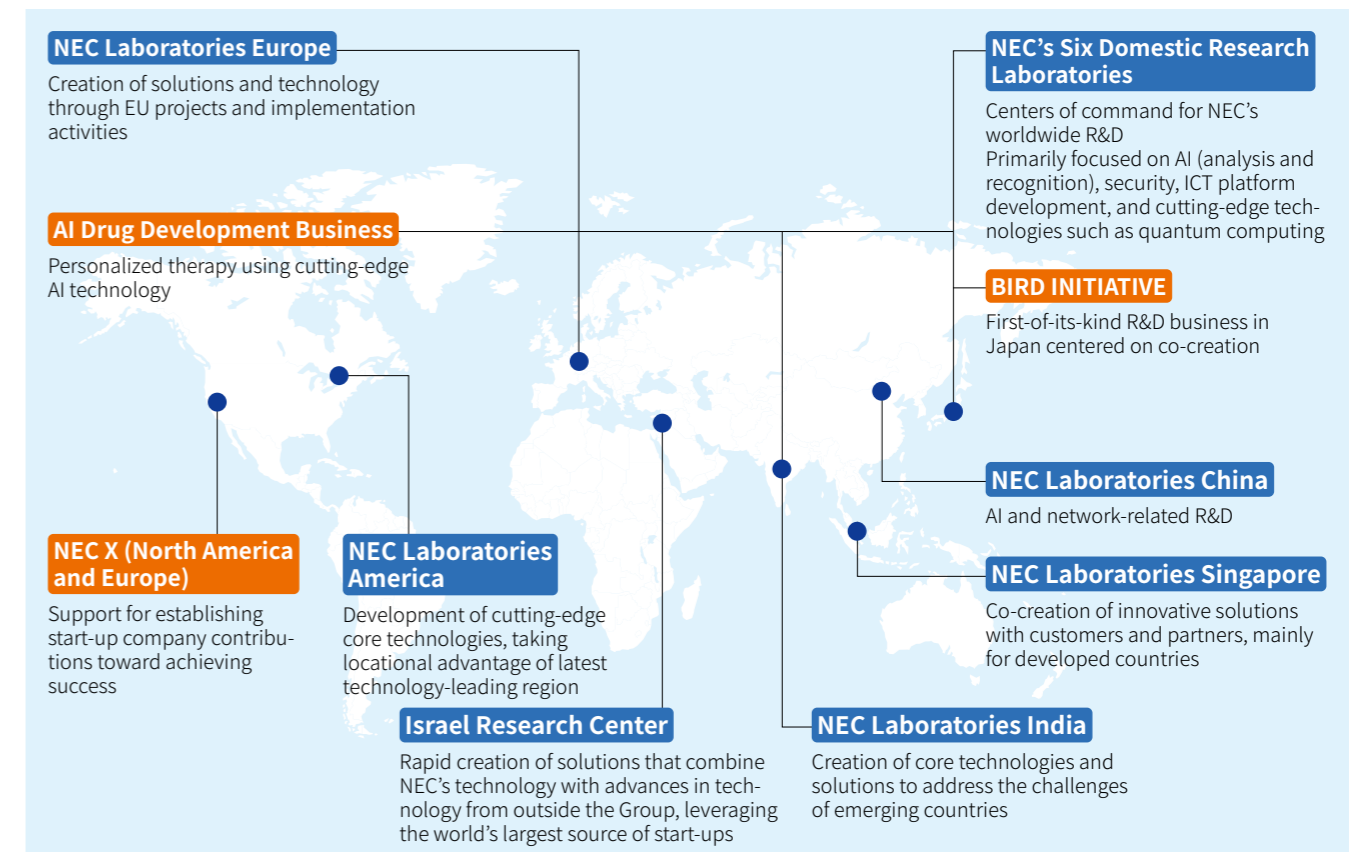| Digital twins for co-creation and trials of the future	AI that works with people and permeates society	Platform to support environmental friendliness, high reliability, and high efficiency
Promote visualization and modeling to power AI-driven simulations on a global scale that will simultaneously help develop society, protect the environment, and support the well-being of individuals	Work toward AI that serves as a partner close to people's lives, draws out their full potential, and feels safe and secure to interact with	Provide environmentally friendly and sustainable infrastructure through integrated optimization that includes applications, IT and networks, while also offering high reliability via security and data protection technologies

Approach to R&D Investment

We allocate approximately 4% of revenue to R&D in order to maintain and improve our R&D capabilities over the medium to long term, independent of any external trends.

Ratio of R&D Expenses to Revenue
(Billions of yen / %)

	FY2021	FY2022	FY2023 (Forecast)
R&D expenses	114.6	126.3	132.0
Ratio of R&D expenses to revenue	3.8%	4.2%	4.3%

■ R&D expenses ○ Ratio of R&D expenses to revenue

Human Resources—The Source of Innovation

Our R&D and Business Development System for Global Human Resources—The Creators of Innovation

NEC's research laboratories are responsible for research and development that is geared toward strengthening the technological competence of the NEC Group. These laboratories adopt a global perspective, working with locations and other research laboratories around the world to conduct R&D that can create new social value and open up possibilities for the future.

NEC Laboratories Europe
Creation of solutions and technology through EU projects and implementation activities

AI Drug Development Business
Personalized therapy using cutting-edge AI technology

NEC's Six Domestic Research Laboratories
Centers of command for NEC's worldwide R&D
Primarily focused on AI (analysis and recognition), security, ICT platform development, and cutting-edge technologies such as quantum computing

BIRD INITIATIVE
First-of-its-kind R&D business in Japan centered on co-creation

NEC Laboratories China
AI and network-related R&D

NEC X (North America and Europe)
Support for establishing start-up company contributions toward achieving success

NEC Laboratories America
Development of cutting-edge core technologies, taking locational advantage of latest technology-leading region

Israel Research Center
Rapid creation of solutions that combine NEC's technology with advances in technology from outside the Group, leveraging the world's largest source of start-ups

NEC Laboratories Singapore
Co-creation of innovative solutions with customers and partners, mainly for developed countries

NEC Laboratories India
Creation of core technologies and solutions to address the challenges of emerging countries

Human Resource Acquisition and Cultivation to Boost Innovation

Introduction of the Selective Compensation Program for Professional Researchers to Attract Top Young Researchers	• Provides researchers with compensation according to their market value, with no upper limit • Launched program in fiscal 2020 in Japan and extended it to applicable new graduates during recruitment activities in the U.S. • Total number of researchers acquired: 22
Continued Enhancement of Our Acquisition of Excellent Talent from India and Other Countries	• Have engaged in recruitment activities at India's prestigious Indian Institutes of Technology (IIT) since 2012 • Part of our continued efforts to keep acquiring top talent from around the world
Internal Side Business System (within Global Innovation Unit)	• Implemented system to accelerate integration of R&D and Business Development divisions • Aimed at developing human resources who are highly skilled in both technology and business
System for Highly Skilled Business Development Professionals	• High-risk, high-return system providing highly skilled business development professionals with benefits based on their market value • Established the new position of Executive Analytics Consultant Lead for data-driven DX-related business in fiscal 2022, in addition to AI drug professionals

NEC's Business Model

Innovation: R&D and Business Development

High Technological Competitiveness on the Global Stage

Artificial Intelligence	
Machine learning: Number of papers accepted by leading international academic conferences[1] **8th in the world**	Video and image processing: Number of papers accepted by leading international academic conferences as of December 2021[2] **No. 1 in Japan**

Communication[3] and Security[4]	
CRYPTO2019, the leading international academic conference on cyber security **Best Paper Award**	Optical communication: Acceptance of papers by leading international academic conferences **45 consecutive years**

Patents		
Top 100 Global Innovators[5] global survey of patent activities **Selected for 11 consecutive years**	Facial recognition: Number of international patent applications[6] **No. 1 in the world**	Biometrics authentication, video analytics, AI: Number of international patent applications[6] **No. 1 in the world**

[1] NeurIPS, ICML, KDD, ECML-PKDD, ICDM
[2] CVPR, ICCV, ECCV, ACCV, ICPR
[3] Communication: OFC/ECOC
[4] Security: ACM, CCS, Eurocrypt, IEEE S&P, etc.
[5] Top 100 Global Innovators: https://clarivate.com/top-100-innovators/
[6] Number of international patent applications: Cumulative number of applications since 2001 (NEC Corporation)

World's No. 1 Biometric Authentication Technology

Beyond facial recognition, NEC boasts world-class biometric technology for key biometrics such as iris and fingerprint recognition.

Ranked No. 1 in benchmark testing conducted by the National Institute of Standards and Technology (NIST)[1]

NEC Rated No. 1 in the World for Biometric Solutions Business
Latest survey by research firm Frost & Sullivan (2020 Global Biometrics in Security Market)

Facial Recognition
No. 1 in the world

FRVT	(2019)	Ranked first in Face Recognition Vendor Test (FRVT) Ongoing: August 2021[2] and January 2022[3]
FIVE	(2017)	
FRVT	(2013)	
MBE	(2010)	
MBGC	(2009)	

Iris Recognition
No. 1 in the world

IREX 10	(2021)
IREX IX	(2018)
(Iris Exchange IX)	

Fingerprint Recognition
No. 1 in the world

MINEX	(2016, 2006)
PFT/PFT II	(2013, 2009)
FpVTE	(2012, 2003)
SlapSeg	(2004)
ELFT	(2007)

[1] NIST testing results do not constitute an endorsement by the U.S. government of any particular system, product, service, or company.
[2] Ranked No. 1 by NIST for FRVT Ongoing 1: N Identification (Aug. 2021) Identification (T>0) under the category Gallery: Mugshot; Probe: Mugshot; N=12,000,000 as well as the category Gallery: Border; Probe: Border ΔT ≥ 10 years; N=16,000,000
[3] Ranked No. 1 by NIST for FRVT Ongoing 1: N Identification (Jan. 2022) Identification (T>0) under the category Gallery: Mugshot; Probe: Mugshot; N=12,000,000, as well as the category Gallery: Border; Probe: Border ΔT ≥ 12 years; N=3,000,000 and the category Gallery: Mugshot; Probe: Mugshot; N=12,000,000

Source: Frost & Sullivan, "Frost Radar™: Biometric Solutions within the Security Industry, 2020"

AI and Human Rights Principles

NEC has formulated the NEC Group AI and Human Rights Principles (hereinafter referred to as the "Companywide principles") to guide our employees to recognize respect for privacy and human rights as the highest priority in our business operations regarding social implementation of AI and utilization of biometrics and other data (hereinafter referred to as "AI utilization"). In addition to facilitating compliance with relevant laws and regulations around the globe, the Companywide principles will guide our employees to recognize respect for human rights as the highest priority in each and every stage of our business operations regarding AI utilization and enable them to take action accordingly.

[S] For more details, please refer to the "AI and Human Rights" section on page 64 of *Sustainability Report 2022*.

Intellectual Property Policy

NEC leverages its intellectual property to increase competitiveness, create new businesses, and enhance corporate value.
1) NEC focuses its intellectual resources toward growth businesses and areas that will serve as pillars of growth in the future. We are working to build an intellectual property network linked to NEC's technological strengths and utilize it extensively.
2) NEC utilizes its intellectual property to support co-creation of new businesses and technologies with stakeholders.

[S] For more details, please refer to the "Innovation Management" section on page 77 of *Sustainability Report 2022*.

Concentration on Focus Areas
(Percentages indicate focus area allocations)

• Patent applications: 45% of all applications (fiscal 2018) → 74% (fiscal 2022)
Scope: NEC Group patent applications filed in Japan and directly filed Patent Cooperation Treaty (PCT) applications

• Patents held: 44% of all patents (fiscal 2018) → 54% (fiscal 2022)
Scope: All patents held by the NEC Group

Examples of Initiatives Based on the NEC Technology Vision

Digital Twins for Co-creation and Trials of the Future

○ Realization of a Safe and Secure Society through Visualization
Multi-satellite image analysis to detect all kinds of changes in the earth's surface
Conventional methods can detect changes only in specific locations every two weeks. This technology, which can seamlessly integrate observed images from multiple SAR* satellites and optical satellites, can detect changes in the ground surface at any point with higher frequency (within an hour to a day), regardless of the time of day, storms, or other bad weather conditions.
* Synthetic Aperture Radar

○ Support for Society via Mission-critical Infrastructure
Invariant analysis and model-free analysis of time-series data
Development of the manned spacecraft *Orion*, part of NASA's manned lunar exploration project Artemis
This technology generates a model for normal operations by finding 22 billion relationships from 150,000 sensors on the spacecraft within several hours, enabling anomaly detection for the design, development, manufacture, and testing stages of spacecraft.
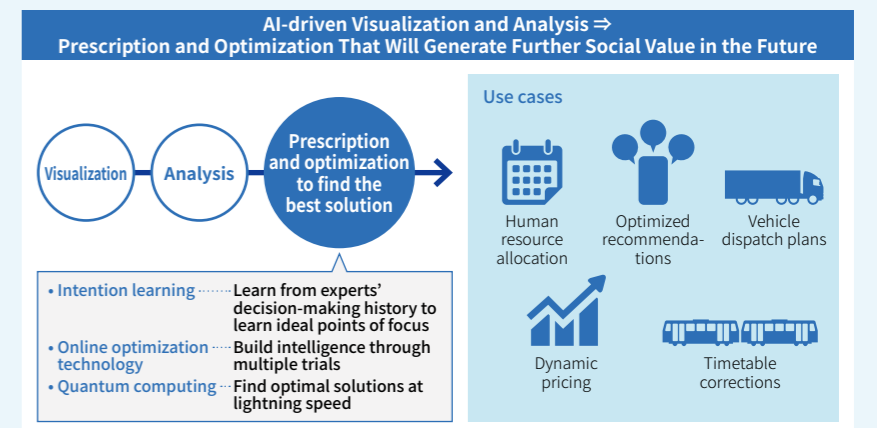
AI That Works with People and Permeates Society

○ Making Society Efficient and Green through Optimal Prescriptions
NEC is developing various types of proprietary technologies in the field of optimization. In addition to quantum computing, these technologies include intention learning, in which AI learns the intentions that underlie the decisions made by experts, and online optimization, which facilitates interactive optimization, even amid uncertain conditions.

These technologies will significantly reduce the amount of labour and increase the speed of operations that require choosing the optimal decision from a massive number of options, such as dynamic pricing, shift scheduling, delivery planning, personalized advertising, and optimized recommendations.

AI-driven Visualization and Analysis ⇒ Prescription and Optimization That Will Generate Further Social Value in the Future

Visualization → Analysis → Prescription and optimization to find the best solution

Use cases: Human resource allocation, Optimized recommendations, Vehicle dispatch plans, Dynamic pricing, Timetable corrections

• Intention learning ········ Learn from experts' decision-making history to learn ideal points of focus
• Online optimization technology ········ Build intelligence through multiple trials
• Quantum computing ········ Find optimal solutions at lightning speed

Platform to Support Environmental Friendliness, High Reliability, and High Efficiency

○ Integrating AI × Communications × Computing

Non-terrestrial Networks (Low-orbit satellite, HAPS, Drones)	**Satellite Constellation / HAPS[1]** • Key Beyond 5G technology that provides a telecommunications environment that can be accessed anywhere in the world
Optical Core Networks	**All Photonics Network (Non-linear distortion compensation / Photonics chips)** • Wavelength conversion technology targeting <1/100 low latency and power • Successfully implemented optical processing on photonics chips, demonstrating the principle during joint research with Princeton University
5G Access Networks	**Communication Prediction and Optimized Bandwidth Allocation (Guarantee end-to-end QoE)** • Optimized ITNW process based on the application's quality demand, reducing bandwidth usage by up to 1/10 **Open RAN Resource Optimization** • 30% less power consumption through automatic optimization of wireless and CPU resource allocation of Open RAN equipment (CU and DU), reducing bandwidth usage by up to 1/10 **Distributed MIMO[2]** • Deployment of small antennas and high-precision clock synchronization to help decentralize Open RAN and reduce cost of implementing Open RAN RUs and DUs
Submarine Optical Fiber Cables	**Submarine Optical Communication** • Succeeded with the world's first long-haul transmission with an uncoupled four-core fiber cable • Conducted joint demonstrations with Facebook, Google, Amazon and other companies, helping increase orders along North Atlantic routes

[1] High-Altitude Platform Station   [2] Multiple Input Multiple Output

NEC's Business Model

Innovation: R&D and Business Development

Venturing into New Business Areas

At NEC, we expect innovation to spur business development in areas where both potential customers and value are yet to be discovered, and we are working on open innovation to develop innovative new businesses that would be difficult for NEC to pursue on its own. We aim to create new social value on the global stage by creating new combinations of diverse knowledge that shatter the boundaries of preconceived notions.

Direction for New Business Development

Development of New Businesses Globally
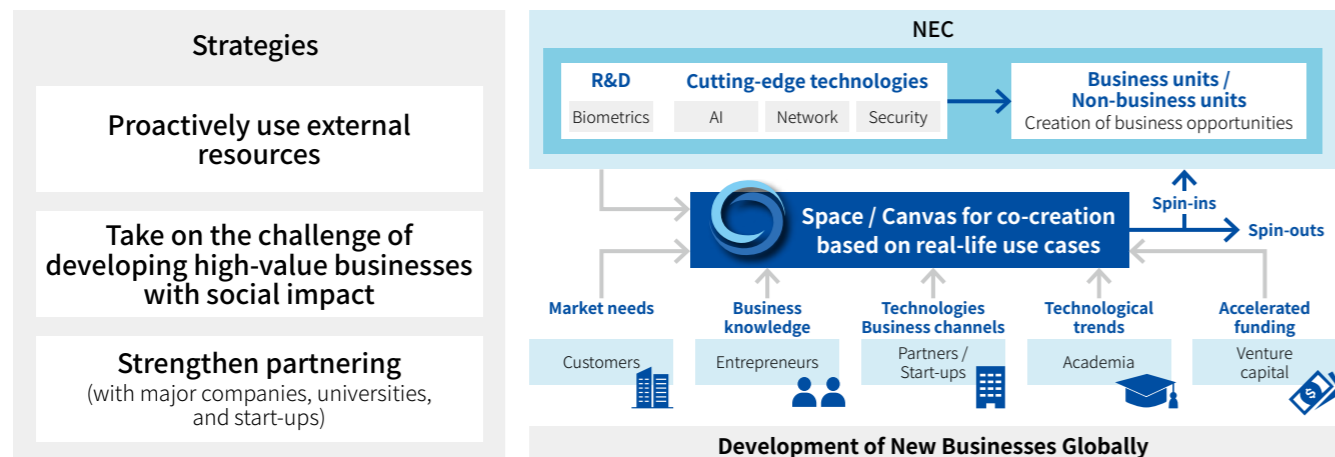
Proactively Use External Resources

➤ **BIRD INITIATIVE—A First-of-Its-Kind R&D Business from Japan Centered on Co-Creation**
In September 2020, NEC became one of six companies to form BIRD INITIATIVE, Inc., a consortium incorporating business, finance, and academia with the goal of using R&D rooted in co-creation to speed up the creation of new businesses.

BIRD INITIATIVE's activities include R&D, commissioned research, consulting, and investment related to digital technology. These efforts are aimed at resolving issues facing organizations and greater society as digitalization moves forward and at creating new businesses.

In September 2020

Established by six companies from different industries, incorporating business, finance, and academia

Carve-outs planned for fiscal 2023

2 projects

assimee
Aiming for a world where digital twins are the natural order
Analysis of assimee's services showed a threefold improvement in investment efficiency at a major semiconductor manufacturer.

Automated Negotiation Plus Drones
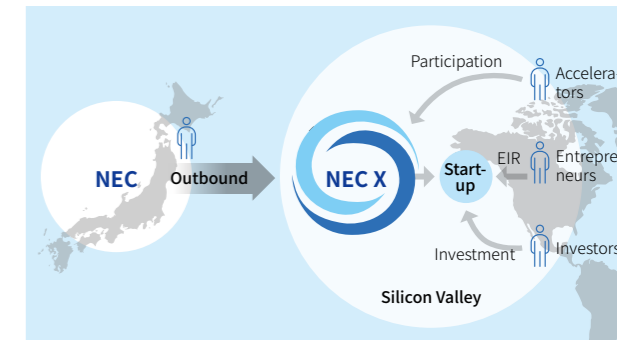Aimed at establishing smart logistics and smart factories
First three domestic tests completed in Wakkanai, Hokkaido

Take On the Challenge of Developing High-value Businesses with Social Impact

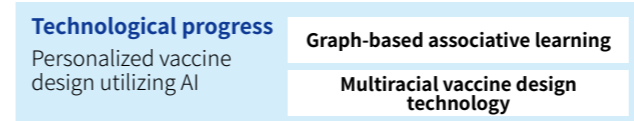➤ **NEC X—Working with the Silicon Valley Start-up Ecosystem**
Ecosystems Rooted in Cutting-edge Technology
NEC established NEC X, Inc. in California to work with Silicon Valley's start-up ecosystem and capitalize on the technology coming from research laboratories in order to accelerate the creation of new businesses. With NEC's human resources and technology at its core, NEC X will promote commercialization through open innovation and create new social value.

➤ **AI Drug Development**

1) Personalized cancer immunotherapy using cutting-edge AI

Technological progress
Personalized vaccine design utilizing AI

| Graph-based associative learning |
| Multiracial vaccine design technology |

Paradigm shift toward drug development processes optimized for each patient

	2019/5	2020/1	2021/11	
Indication	Preclinical		Phase I	Phase II
Ovarian cancer				
Head and neck cancers				

2025 business value: 300 billion yen*

* Calculation by market scale of drug development pipelines, development phases, value amounts of competitors, and pipelines of drug development, as general methods of medicine development

2) Development of a next-generation coronavirus vaccine

NEC's AI technology makes the next generation of coronavirus vaccines a possibility

| One vaccine for over 100 betacoronaviruses |
| Resistant to virus mutations and expected to help maintain long-term immunity |

Helping realize a safe and secure world

First Japanese corporate group to partner with the Coalition for Epidemic Preparedness Innovations (CEPI)
Project launched to develop a next-generation vaccine using AI technology put forth by NEC

CEPI's call to action
Public-private partnerships to accelerate vaccine development

CEPI
CEPI's call to action
Develop a universal vaccine against betacoronaviruses

Strengthen Partnering

Progress in our strategic partnership with NTT	Innovative technological development	Drastically reduce security risks associated with using open systems and capture the global 5G market using a safe and secure Open RAN system
Construction of ecosystems through collaboration with universities	Implementation of technology in society	Deliver results, form a vision, and foster social acceptance with a view toward implementing "Beyond 5G" in society

Establishment of the NEC Orchestrating Future Fund
This NEC-anchored fund raises capital from external sources, which is then invested in early stage and late-stage start-ups in order to develop co-creation ecosystems.

Investment focused on six areas