NTT R&D numbers at a glance

- 16,000+ patents granted
- 2,500 researchers working
- $2B/year invested in R&D (total of group companies*)
- 1,300 technical papers annually
- 3 times awarded IEEE Milestones
- 40 persons IEEE Fellows (including former colleagues)

Top 100 Global Innovators by Clarivate Analytics

*) Note that $1B/year was invested by the R&D Labs. of NTT holdings and the remainder by the operating companies.
Overview of NTT R&D
Overview of NTT R&D

Undertaking research and development in a wide range of fields, including media, security, networks and physics, NTT R&D has great potential to create new values in society worldwide.

Communications services
- Video & image
- User experience
- Audio, speech & language
- Cryptography & security
- Software development
- OSS support

Information networks
- NFV
- SDN
- Network & operations technology
- Communication traffic & service quality
- Optical communication

AI
- Cuttting-edge technologies

- Communication science
- Physics & materials science
- Machine learning data-centric science
- Innovative network
Overview of NTT R&D

NTT R&D organization

President & Vice President

R&D Planning Department (O)

Service Innovation Laboratory Group (Y)

Communication services

Service Evolution Laboratories (Y-M)

Media Intelligence Laboratories (Y-M)

Software Innovation Center (M-S)

Secure Platform Laboratories (M)

Information networks

Information Network Laboratory Group (M)

Network Technology Laboratories (M)

Network Service Systems Laboratories (M)

Access Network Service Systems Laboratories (T-Y-M)

Science and Core Technology Laboratory Group (A)

Cutting-edge technologies

Network Innovation Laboratories (Y-M)

Device Innovation Center (A)

Device Technology Laboratories (A)

Communication Science Laboratories (K-A)

Basic Research Laboratories (A)

NTT Innovation Institute Inc. (V)

Cloud development

2,500 researchers working

- 6 -
NTT R&D has been publicizing its research results in many technical papers that have been highly rated overseas and received various awards.

### Technical Papers
NTT is ranked 13th in the number of technical papers published by corporations, and in the Top 6 for ICT companies.

<table>
<thead>
<tr>
<th>Corporation</th>
<th>Papers (x1,000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBM</td>
<td>15</td>
</tr>
<tr>
<td>Samsung</td>
<td>10</td>
</tr>
<tr>
<td>Siemens AG</td>
<td>10</td>
</tr>
<tr>
<td>Microsoft</td>
<td>5</td>
</tr>
<tr>
<td>Intel</td>
<td>5</td>
</tr>
<tr>
<td>NTT</td>
<td>3</td>
</tr>
</tbody>
</table>

Number of English papers published by ICT companies (2006-2015)

Source: Clarivate Analytics

### Awards
3 NTT developments are recognized in IEEE Milestones*. Among its present and former researchers are 40 IEEE Fellows.

In 2017, it received 21 overseas awards in a variety of fields.

*IEEE milestones recognize the technological innovation and excellence for the benefit of humanity found in unique products, services, seminal papers and patents that occurred at least twenty-five years ago in an area of technology represented in IEEE and having at least regional impact.
Overview of NTT R&D

Patents

NTT files thousands of patent applications every year and owns more than 16,000 patents.

**Patent applications**

<table>
<thead>
<tr>
<th></th>
<th>FY2015</th>
<th>FY2016</th>
<th>FY2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreign patents</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
</tbody>
</table>

Clarivate Analytics has included NTT among its Top 100 Global Innovators for 7 consecutive years.

**Award**

Clarivate Analytics presents this award to 100 companies selected from firms across the globe as “innovative companies and institutions vigorously engaged in protecting intellectual property rights and creating innovations with global impact,” by evaluating, from an objective viewpoint, four principal criteria: 1. Volume (of patents); 2. Success (grant rate of patent application); 3. Globalization, and 4. Influence.

This award is clear evidence that the NTT Group’s R&D activities are making highly valuable and groundbreaking contributions to the global market.
Our Mission

As part of the NTT Group, NTT R&D is the source of new value creation in a wide variety of fields.

Business of the NTT Group

The NTT Group is a world-leading ICT enterprise operating globally in diverse fields.

Mission of NTT R&D

The mission of NTT R&D is to continue to contribute to value creation of the NTT Group by producing “the best / first in the world,” “exciting / amazing” research results.
Technologies and Contributions

- AI and IoT
- Highly realistic media
- Security and cryptology
- Communication networks
- OSS development
- Basic science
**corevo™** is a generic name for activities using artificial intelligence (AI) built up through R&D, and is a unified brand for the NTT Group to accelerate collaboration with various partners. By combining different **corevo™** products, NTT Group companies aim to create new value together with collaboration partners.

**corevo**

**collaboration + revolution**

Create revolutionary change together with partners and customers.
We are exploiting four types of AI technologies that make up corevo™.

Our aim is to support the creation of a safe, secure society in which people can find fulfilment.

**Agent- AI**
Monitors human-generated information and understands human intentions and emotions.

**Ambient- AI**
Analyzes people, things and the environment so that it can instantly make predictions and provide control.

**Heart-Touching- AI**
Analyzes people’s minds and bodies to understand their deep psyche, their intellect and their instincts.

**Network- AI**
Connects multiple AIs to optimize the entire social system.
AI and IoT: Four types of AI

Agent-AI

Agent-AI
Monitors human-generated information and understands human intentions and emotions

Substitutes for and assists with operations carried out at contact centers and service kiosks

Assists with everyday activities

Monitors the elderly and assists them in their activities

Technologies

Speech recognition
Natural language processing
Emotion discrimination
Chat dialog
etc.
Heart-Touching-AI

Heart-Touching-AI

Analyzes people's minds and bodies to understand their deep psyche, their intellect and their instincts

- Improves sport skills
- Supports mental wellness
- Improves human relations

Technologies

- Human sciences
- Sports brain science
- Mind and body reading
- Tactile feedback
- etc.
AI and IoT: Four types of AI

**Ambient-AI**

Analyzes people, things and the environment so that it can instantly make predictions and provide control

- Optimizes city management
- Assists with driving
- Avoids traffic congestion at the time of special events

**Technologies**

- Spatio-temporal analysis
- Large-scale graph mining
- Video analysis
- Assessment of travel conditions
- etc.
AI and IoT: Four types of AI

Network-AI

Network-AI
Connects multiple AIs to optimize the entire social system

- Failure prediction
- Total optimization on a global scale
- Maintenance-free oriented network

Technologies

- Integrated log analysis
- Anomaly detection
- Distributed resource utilization
- etc.
AI and IoT
World best technologies in media recognition

NTT’s speech/video recognition technologies have won first place in various competitions.

### Speech recognition in noisy environments

Won **first place** for accuracy in an international technical evaluation

Speech recognition in various noisy environments:
- (bus, cafe, street, and pedestrian areas)

Top among **25 participating organizations** in CHiME-3

<table>
<thead>
<tr>
<th>Speech recognition rate (%)</th>
<th>94.2</th>
<th>90.9</th>
<th>89.4</th>
<th>88.7</th>
<th>88.3</th>
<th>88.2</th>
<th>88.1</th>
<th>87.9</th>
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<tbody>
<tr>
<td>NTT</td>
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</tr>
</tbody>
</table>

**Reduce noise without distorting speech**

- Distortionless speech emphasis
- Speech recognition based on deep learning

### Video analysis

Continues to win **first, second or third places** in an international technical evaluation

#### 1st and 3rd places in TRECVID MED task (2016)
- **MED**: Multimedia event detection
  - Difficult task of detecting 20 significant events from a large volume of video

#### First place in TRECVID CCD task (2011)
- **CCD**: Content-based copy detection
  - Task of identifying the original video from processed video segments

#### Second place in TRECVID INS task (2013)
- **INS**: Instance search
  - Task of finding scenes showing a searched-for person, place or object from a large volume of video

**Events to be detected**

- Horse riding competition

**Video detection**

- Original video
- Processed video
AI and IoT
Sound processing that enhances audio recognition

NNT’s sound processing technology, called “Intelligent Microphone,” enables powerful noise suppression and speaker separation for a range of audio recognition services in a wide variety of situations.

Noise suppression

- Ambient noise is reduced to 1/10,000
- Cheering
- Machine noise
- Road noise

Speaker separation

- Voices of different speakers (directions) are separated.
- Example of use at a service desk

Intelligent Microphone Processing

This technology is compliant with the standards for emergency calls from vehicles, ITU-T P.1140 TYPE1 (Full duplex, under 3dB of transmission loss) and GOST-R55513.
NTT has achieved leading-edge research results in various technical elements, from basic elements to applications, in the field of natural language processing.

- NTT maintained the top position until 2015 in the benchmark of syntactic analysis, named entity extraction and part-of-speech tagging, which are technical elements that provide the basis for natural language processing.
- NTT has also achieved the world’s top performance in applications, such as patent translation and summarization.

**NTT achieves top position in many major technical elements of natural language processing:**

- **Morphological analysis** (Part-of-speech tagging) *Best* algorithm in 2015 *benchmark using PTB dataset
- **Syntactic analysis** *Best* algorithm in 2015 *benchmark using CoNLL00 dataset
- **Named entity extraction** *benchmark using CoNLL00 dataset
- **Information search**
- **Information extraction**
- **Sentence generation**
- **Machine translation**
- **Dialog**
- **Questions and answers**
- **Summarization**
- **Narrative analysis**
- **Headline generation** Best* algorithm in 2017 *benchmark using DUC-04 very short summarization dataset
- **Scientific paper translation** 1st prize in WAT-2017 competition (2017)
- **Patent translation** 1st prize in NTCIR-9 competition (2010)
- **2nd prize in CoNLL-2015 competition**
- **Scientific paper translation** 1st prize in NTCIR-9 competition (2010)
- **Very short summarization dataset**
AI and IoT

Media recognition of video, audio, image and objects

NTT’s “Robust Media Search” technology has been developed for identifying media content such as video, audio and images, and successfully used in commercial services. Furthermore, the development of “Angle-free Object Information Retrieval” facilitates recognition of even 3-dimensional objects.

Robust Media Search

- Movies on TV, Net, etc.
- Music in noisy environments
- Photos of landmarks, etc.

Angle-free Object Information Retrieval

- Detects 3-dimensional objects from various angles with high accuracy

Use cases

- TV ad monitoring
- Music identification
- Copyright protection
- Instance search

Title: XXXX
Year: 20XX
Director: XXXX

Title: XXXX
Artist: XXXX

Eiffel tower, Paris

from various angles

conventional

needs many reference images

NTT Tech.

only a few reference images

Music in noisy environments

Movies on TV, Net, etc.

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In the era of IoT, Big Data, and AI, machine learning techniques for data analysis related to time and space are coming to the fore. At the Machine Learning and Data Science Center in NTT, our research and development in **spatio-temporal multidimensional collective data analysis** is making groundbreaking advances. This technology models spatio-temporal effects, predicts when events will occur, and proactively initiates behaviors of humans and things.
AI and IoT

Results of machine learning research

Research into technology for spatio-temporal multidimensional data analysis has led to the development of cutting-edge mathematical models, which are expected to be applicable to a wide variety of fields.

World’s 1st mathematical model predicts smart city behavior

Various Big Data in a real environment

- Location information
- Vehicle sensor
- Geographical information

Graph-regularized tensor factorization

Example: prediction of rental bicycle use in New York

http://www.ucs.louisiana.edu/~sxk6389/Program/ListofAcceptedPapers.html

World’s 1st mathematical model discovers higher order interactions among multidimensional data

Higher-order factorization machines

- Prostate cancer
- Ovarian cancer
- Lymphoma

Example: analysis of how genes are related to diseases

https://papers.nips.cc/paper/6144-higher-order-factorization-machines

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Deep learning is expected to be put to practical use in various AI technology applications. However, the training cost is very high due to failure achieve convergence or the prolonged time required for convergence. NTT developed an efficient training algorithm that cuts down the training time, making a trial and error approach unnecessary.

Adastand (deep learning optimization technology)

### Conventional deep learning
- Failure of convergence
- Long training duration (from few days even to several months)

### NTT’s technology
- Stabilizes training
- Speeds up training

#### Comparison of accuracy by number of training iterations

![Graph showing comparison of accuracy by number of training iterations](https://labevent.ecl.ntt.co.jp/forum2018/elements/pdf_eng/E15_e.pdf)

NTT’s technology: 2~5-fold faster

*“Efficient training algorithms for deep learning” https://labevent.ecl.ntt.co.jp/forum2018/elements/pdf_eng/E15_e.pdf*
AI and IoT
IoT architecture for sensing and analyzing Big Data

NTT has defined the basic architecture for IoT systems that use corevo™ to analyze Big Data collected from various devices, and is pursuing R&D to ensure that functions are allocated in a way that is optimal for each application field.

**Combination of functions suited to each application**

- **Analytics & prediction**
  - Applications
  - Integrated security management
  - Library middleware
  - High-speed distributed processing
  - Software component management
  - Edge computing

- **Data & software logistics**
  - IoT data sharing
  - Security gateway
  - IoT gateway
  - Network (wireline/wireless)

- **Sense, digitize & drive**
  - Devices/sensors
  - IoT device security
  - External systems
  - Security orchestration
  - Management

- **Combination of functions suited to each application**
NTT R&D has significant presence in AI, presenting papers in top conferences in the fields of audio processing, in particular, and visual processing, machine learning and databases.

**Number of papers from NTT accepted in recent top AI-related conferences**

*h5-index: (source) Google Scholar (Index indicating the degree of scientific contribution of a conference. It is calculated based on the number of citations. The higher the index, the greater the contribution)*
## Number of papers from NTT accepted in recent top AI-related conferences

<table>
<thead>
<tr>
<th>Conference name</th>
<th>Category</th>
<th>h5-index*</th>
<th>Papers from NTT</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVPR 2017</td>
<td>Visual processing</td>
<td>158</td>
<td>1</td>
</tr>
<tr>
<td>NIPS 2017</td>
<td>Machine Learning</td>
<td>101</td>
<td>5</td>
</tr>
<tr>
<td>ICML 2017</td>
<td>Machine Learning</td>
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<tr>
<td>ACM SIGCHI 2018</td>
<td>Human Interaction</td>
<td>85</td>
<td>5</td>
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<tr>
<td>VLDB 2017</td>
<td>Database</td>
<td>73</td>
<td>1</td>
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<tr>
<td>WWW 2018</td>
<td>Web / Data analysis</td>
<td>77</td>
<td>1</td>
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<tr>
<td>ICASSP 2018</td>
<td>Audio Processing</td>
<td>67</td>
<td>22</td>
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<tr>
<td>SIGMOD 2017</td>
<td>Database</td>
<td>59</td>
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<tr>
<td>AAAI 2018</td>
<td>AI</td>
<td>56</td>
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<td>IJCAI 2017</td>
<td>AI</td>
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<tr>
<td>BMVC 2017</td>
<td>Visual processing</td>
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</tr>
<tr>
<td>ICIP 2017</td>
<td>Image Processing</td>
<td>34</td>
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</tr>
<tr>
<td>ECML-PKDD 2017</td>
<td>Machine Learning</td>
<td>31</td>
<td>2</td>
</tr>
</tbody>
</table>

*h5-index: (source) Google Scholar
(Index indicating the degree of scientific contribution of a conference. It is calculated based on the number of citations. The higher the index, the greater the contribution)
AI and IoT

NTT’s presence in audio processing research

NTT leads the world in research on audio and acoustic processing.

**Presence in top conference**

One of the top companies in the number of papers presented at ICASSP, a top conference in the field of audio and acoustic processing.

<table>
<thead>
<tr>
<th>Corporate Research Institute</th>
<th>Number of Papers</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBM</td>
<td>25</td>
</tr>
<tr>
<td>NTT</td>
<td>23</td>
</tr>
<tr>
<td>Microsoft Research</td>
<td>22</td>
</tr>
<tr>
<td>MERL</td>
<td>15</td>
</tr>
<tr>
<td>Google</td>
<td>14</td>
</tr>
<tr>
<td>Toshiba (JPN+EU)</td>
<td>8</td>
</tr>
</tbody>
</table>

**Recently received awards**

NTT papers are continuously receiving awards from scientific societies. NTT achievements have received recognition in IEEE Milestones.

- **2016 APSIPA Industrial Distinguished Leader**
  Takehiro Moriya, Research Fellow & Director, NTT Fellow

- **2016 IEEE James L. Flanagan Speech and Audio Processing Award**
  Takehiro Moriya, Research Fellow & Director, NTT Fellow

- **2014 IEEE Signal Processing Society Best Paper Award**
  Hiroshi Sawada, Shoko Araki and Shoji Makino

**IEEE Milestone in 2014**

Line Spectrum Pair (LSP) for high-compression speech coding, 1975

**IEEE Milestone for LSP**

May 2014
AI and IoT

NTT’s presence in human sciences

With a view to developing “**Heart-Touching AI**” that understands even deep psyche, NTT is working on human sciences, such as perception and psychology, and producing distinguished scientific results.

*Impact Factor: (source) Clarivate Analytics
(Index indicating the degree of scientific contribution of a journal. It is calculated based on the number of citations. The higher the index, the greater the contribution)*

**High-impact-factor journals in which papers on human science from NTT were accepted (2007-2017)**
High-impact-factor journals in which papers on human science from NTT were accepted (2007-2017)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nature</td>
<td>40.1</td>
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<tr>
<td>Nature Neuroscience</td>
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<td>PNAS</td>
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<tr>
<td>Current Biology</td>
<td>8.9</td>
<td>5</td>
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<tr>
<td>Cerebral Cortex</td>
<td>6.6</td>
<td>1</td>
</tr>
<tr>
<td>Current Opinion in Neurobiology</td>
<td>6.1</td>
<td>1</td>
</tr>
<tr>
<td>J. Neuroscience</td>
<td>6.0</td>
<td>6</td>
</tr>
<tr>
<td>Philosophical Trans. of the Royal Society B</td>
<td>5.8</td>
<td>5</td>
</tr>
<tr>
<td>Proceedings of the Royal Society B</td>
<td>4.9</td>
<td>4</td>
</tr>
<tr>
<td>Scientific Reports</td>
<td>4.6</td>
<td>11</td>
</tr>
</tbody>
</table>

*Impact Factor: (source) Clarivate Analytics  
(Index indicating the degree of scientific contribution of a journal. It is calculated based on the number of citations. The higher the index, the greater the contribution)
Highly realistic media

Media technologies for highly impressive UX

NTT is developing media technologies that enable users to have highly realistic experiences that break spatio-temporal barriers, thereby enhancing the appeal of content and offering new forms of excitement.

Media technologies that break the limits of space & time

- Transmit through space
- Go into space
- Create space
- New values
  - New excitement
  - Attracting more customers
  - Cultivating new customers

Event venue
Broadcasting venue

Virtual reality for athletes
Presentation of virtual space

Entertainment
Sports
Traditional culture

Innovative R&D by NTT

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Highly realistic media
Immersive telepresence technologies Kirari!

Kirari! A world in which you can experience the excitement as if you are in the real sporting venue

Features
A sports or entertainment event is reproduced in high reality by combining media technologies being developed by NTT Laboratories to transport information that enables viewers to feel as if they are at the event site.

Use cases
• Public viewing of sporting events and games
• Live viewing in the field of entertainment, such as theatrical plays and music concerts
• Live streaming, such as keynote speeches, seminars and launch events for a new product


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Kirari! is not only used in the area of entertainment but also for a range of services, such as service desks in banks, remote presentation of keynote addresses, lectures, etc.

Kirari! use case is not only entertainment services but also various enterprise services, such as future service desks at a banking office, remote presentation of keynotes or lectures, etc.

**Virtual assistant**

Combination of 2D floating display and AI conversation

**Remote service desk**

Makes it seem as if the assistant is actually present

**Remote presentation**

Speaker appears to be addressing the entire audience in person
Highly realistic media
Media technologies based on human sciences

Deep insight into how the brain works in the human sciences is bearing fruit in a variety of media processing technologies that use human perceptual characteristics.

Accumulation of deep knowledge about brain mechanisms

Attributes, such as color and movement, are processed separately and then integrated.

Depth is determined based on the phase difference of images captured by the two eyes.

Create media processing technology that uses human perceptual characteristics

HenGenTou (Morphing Lamps)
Light projection that gives the impression of movement to a static object

Hidden Stereo
Generates a stereo image that does not blur even when seen by the naked eye

Conventional method
Proposed method

Commercial moving POP advertisements

“HenGenTou (Deformation Lamps): A magical lighting system to produce illusory movements in static photos and paintings”

“Hiding of Phase-Based Stereo Disparity for Ghost-Free Viewing Without Glasses”
http://www.kecl.ntt.co.jp/human/hiddenstereo/
With its world-leading cyber-security technology, NTT is supporting safe and secure business operation.

- Prevention of information leakage and tampering
- Adapting to the era of IoT
- Promotion of data utilization
- Maintenance of social and corporate infrastructure

Research into world-leading cyber-security

- Data protection and authentication based on cryptographic theory
- Attack detection, collection and analysis technologies
Camellia (cryptographic technology jointly developed by NTT and Mitsubishi Electric) is continuously adopted as an international standard.

**Security**
- Camellia is an international standard cryptography that is extremely secure against known strong attacks, such as differential cryptanalysis and linear cryptanalysis, and recently developed attacks.
- No successful attacks to Camellia have been observed.
- Camellia has the world’s highest security margin against future unknown attacks.

**Standard**
- **De jure standard**: ISO/IEC 18033, ITU-T Y.2704(NGN)
- **De facto standard**:
  - IETF: SSL/TLSIPsec, S/MIME, Open PGP, XML, Kerberos
  - RSA PKCS#11
  - Selected for e-Government Recommended Ciphers List 2013 in Japan
- **Evaluation projects**:
  - CRYPTREC (Japanese e-government recommendation ciphers)
  - NESSIE (European Union recommendation ciphers)

**Users**
- Japanese government’s systems, financial services, online games, SNS services, network services, manufacturing systems, universities, etc.

**Products equipped with Camellia (As of 2012)**
- **Main OSS communities**
  - OS Kernel: Linux Kernel 2.6.21 and later, Fedora Core 7 and later, FreeBSD 6.4 and later
- **Cryptomodules**: OpenSSL toolkit 0.9.8c and later, NSS 3.12 and later, Crypto++ library 5.4 and later, The Legion of the Bouncy Castle 1.30 and later, GNU Transport Layer Security Library 2.20 and later
- **Applications**: Firefox 3.0 and later, ipsec-tools 0.7 and later, GnuPG 2.0 and later, Kerberos KRB5 1.9 and later (tentative)
- **Main enterprises**
  - Oracle: T4 Sparc
  - Cisco: Secure Access Control Server
  - Renesas Technology Symantec: Cross-Platform Cryptographic Module
  - HP: TippingPoint Security Management System
  - RIM: Blackberry
  - AuthenTech (prev. Safenet): QuickSec
  - THALES (prev. nCipher): HSM
  - IAIK: Crypto-library
  - NTT Group (NTT TechnoCross, NEL, etc.)
  - Mitsubishi Electric Group
  - CAPCOM, Nintendo, etc.

**Detailed information**
- **Website** [http://info.isl.ntt.co.jp/crypt/eng/camellia/](http://info.isl.ntt.co.jp/crypt/eng/camellia/)
- **Open source codes** [http://info.isl.ntt.co.jp/crypt/eng/camellia/source.html](http://info.isl.ntt.co.jp/crypt/eng/camellia/source.html)
Secure computation system “San-Shi”

NTT’s secure computation system “San-Shi” allows creation of new value from confidential data without the risk of compromising data.

Secure computation “San-Shi”

Analyze data owned by multiple organizations without disclosing data

Examples
- Health consultation by combining health check data and medical expense data owned by health insurance associations
- New service development by combining IoT product log and personal data

Process data to allow secure data distribution

Creation of new value by third parties

Application example

Tohoku University Joint research
Analyze genome data of 1000 people

“Performing a statistical analysis of multiple companies’ sensitive data”
http://www.ntt.co.jp/RD/active/201702/en/pdf_eng/03/C-28_e.pdf
NICT-CERT is the Computer Security Incident Response Team (CSIRT) of the NTT Group, and is managed by NTT Security Platform Laboratories.

As a trusted point of contact for the CSIRT and security specialists, NTT-CERT receives information on computer security incidents related to the NTT Group, supports computer-incident response, discusses preventative measures, develops training programs, and provides consultation.
Security and cryptology
Contribution to cryptology field

NTT leads the world in R&D of cryptology.

Many papers are continuously accepted in top cryptology conferences (IACR flagship conferences)

Number of accepted papers in CRYPTO, Eurocrypt and Asiacrypt

Recently received awards

RSA Conference 2017 Award for Excellence in the Field of Mathematics
Tatsuaki Okamoto, NTT Fellow

Asiacrypt 2016 Invited paper to Journal of Cryptology
Yosuke Todo, Gregor Leander and Yu Sasaki

CRYPTO2015 Best Paper Award, Best Young Researcher Award
Yosuke Todo

2009 IACR Distinguished Lecture
Tatsuaki Okamoto, NTT Fellow

IACR Fellow
Tatsuaki Okamoto, NTT Fellow

RSA Conference 2017 Award
NTT is supporting communication, a key social infrastructure, by developing technologies for leading-edge optical communication and for flexible and intelligent network construction and operation.

Flexible network construction adaptable to various businesses and changes in the business environment

Software-defined networks
OSS-based network development etc.

Logical networks

World-leading communication technologies to meet an increase in traffic

Physical network

Intelligent network operation to support secure and robust communication

Anomaly detection by AI
Automated facility inspection etc.

Optical communication
Wireless communication etc.
NTT is internationally acclaimed for its optical transmission technology due to its **unrivalled performance**.

### Successful optical transmission over 200 km, the world’s longest, at 1 petabit per second

- NTT demonstrated ultra-large capacity inline optical amplified transmission of 1 petabit (1000 terabit) per second over a distance of 205.6 km using 32-core optical fiber in collaboration with the Technical Univ. of Denmark, Fujikura, Hokkaido Univ., the Univ. of Southampton, and Coriant GmbH.

- This sets a new world record for transmission distance at 1 petabit per second over a single strand of optical fiber within a single optical amplifier bandwidth (C-band).

- Recognized at OFC2017 for a post-deadline paper that reported the highest ever recorded performance.

- NTT et. al. (2012) *One Petabit per Second Fiber Transmission over a Record Distance of 200 km* http://www.ntt.co.jp/news2017/1703e/170323a.html

---

**World’s longest optical transmission at 1 petabit per second**

**Capacity (Pbit/sec)**

- **C-band only**
- **C+L-band**

**Transmission distance (km)**

- **(2015)**
- **(2013)**
- **NTT et. al. (2012)**

---

"One Petabit per Second Fiber Transmission over a Record Distance of 200 km" http://www.ntt.co.jp/news2017/1703e/170323a.html

---

- Conventional 12-core fiber (annular structure)
- Proposed 32-core fiber (square lattice structure)
NTT is developing optoelectronics technologies for ultrahigh-capacity optical communication at 250 Gbps per wavelength.

### Bandwidth doubler with Analog-MUX

- Novel concept for doubling the analog bandwidth of DACs based on a digital preprocessor and an analog multiplexer (AMUX)
- InP-HBT-based analog circuit technologies for enabling AMUX IC with ultra high-speed switching with 64 GHz clocks
- Demonstration of the record 250 Gbps/λ optical transmission

---

NTT leads the world in R&D of optical communication.

**Presence in top conferences**

Many NTT papers are continuously accepted in top conferences in optical communication.

*Second highest in terms of the number of papers accepted by the OFC, one of the top conferences in the area of optical communications*

<table>
<thead>
<tr>
<th>Year</th>
<th>OFC</th>
<th>ECOC</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>50</td>
<td>20</td>
<td>70</td>
</tr>
<tr>
<td>2015</td>
<td>70</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>2016</td>
<td>60</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>2017</td>
<td>80</td>
<td>50</td>
<td>130</td>
</tr>
</tbody>
</table>

OFC: The Optical Fiber Communication Conference
ECOC: European Conference on Optical Communication

**Top 5 institutes in terms of total number of papers presented at OFC2014-2017**

- Nokia / Alcatel / Bell Labs.
- NTT
- Huawei
- Univ. of California* (total of UC Davis, Santa Barbara, San Diego, Los Angeles and Berkeley)
- Fujitsu

Source: Calculated by NTT from data of Clarivate Analytics
Many post-deadline papers* reporting NTT achievements were accepted in top conferences.

<table>
<thead>
<tr>
<th>Conference</th>
<th>Paper Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECOC2017</td>
<td>Masaki Wada, et. al. &quot;Full C-band Low Mode Dependent and Flat Gain Amplifier using Cladding Pumped Randomly Coupled 12-core EDF&quot;</td>
</tr>
<tr>
<td></td>
<td>Taiji Sakamoto, et. al. &quot;High Spatial Density Six-mode Seven-core Fibre for Repeated Dense SDM Transmission&quot;</td>
</tr>
<tr>
<td>OFC2017</td>
<td>Takayuki Kobayashi, et. al. “1-Pb/s (32 SDM/46 WDM/768 Gb/s) C-band Dense SDM Transmission over 205.6-km of Single-mode Heterogeneous Multi-core Fiber using 96-Gbaud PDM-16QAM Channels”</td>
</tr>
<tr>
<td>OFC2016</td>
<td>Taiji Sakamoto, et. al., &quot;Low-loss and Low-DMD Few-mode Multi-core Fiber with Highest Core Multiplicity Factor&quot;</td>
</tr>
<tr>
<td>ECOC2016</td>
<td>Takuro Fujii, et. al. “1.3-μm Directly Modulated Membrane Laser Array Employing Epitaxial Growth of InGaAlAs MQW on InP/SiO2/Si Substrate”</td>
</tr>
</tbody>
</table>

*Post-deadline paper: paper accepted after the deadline of ordinary papers. Research institutes in this field vie with each other in optical transmission performance with their latest technologies available just before the conference. Only those achievements that are highly rated in paper selection held during the conference period are reported.
NTT is participating in various consortium and community activities to actively promote open innovation and efficient development of communication networks through enhanced scalability and reliability, which are the result of NTT’s long-term R&D of communication systems.
OSS development
R&D activities in OSS development

NTT is at the leading edge in the development of open source software.

- NTT has many committers in major OSS development communities, such as OpenStack.
- NTT members’ contributions are 16th highest*1 in the world in OpenStack.
- In the Asia Pacific region, the NTT Group was the first to receive the OpenStack Superuser Award.

*1 According to May. 2018 survey. Module-wise contribution is the 5th in Congress and Swift.

• Contributions to various OSS communities

- NTT has provided many items of OSS, which are also used overseas.

Ryu has been adopted in the inhouse network of the US National Security Agency

GoBGP is OpenStack Neutron standard BGP driver

GoBGP

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Looking forward to 10 years from now, NTT is undertaking leading-edge research with a view to creating new principles and concepts that far surpass the limits of conventional technologies in terms of speed, capacity, size or energy.

100 million times faster computation

1/10,000th of current power consumption

Absolutely secure transmission path

Network performance barriers broken

Quantum physics

Quantum optics

Core technologies with new principles and new concepts

Nanophotonics / quantum-optical integrated circuits

Ultrashort light pulses

Nanobiology

Nanostructural characterization

Theoretical physics

Nanoelectronics

Nanomachinery

Low-dimensional nanomaterials

Materials science

Nanobiology
NTT has verified a new computer principle that solves complex optimization problems using light.

LASOLV (Laser + Solve)

- We have developed a quantum neural network system, LASOLV, which finds solutions to combinatorial optimization problems by simulating interacting spins using a networked optical parametric oscillator. Our QNN found solutions to maximum cut problems consisting of 2000 nodes in less than a ten-thousandth of a second.

- We anticipate that this achievement will contribute to future applications such as drug discovery, planning optimal production, etc.

Max-cut problem

Nodes: 2000
Edges: 19990

About 50 times faster than conventional digital computers

Result

Will operate even at room temperature

Basic science

Future development of LASOLV

In the future, we will expand performance by **increasing the scale of LASOLV** and develop new applications by providing software environment that makes it easy to develop LASOLV applications.

**Current**
- 2,048 nodes
- 2,000,000 combinations

**Next step**
- 100,000 nodes
- 10 billion combinations

Future applications to resolve various social issues:
- Resolve traffic jams
- Develop new drugs
- Optimize Wi-Fi network

Software

Hardware (current)
Basic science
Verification of the breaking of macroscopic realism

NTT has confirmed the breaking of macroscopic realism using a superconducting flux qubit.

- The idea that an observed object exists even before it is observed is called “realism.” This is commonly accepted in the macroscopic world in which we live, but in the microscopic world described by quantum mechanics, realism is “broken.”
- In this investigation, we confirmed the breaking of macroscopic realism for electrical currents composed of a huge number of electrons in a superconducting circuit.

Can quantum dice exist?

- Macroscopic realism breaking
- Observation
- Quantum dice where the pips are not determined before looking

We confirmed the superposition of macroscopic clockwise and anti-clockwise current states.

Superconducting flux qubit state: \( |\psi\rangle \)

\[
|\psi\rangle = |+1\rangle + |-1\rangle
\]

publication in Nature Communications (UK) (Nov. 2016)

Significant contribution to fundamental physics


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NTT is the first to generate power using the principle of Maxwell’s demon.

- NTT succeeded in generating an electrical current and power by sorting the random motion of electrons (thermal noise) in transistors. In the experiment, the random motion was sorted on the basis of a principle related to a famous thought experiment known as Maxwell’s demon.

- Since Maxwell’s demon is related to the lower bound of energy consumption in electrical devices and power generation efficiency in small heat engines, such as biomolecules, we anticipate that this achievement will contribute to the creation of small, energy-efficient electrical devices.

Future development of new, highly energy efficient conceptual devices

"Electrical current generation by sorting thermal noise"
http://www.ntt.co.jp/news2017/1705e/170516a.html
Basic science
The first observation of electrons oscillating on an attosecond scale

NTT was the first to observe electrons oscillating on an attosecond scale in various materials.

- NTT has successfully observed electron oscillation with attosecond (as: $10^{-18}$ of a second) periodicity in various materials. Oscillations of several hundred attoseconds are the fastest that have ever been measured in direct time-dependent spectroscopy in solid-state material.
- This study lays the essential groundwork for exploring various optical phenomena and shows the potential of future petahertz signal processing technology.

Joint research with Tokyo University of Science

Joint research with Yokohama National University

"Attosecond time resolved electronic oscillation within gallium nitride (GaN) semiconductor" http://www.ntt.co.jp/news2016/1604e/160411b.html
Basic science

NTT’s presence in basic science

With many papers accepted in high-impact-factor journals, NTT has a significant presence in basic science.

High-impact journals in which papers on basic science from NTT were accepted in 2017

*Impact Factor: (source) Clarivate Analytics
(Index indicating the degree of scientific contribution of a journal. It is calculated based on the number of citations. The higher the index, the greater the contribution)
### High-impact journals in which papers on basic science from NTT were accepted in 2017

<table>
<thead>
<tr>
<th>Journal</th>
<th>Impact Factor</th>
<th>Papers from NTT in 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nature Photonics</td>
<td>37.9</td>
<td>2</td>
</tr>
<tr>
<td>Nature Physics</td>
<td>22.8</td>
<td>2</td>
</tr>
<tr>
<td>Nano Letters</td>
<td>12.7</td>
<td>1</td>
</tr>
<tr>
<td>Nature Communications</td>
<td>12.1</td>
<td>1</td>
</tr>
<tr>
<td>NPJ Quantum Information</td>
<td>9.1</td>
<td>1</td>
</tr>
<tr>
<td>Physical Review Letters</td>
<td>8.5</td>
<td>2</td>
</tr>
<tr>
<td>Optica</td>
<td>7.7</td>
<td>1</td>
</tr>
<tr>
<td>ACS Photonics</td>
<td>6.8</td>
<td>2</td>
</tr>
<tr>
<td>Physical Review Applied</td>
<td>4.8</td>
<td>1</td>
</tr>
<tr>
<td>Journal of Physical Chemistry C</td>
<td>4.5</td>
<td>1</td>
</tr>
</tbody>
</table>

*Impact Factor: (source) Clarivate Analytics (Index indicating the degree of scientific contribution of a journal. It is calculated based on the number of citations. The higher the index, the greater the contribution)
Scientific contributions to physics of NTT’s papers are very high. NTT is among enterprises producing top-class R&D results.

NTT is fourth place in the number of citations in papers from enterprises in physics.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Institution</th>
<th>Citations*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IBM</td>
<td>57,190</td>
</tr>
<tr>
<td>2</td>
<td>SAMSUNG</td>
<td>41,217</td>
</tr>
<tr>
<td>3</td>
<td>Gen Atom Co.</td>
<td>23,747</td>
</tr>
<tr>
<td>4</td>
<td>NTT</td>
<td>21,071</td>
</tr>
<tr>
<td>5</td>
<td>AT &amp; T</td>
<td>19,499</td>
</tr>
<tr>
<td>6</td>
<td>ALCATEL LUCENT</td>
<td>19,372</td>
</tr>
</tbody>
</table>

Number of citations in papers published by enterprises from Jan. 1, 2007 to Dec. 31, 2017

Source: Clarivate Analytics

The average impact factor of papers from NTT BRL* exceeds those of other companies.

Average impact factor of papers from major companies (2017)

<table>
<thead>
<tr>
<th>Institution</th>
<th>Impact Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>NTT BRL*</td>
<td>4.87</td>
</tr>
<tr>
<td>IBM</td>
<td>4.40</td>
</tr>
<tr>
<td>Samsung</td>
<td>3.84</td>
</tr>
</tbody>
</table>

*NTT Basic Research Laboratories

Source: Calculated by NTT from data of Clarivate Analytics
NTT papers sometimes adorn the covers of distinguished journals, attracting attention from scientists.

- **Biocompatibility mobile electrode**  
  Source: Advanced Functional Materials (December 2016)

- **Super-short optical pulse**  
  Source: Nature Physics (August 2016)

- **Nanomechanics**  
  Source: Applied Physics Letters (August 2016)

- **New electronic device**  
  Source: Applied Physics Letters (September 2015)
People of NTT R&D

The title of “NTT Fellow” is reserved for those individuals whose research results and performance have brought them distinction and who are extremely highly regarded both within and outside NTT.
Dr. Tatsuaki Okamoto
Secure Platform Labs.

Research Subject
Cryptography

Awards
2017 RSA Conference Award for Excellence in the Field of Mathematics
2015 IACR Fellow
2009 IACR Distinguished Lecturer
2007 Certicom ECC Technology Award

Professional Services / Visiting Positions
Director of IACR (1998-2000)
Visiting Assistant Professor of Univ. of Waterloo (Canada) (1989-1990)
Visiting Researcher of Bell Labs (USA) (1994-1995)

Selected Papers
Dr. Takehiro Moriya
Moriya Research Laboratory, Communication Science Labs.

Research Subject
Speech/audio signal encoding

Awards
2016 APSIPA Industrial Distinguished Leader
2016 IEEE James L. Flanagan Speech and Audio Processing Award
2003 IEEE Fellow

Professional Services
IEEE SP society Fellow evaluation committee member (2008-2010)
IEEE Signal Processing Society Speech Technology Committee (2015-)

Selected Papers
People of NTT R&D

NTT Fellows

Dr. Naonori Ueda
Ueda Research Laboratory, Communication Science Labs.

Research Subject
Big data analysis & statistical machine learning

Awards
2017 Fall APSIPA Industrial Distinguished Leader
2010 SIGKDD Best Research Paper Award Honorable Mention
2009 Best Paper Award, ICONIP (Intl. Conf. on Neural Information Processing)

Professional Services
Area Chair, NIPS (2015)
Senior Program Committee, ICML (2007), IJCAI (2018)

Selected Papers
People of NTT R&D

NTT Fellows

Dr. Makio Kashino

Project Manager, Sports Brain Science Project, Communication Science Labs.

Research Subject

Human information science, cognitive neuroscience

Professional Services / Visiting Positions

Specially Appointed Professor, School of Engineering, Tokyo Institute of Technology (2016-present)
Visiting Professor, Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology (2006-2016)
Visiting Professor, Dr. Daniel Pressnitzer Lab., Université Paris-Descartes (2008)

Selected Papers

Dr. Shingo Tsukada
Basic Research Laboratories

Research Subject
Medicine, Physiology, Biomedical interface & data analysis

Visiting Positions

Selected Papers


Projects and Partners
ForeSight Voice Mining is an advanced system that provides insights in order to offer better customer experience and to train agents more efficiently by enabling real-time monitoring and quantitative and objective analysis of massive call data.

- Improve customer satisfaction
- Lower operation cost
- Increase revenue

Customers
Agents in a contact center
Manager/analyst

Speech recognition
Emotion recognition
Utterance comprehension

Supports their responses by automatically searching for an appropriate FAQ for each call

10,000 individual work stations in offices are now using this service

Sompo Japan Nipponkoa
corevo™ machine learning technology can be used to detect abnormal operation sounds in real time, thereby improving the efficiency of maintenance and inspection work in factories. Intelligent microphone technology is also used to pick up only machine operation sounds in the presence of ambient factory noise.
Using **corevo image recognition technology**, we have developed a hospitality service in which users need **only to point their smartphone camera** towards a sign board or an object to get **useful information in their mother tongue**.

This is being tried out at Haneda Airport in collaboration with Tokyo International Air Terminal Corporation (until August 2018).

**Easy to use on the Web**

**Only 2 - 3 images need to be registered in advance**

**Navigation information**
- Multilingual information from signage boards
- Map to destination

**Menu**
- Multilingual translation of the menu
- Detailed information

**“Public Testing of Information Universal Design begins at Haneda Airport”** http://www.ntt.co.jp/news2017/1708e/170808a.html
With a view to spreading the use of partner robots that work closely with humans, Toyota Motor and NTT have started joint research on using Toyota’s support robot, Human Support Robot (HSR), and corevo™ to support humans in everyday lives.

Visitor guidance service prototype

We have developed a service that forecasts taxi demand by geographic location by combining corevo™ machine learning technology and the demographic data created based on mobile network usage. The forecasting is so accurate that taxi drivers have been able to increase their revenue.

Al Taxi
Forecasting demand after 30 minutes to optimize driver placement

Service launched Feb. 2018

Reduce waiting

Growth in sales

Handling sudden demand increase

Demographic data created based on mobile network usage

Operation data

Spatio-temporal multidimensional collective data analysis

Operation data
Toyota Motor and NTT are collaborating to develop, validate, and standardize technologies used in the connected car field.

TOYOTA & NTT Group

Technologies related to vehicles

Technologies related to ICT

Platform for data collection, storing and analysis

Data center

IoT network

5G

Agent

Edge computing

A field trial is planned for 2018

NTT is conducting research on **car security** to make **safe and secure connected cars** a reality by drawing upon its extensive experience and technical expertise accumulated in the IT security field.

**Car security research**

- **Cloud measures**
  - Advanced attack detection in cloud
- **In-vehicle measures**
  - Rapid attack detection in vehicle

**Cyber attack countermeasures** specialized for “in-vehicle”

**In-vehicle network**

*Service provider*  
*Auto manufacturer/supplier*  

Network traffic

Vehicle data/Log
Using its R&D technology, the **NTT Group** is collaborating with **FANUC**, a global supplier of factory automation systems, to contribute to **improving productivity** and **industrial competitiveness** at manufacturing sites.

**Projects and Partners**

**IoT smart manufacturing with FANUC**

FIELD system is an IoT system for manufacturing industry developed jointly with Cisco systems, Rockwell Automation, Preferred Networks and NTT group under FANUC’s initiative.

---

**Open**

- Software component management makes it possible to implement functional updates, such as device control and failure prediction, easily and rapidly.

**Real time**

- Edge computing makes it possible to achieve the coordinated operation of multiple devices in a scalable manner.

**Connective**

- IoT data sharing makes it possible to interconnect various devices and sensors in a factory.

---
Nippon Yusen (NYK), MTI and the NTT Group have successfully conducted a proof-of-concept experiment for a next generation IoT platform designed for modern ships.

Optimization of vessel operation
Reduction of operational workload
Environmentally friendly vessels

Proof-of-concept experiment for an on-board IoT platform

Rapid use of data onboard
Satellite communication
Detailed analysis at onshore operation centers

Onboard data collection box
Software component management
IoT data sharing

SAP and NTT are collaborating to develop a solution which enables driver’s fatigue and stress level to be analyzed in real time through the use of “hitoe” together with biometric information analysis technology.

Vehicle operation management solution

Biometric data
Driving data

“hitoe” shirt for drivers

Sample fatigue analysis (highway bus driver)

Fukui to Nagoya
Nagoya to Fukui

Good
Fatigue estimation

Rest

Rest at Service Areas

Instructions to drivers
Improve safety, etc.

“SAP and NTT Enhance Global Partnership, IoT Solution Development to Support Safe Operation of Transportation Industry”

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Toray and NTT have jointly developed a functional fabric “hitoe” which can collect biometric information reliably without irritating the skin.

New functional fabric

Unlikely to cause skin rash

Continuous long-term monitoring
The functional fabric “hitoe” is expected to be applied in a **wide range of fields**, from sports and safety control to medical care.
A realistic image, enabling the viewer to feel as if they were in the field during a game, is synthesized in a virtual space. By experiencing, virtually, balls thrown by a pitcher during preparation, a batter can achieve a better, stable performance in a game.

Service introduced by Rakuten Baseball Team from 2017 season

“NTT DATA to Launch Virtual Reality Baseball Coaching System Developed in Collaboration with Rakuten Baseball, Inc.”
The **synchronous live streaming** technology of “Kirari!” was demonstrated through a worldwide synchronous live performance of **Perfume**, a trio of Japanese female artists. **A new moving experience** was shared all over the world by real-time synchronization of videos of 3 venues separated by a distance of 10,000 km.

**Perfume x docomo**

**FUTURE-EXPERIMENT “Eliminate distance”**

New live experience as if three artists were in one place

- **Tokyo**
- **London**
- **New York**

https://www.youtube.com/watch?v=lgdASCXJjNk
Mitsubishi Heavy Industries (MHI) and NTT have jointly developed “InteRSePT”, cyber-security technology for critical infrastructures.

Features
InteRSePT detects and neutralizes anomalies from an unknown cyber-attack in real time, facilitating safe and secure system operation of industrial control systems.

Highly reliable control technology developed for defense/space fields

For safe and secure operation
- Power plants
- Transportation systems
- Chemical plants

Many control signals
Detect and block anomalies in communications specific to industrial control systems

Detect errors

Control whether to pass or block

Information from sensors

100-msec cycle

(InteRSePT is a registered trademark of MHI in Japan.)


Cutting-edge security technologies

Commercial release from May. 2018

Critical infrastructures

Market Expansion
Mitsubishi Heavy Industries (MHI) and NTT have demonstrated kW class high power single-mode laser transmission over long distances by harmonizing MHI’s high power laser processing and NTT’s photonic crystal fiber (PCF). This is a key technology for expanding the applications of laser processing technology and advancing innovation in social infrastructure products.

High power laser processing technology

Photonic crystal fiber (PCF) technology

Conventional optical fiber

Photonic crystal fiber

Silica Glass (Cladding)

Core (Optical Path)

air holes

Enables properties impossible with conventional optical fiber

In addition to physical abilities, such as muscle strength and cardiopulmonary functions, perceptual functions, such as situation assessment, tactical maneuvers, and decision making under pressure, play an important role in winning a game.

The **Sports Brain Science Project** is using leading-edge ICT, such as wearable sensing and virtual reality, to analyze the **brain mechanisms** that support the outstanding perceptual abilities of top athletes, and developing **effective training methods** based on these analyses.

**Targets of conventional sports science**
- Body
  - Muscle strength
  - Cardio-pulmonary function
  - Injury prevention etc.
- Mind
  - Mental drive
  - Tension/relaxation
  - Tactical maneuvering etc.
- Skill
  - Skillful coordinated motion
  - Accurate situation assessment
  - Instantaneous decision making etc.

**Targets of SBS Project**
- Measurement using wearable sensing and virtual reality
- Estimation of psychological state using measurement of eye movements
- Estimating attentional span
- Understanding of the mechanism of information processing in brain by measuring various biometrics of athletes

“Split seconds matter - the brain and sport”  
Dell Technologies and NTT Group are collaborating on the first smart city proof-of-concept with Las Vegas as part of the city's digital transformation. NTT's Cognitive Foundation enables one-stop operation of information and communications technology (ICT) resources, from devices and networks to the cloud.

Proof-of-concept experiment for smart city

- NW configuration
- IaaS/PaaS setup
- Sensors operation

Response to public safety incidents

One-stop operation

ICT resource
Data center (Core)

ICT resource
Micro data center (Edge)

ICT resource
Sensors (Video/Audio)

Visit our website for updated information on NTT R&D
http://www.ntt.co.jp/globalRD/
Next Value Partner for Transformation of Business models and Lifestyle by Trusted Solutions of Global, Secure, End-to-end, and Full-line ICT services