TOSHIBA

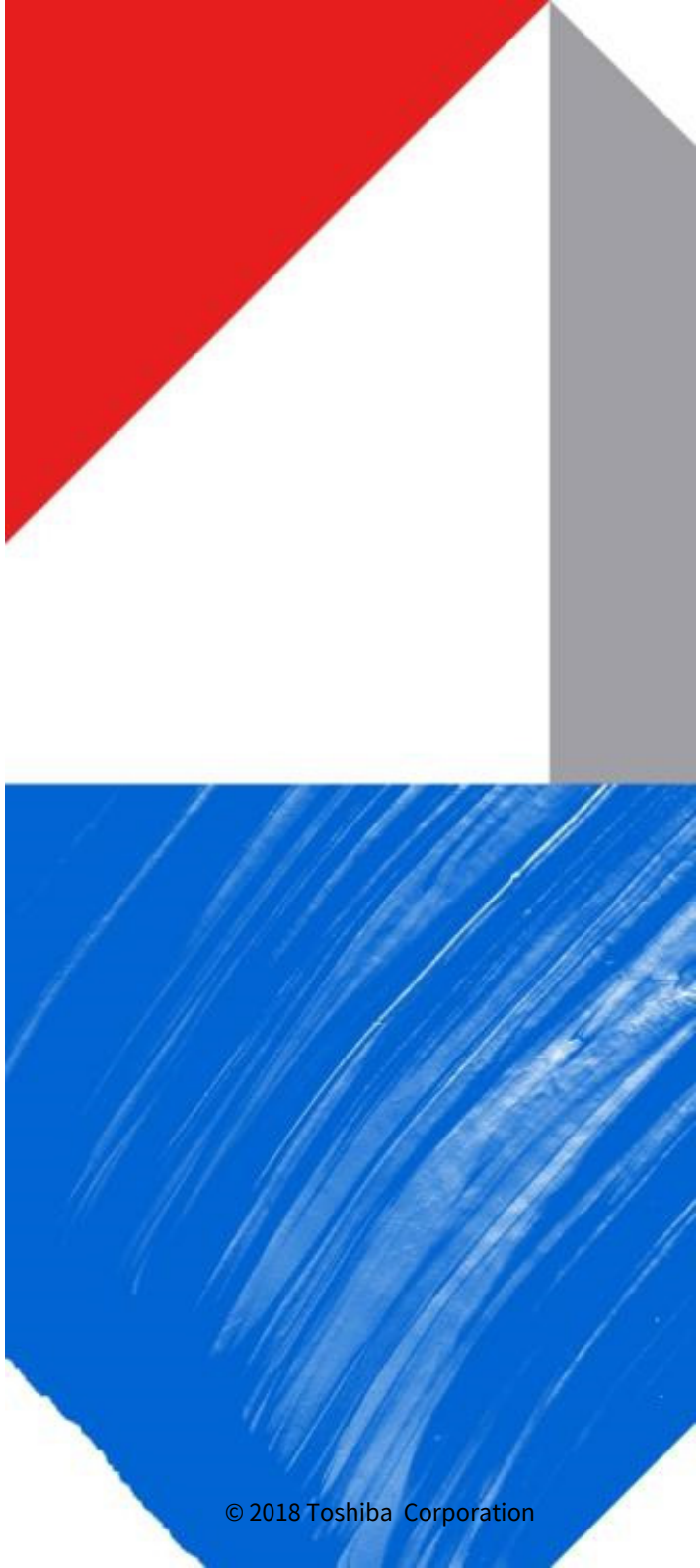
Toshiba's Technology Strategy

Dr. Shiro Saito

Corporate Executive Vice President

Toshiba Corporation

November 22, 2018



We turn on the promise of a new day

Toshiba Group's Vision

Become world's leading CPS*1 technology company, ensure profitability by implementing the Toshiba Next Plan

2018

Secure core earning power,
Grow with technology
Toshiba Next Plan

An excellent company with core earning power and growth potential

2023

Help solve social issues
Maximize enterprise value

Contribute to social development through the combination of cyber & physical technologies

2028

2030

World's Leading CPS Technology Company

Infrastructure
Energy
Storage & Electronic Devices
Industrial ICT solution
R&D

Evolution

Incubation

Urbanization, Automation,
Renewable energy,
Edge rich devices,*2
AI and digital solutions,
Batteries, Power electronics,
Precision medicine

*1 CPS(Cyber Physical Systems): CPS collect data from the physical world to be analyzed and processed using digital technology. CPS create value through a constant feedback loop between the cyber and physical worlds.

*2 Devices that use sensing technology such as LiDAR, Spin MEMS, hydrogen sensors, pressure sensors, RIG (rate integrating gyroscope), and ULP gyro

Contents

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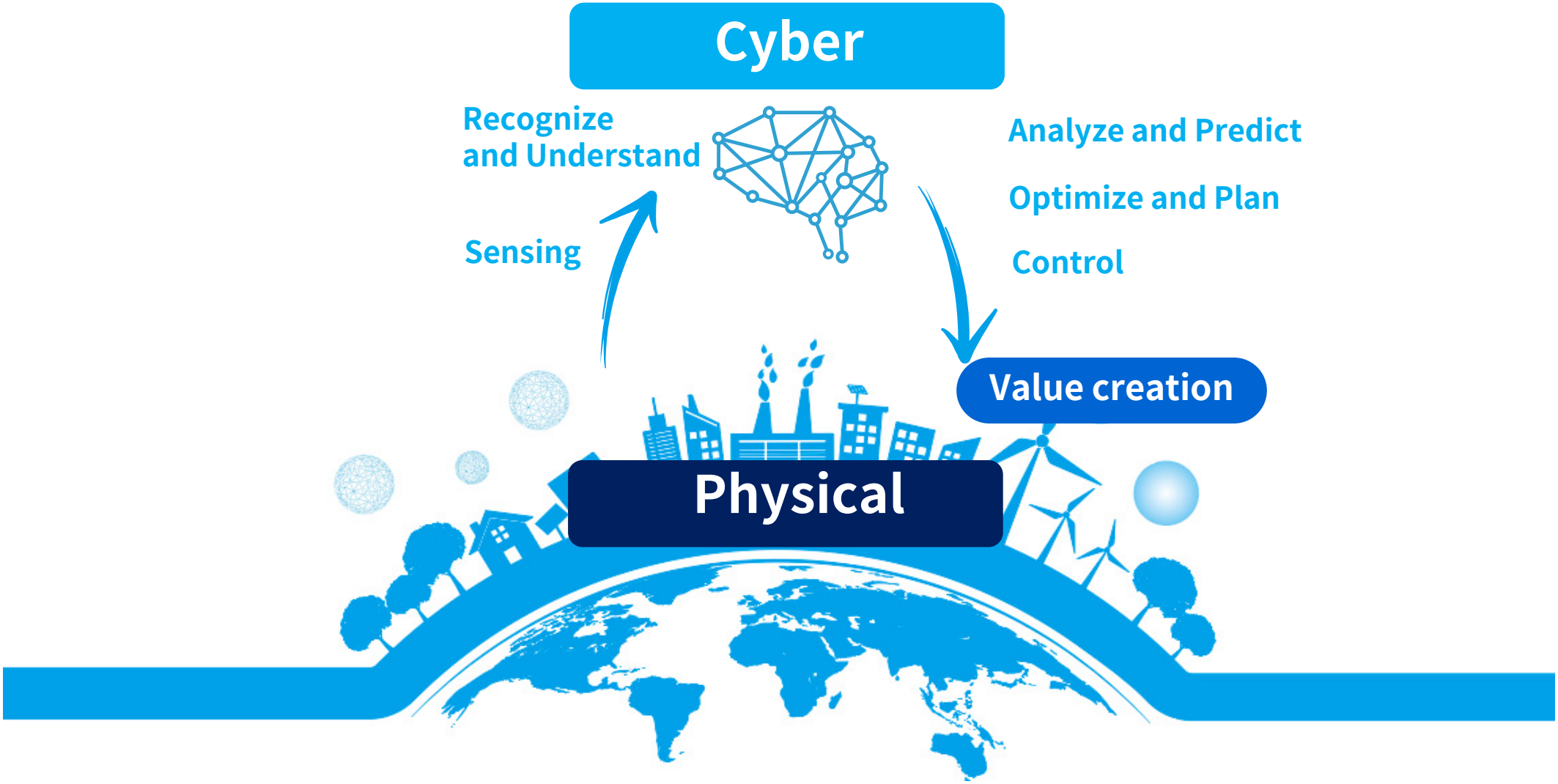
Research & Development Policy

1. Cyber Physical Systems (CPS)
2. To become a CPS Technology Company
3. Research & Development Policy

Cyber Physical Systems (CPS)

CPS creates value by collecting data at the physical world, recognizing/analyzing that with digital technology, and giving feedback to the physical world



To Become a CPS Technology Company

Relationships with customers in various business domains built through products are valuable assets

AI & digital technologies unique to Toshiba

Core components with overwhelming performance

Cyber

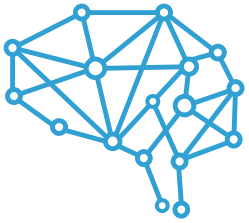
Recognize and Understand

Analyze and Predict

Optimize and Plan

Control

Sensing



Value creation

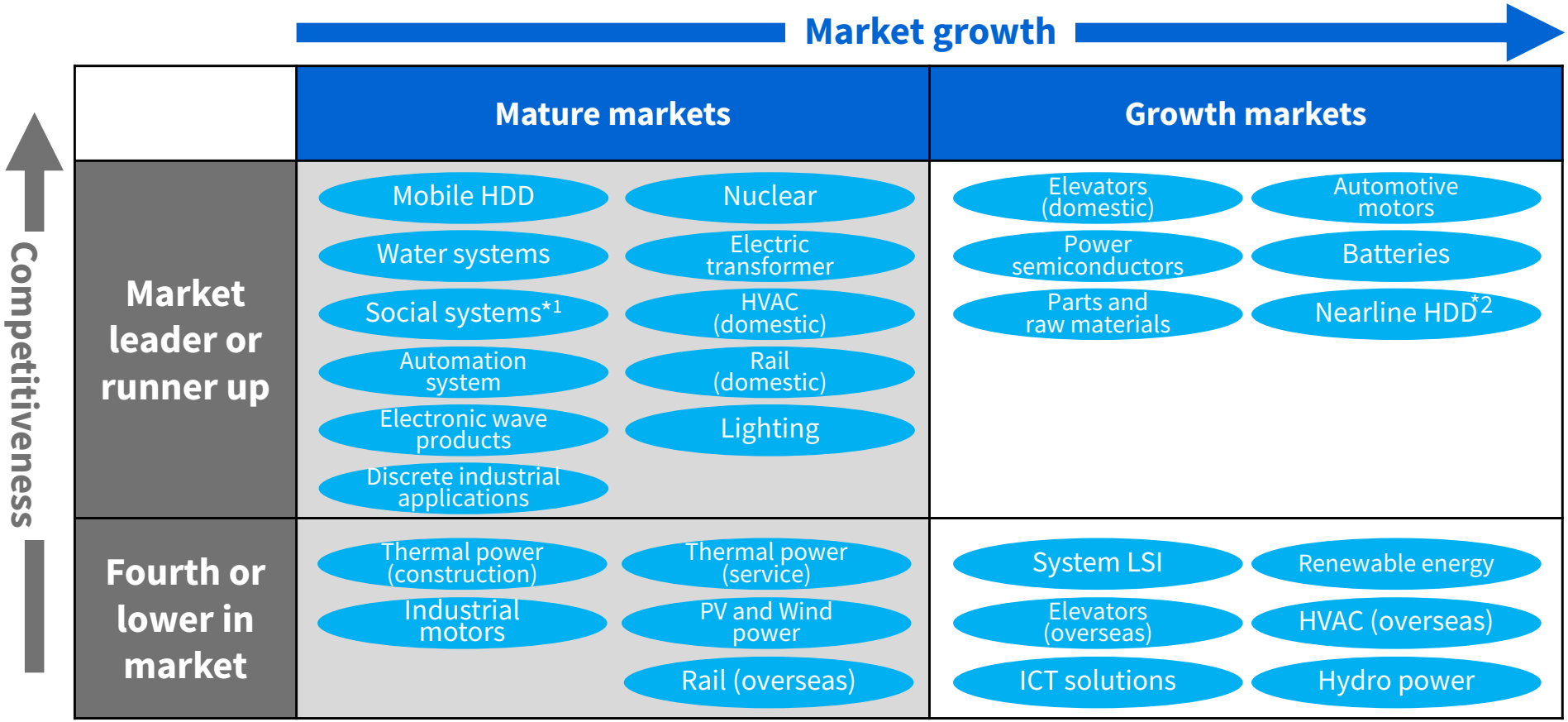
Physical

Abundant assets in business domains

Energy	Transmission & Distribution	Buildings & Offices	Industry	Public・Transportation・Broadcasting
Devices and storage	Telecommunications	Automobiles	Logistics	Medicine

To Become a CPS Technology Company

Relationships with customers in different business domains built through products are important assets



*1 Social systems, power distribution, broadcasting systems, telecommunications, road systems

*2 Nearline HDD: Large capacity HDD for data centers

*Retail & printing businesses are not included

Research & Development Policy

Creating original CPS by competitive components and AI & IoT technologies
Resolve social issues and maximize enterprise value through technology

Towards CPS technology company

Further strengthen components technologies based on abundant assets in business domains

- SCiB™ Rechargeable battery - Power electronics - Large capacity Nearline HDD
- Supercritical CO_2 cycle power generation system - Railway systems - Automation/Robotics
- Semiconductors for automobiles - Hydrogen energy

Develop technologies that improve customer value through digitization based on AI & IoT technologies

- Toshiba Analytics AI SATLYS™ - IoT solution for power plants - VPP - Digital substation
- Demand forecasting - Image segmentation - Structure health monitoring
- Wireless Multi-hop Video Transmission

Create cutting-edge technologies to solve social issues that will emerge in the future

- Heavy-ion therapy solution - Biodegradable liposome
- AI hardware - Quantum branching machines - Quantum cryptographic communication

02

Technologies that Differentiate Toshiba's CPS

1. Component technology (Policy 1)
2. Digital & AI technology (Policy 2)
3. Cutting-edge technology (Policy 3)

Further strengthen components technologies based on abundant assets in business domains

- SCiB™ Rechargeable battery - Power electronics - Semiconductors for automobiles
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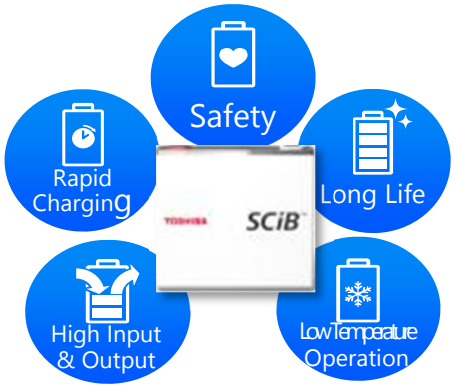
SCiB™ Rechargeable Battery

Further high capacity and high output to respond to potential growth markets & needs

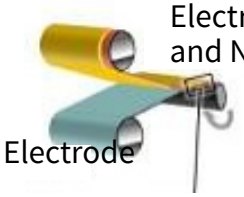
Focus on markets where the SCiB™'s characteristics of rapid charging, safety and long life are attractive

High output (for ISS/HEV)



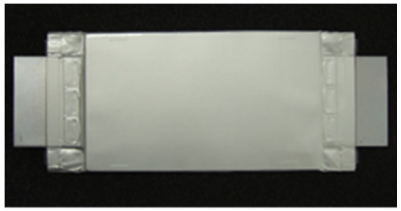
Separator-free

Nanofiber film formed directly on electrode with electrospinning technology. Thinner film and higher porosity result in higher output and capacity



Next-generation anode material

Higher capacity by niobium titanium oxide anode results in 1.5-times drive range of current SCiB™



LTO*1 Anode (current SCiB™)

NTO*2 Anode

Composite solid electrolyte

Bipolar structure

Range (6mins rapid charge) *3:

200km

320km

~400km

High capacity (for EV/PHEV)

Applications Automotive(HEV, Commercial vehicle, etc.) Industrial (railways, AGV, etc.)

*1: Lithium Titanium Oxide
*2: Niobium Titanium Oxide
*3: A compact EV with a 20kWh for LTO or a 32kWh for NTO in JC08 test cycle

Power Electronics

Integrated development from device to equipment
Low conduction and switching loss semiconductors improve efficiency and reduce energy consumption of equipment and

Devices → **Equipment** → **System**

Power devices | Power electronics controls | Industrial equipment | Mobility | Power generation/Transmission/Distribution

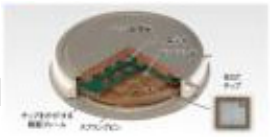
Power Devices

- **High precision materials processing technology**
- **Developing low conduction and switching loss device structures**
- **Circuit and control technology that maximizes device performance**

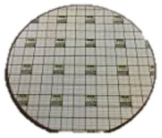
Si Power Devices

● Industry's top class*1 of low-on-resistance MOSFETs

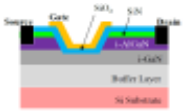
● IEGTs with low loss and wide safe operating area for transmission and distribution power grid



Next generation Power Devices (SiC, GaN)



● SiC-MOSFET: Original process reduces channel resistance by 40%*2



● GaN-MOSFET: Industry's top class threshold voltage stability*3

Create differentiation technologies, from properties of materials to application in circuits, and take lead in efficiency and miniaturization of power converters

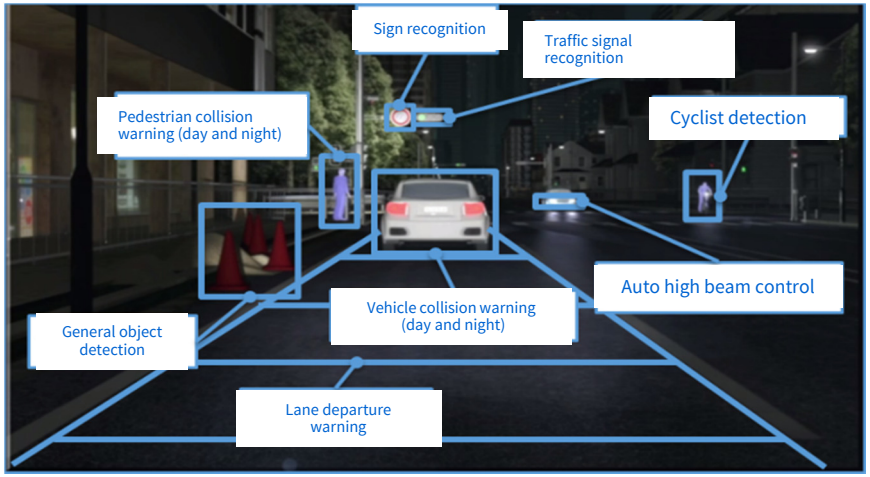
MOSFET: Metal-Oxide-Semiconductor Field-Effect Transistor
IEGT: Injection Enhanced Gate Transistor

*1: in 100V-class MOSFET as of October 2018, Toshiba Electronic Devices & Storage Corporation
*2: S. Asaba et al., Int. Conf. on Silicon Carbide and Related Materials 2017, 33.3
*3: T. Yonehara et al., Int. Electron Devices Meeting 2017, MO.C2.1

Semiconductors for automobiles

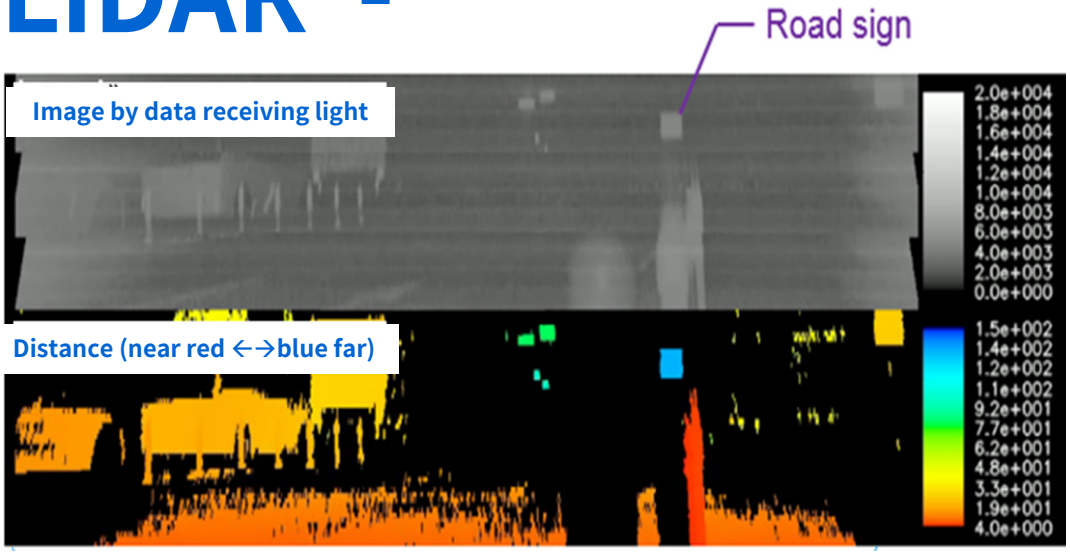
Support automated driving by high resolution image recognition processor and high sensitivity distance sensor

Image recognition processor
Visconti™



- Enhanced night time recognition performance with original recognition algorithm
- Develop advanced recognition technology based on deep learning, in cooperation with Denso Corporation

Distance sensor
LiDAR *1



- SiPM*2 light receiving element and measurement logic circuit enable multi-channel and higher sensitivity
- Achieve longer range measurement (200m) with high level distance measurement accuracy (0.125%)

*1: Light Detection and Ranging *2:Silicon Photo-Multiplier

Large Capacity Nearline HDD for Data Centers

Evolution of magnetic recording density to support higher capacity demand from mega data centers

14TB nearline HDD

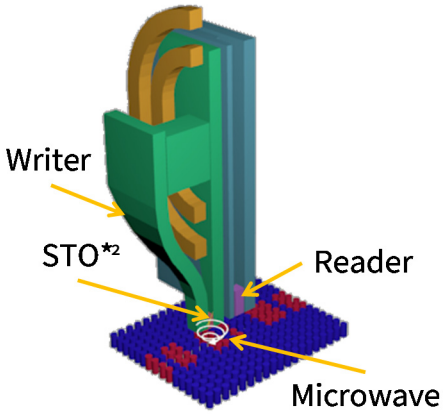
World's largest capacity*1 and low power consumption

- **Stabilizing heads and rotation of disks by Helium sealing**
- **Toshiba's innovative mechanical design to realize 9-disk inside**

Next generation higher density technology

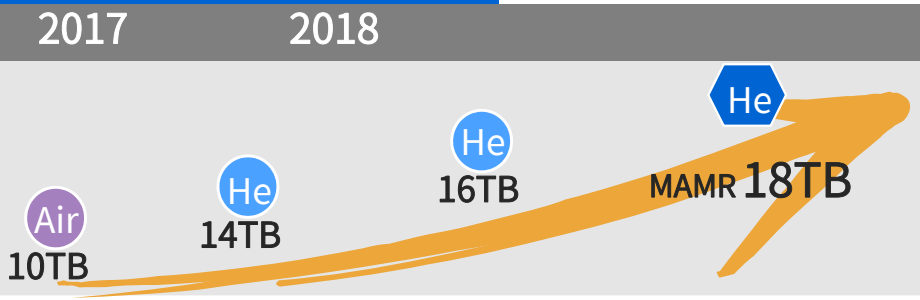
MAMR

(Microwave Assisted Magnetic Recording)



Technology to boost disk recording capacity using microwave oscillators on magnetic heads

Product Roadmap



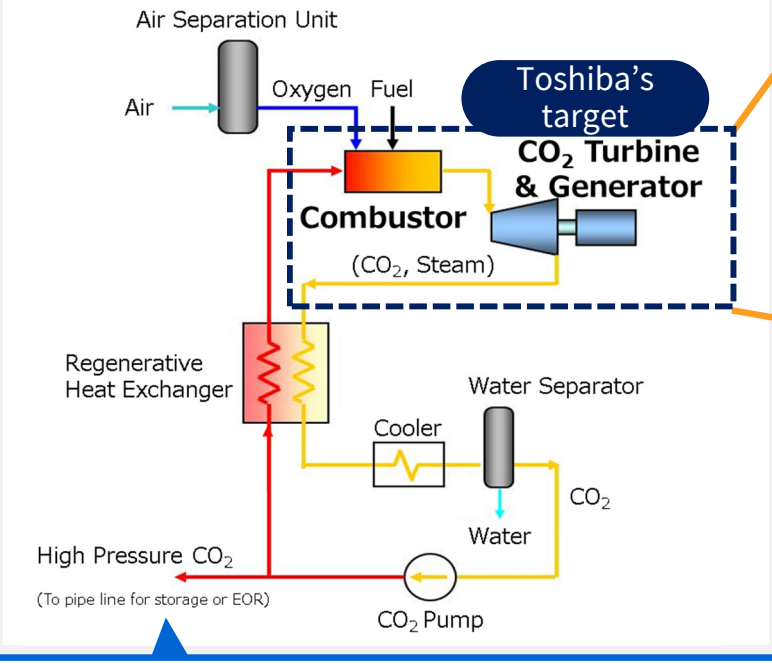
*1: Form Factor: 3.5-inch and 26.1mm-height. Source: Toshiba Electronic Devices & Storage Corporation, as of December 2017.
*2: Spin Torque Oscillator

Gas turbine and Combustor for Supercritical CO_2 Cycle Thermal Power Plant System

Develop key components for decarbonized and near-zero emission thermal power plant system

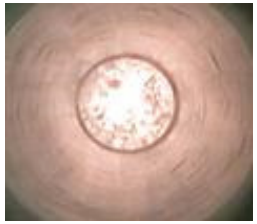
Supercritical CO_2 cycle thermal power plant system*

- Realization of near-full carbon capture without additional carbon dioxide capture system
- Generate power by rotating turbine using CO_2



Compared with conventional thermal power plant
- No emission of nitrogen oxides
- CO_2 is captured at high-pressure and high-purity, and can be used for enhanced oil recovery (EOR) and chemical plants

World's first supercritical CO_2 combustor



Center is the flame inside the combustor

Compact and high efficiency super critical CO_2 turbine

Future outlook **Testing at demonstration plant**

～ Joint development with NET Power, Exelon Generation and McDermott ～

25MWe demonstration plant Texas, U.S.A

* "Allam Cycle" developed by 8 Rivers Capital

Further strengthen components technologies based on abundant assets in business domains

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- Biodegradable liposome
- AI hardware
- Quantum cryptographic communication

AI to solve on-site essential problems

Realizes necessary functions from data acquisition from the physical world to providing feedbacks to the physical world

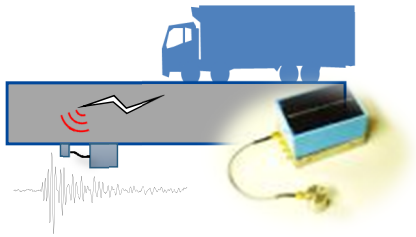
1967
Demonstration of automatic postal code reading and sorting device

Accumulation of long-standing AI technologies

Data-rich work sites

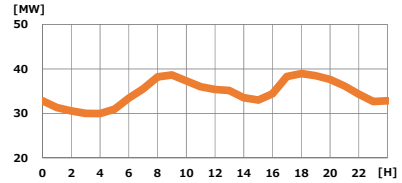
Analysis

- Classification of defects in the product
- Analysis of deteriorated infrastructure*1



Prediction

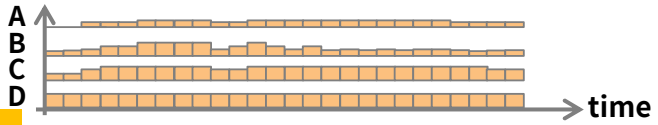
- Failure prognostic of equipment
- Forecast of power demand



1st prize in the electricity load forecasting technology contest out of about 100 teams*2

Optimal planning

- Plant operation plan
- Train operation plan
- Infrastructure maintenance plan



Situations where humans and AI co-exist

Recognition

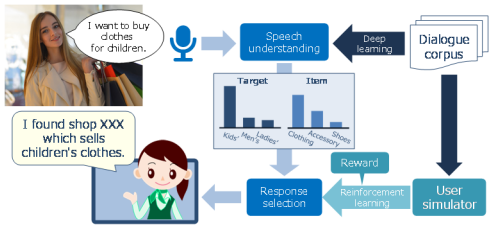
- In-vehicle image recognition
- Object recognition for logistics
- Person tracking for surveillance cameras
- Image and voice recognition for operation support
- Tumor-tracking for heavy-ion therapy

Decision & Control

- Action decision for robots
  - Path planning for autonomous driving

Interaction

- Automatic speech dialogue

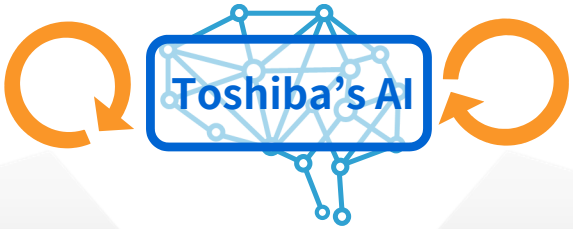


*1: This work was supported by the New Energy and Industrial Technology Development Organization (NEDO) of Japan.
*2: https://www.toshiba.co.jp/about/press/2017_11/pr_j0801.htm (2017 / Sponsorship: Tokyo Electric Power Company Holdings, Inc.)

R&D Direction of AI Technologies

Enhancement through on-site application and open innovation
From AI with manual intervention to self-learning AI

Field
Domain knowledge

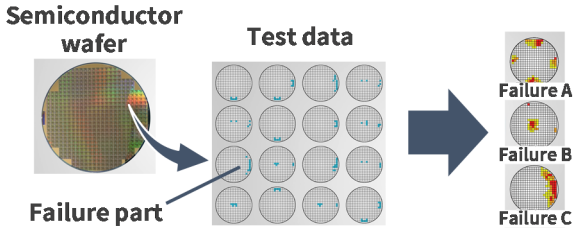


Partners
Joint research

Enhancement at business fields with large amounts of data

R&D aligned with on-site problems

Product failure analysis based on data mining



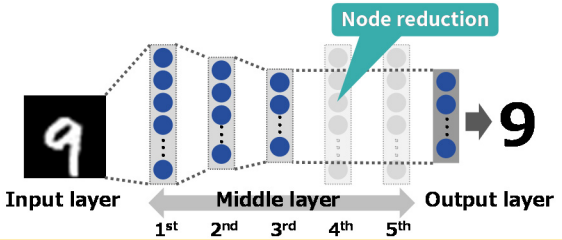
Automatic classification of tendency to defect occurrence through unsupervised learning

Gold Medal in the Japanese Society for Artificial Intelligence's Field Innovation Award

Enhancement at cutting-edge research laboratories

R&D leveraging open innovation

DNN compaction for high speed processing in edge devices



Joint research at the RIKEN AIP*1-TOSHIBA Collaboration Center

Details are to be announced at ICMLA2018 in December 2018

AI with manual intervention

- Supervised learning
- Semi-supervised learning
- Unsupervised learning
- Reinforcement learning
- Manual design of DNN structure
- Automatic optimization of DNN structure

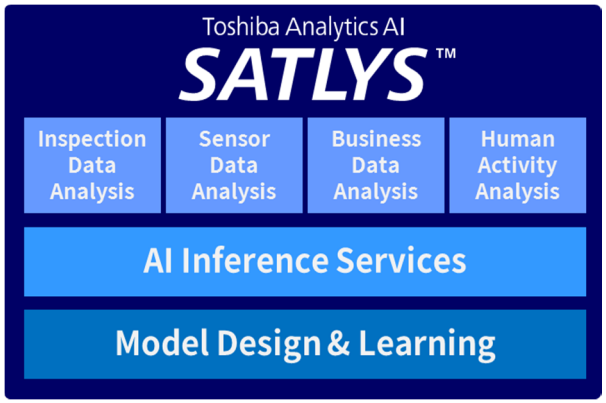
Self-learning AI

DNN: Deep Neural Network

*1: RIKEN Center for Advanced Intelligence Project

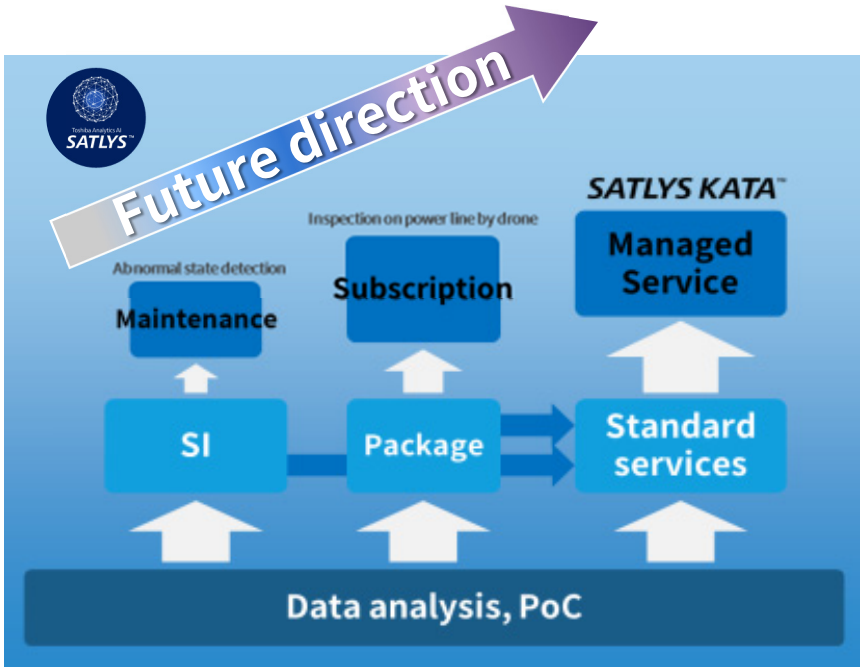
Toshiba Analytics AI SATLYS™

Use knowledge from Toshiba's wide business domains for AI inference service
Integrate knowledge from experience for standardization and managed services



Features

- Big data analysis with over tens of thousands of dimensions
- Realize highly accurate inference with limited learning data (automatic generation of learning data with AI)
- Intuitive explanation of abnormal factors (visualization, AI with high level explanation)

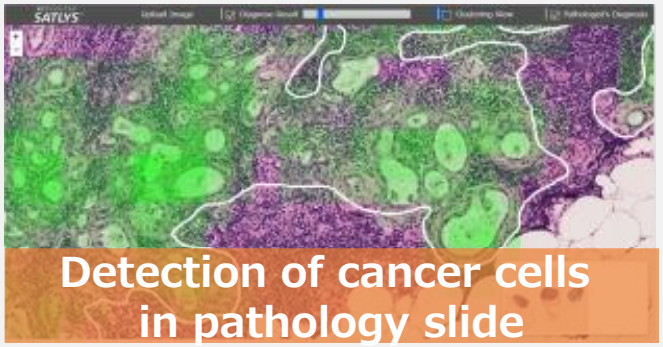


SATLYS KATA™

- Standardized AI analysis knowledge verified on site
- Delivered in different forms such as SaaS and micro-services

Combustion image analysis

For JFE Engineering Corporation
AI detects abnormal combustion state from combustion images at waste treatment facilities



Detection of cancer cells in pathology slide

Joint research with Chiba University Hospital
AI learns the knowledge of skilled pathologists to overcome a shortage of pathologists

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- AI hardware - Quantum cryptographic communication

Cutting-edge technologies to realize Precision Medicine

Deepen technologies for very early detection and individualized treatment to contribute to improving cancer cure rates

Realization of Precision Medicine

Prevention	Examination	Diagnostics	Treatment
Genome analysis	Liquid cytology	Cell diagnosis	Minimally invasive treatment

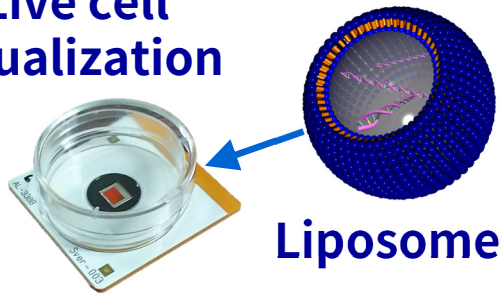
Japonica Array*1

Next generation sequence

Heavy-Ion Therapy

Micro RNA

Live cell visualization



Liposome

Toshiba owns core technologies through all phases from prevention to treatment

*1 Collaboration with Tohoku University

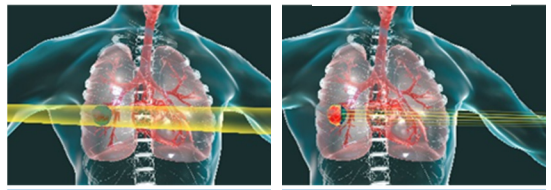
Heavy-Ion Therapy Technology

Downsize the equipment and realize precise treatment using superconductivity and Image recognition technologies to reduce burden on patients and increase treatment opportunities

Reduce impact on healthy tissue by matching the peak energy of the heavy ion beam to cancerous cells

X-ray

Heavy-Ion



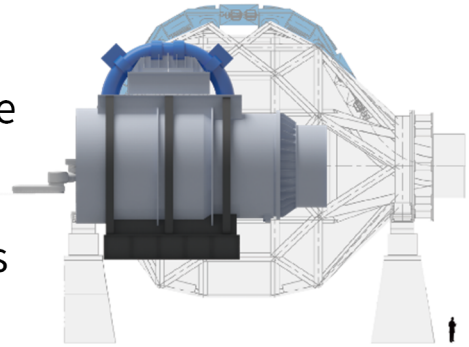
Go through | Stop

The world's first adaption of superconducting technology for the rotating gantry

(Delivered to NIRS*1. Orders received from Yamagata University Hospital and Yonsei University Health System in South Korea)

More compact and light rotating gantry

Successfully downsized the rotating gantry by use of superconducting magnets and improved scanning electromagnets



40% volume reduction comparing to conventional one

Tumor tracking without fiducial markers

Track tumor motion and secure precise delivery without implantation of fiducial markers by use of Image recognition technology

Education, Culture, Sports, Science Minister's Commendation Science and Technology Award in 2017

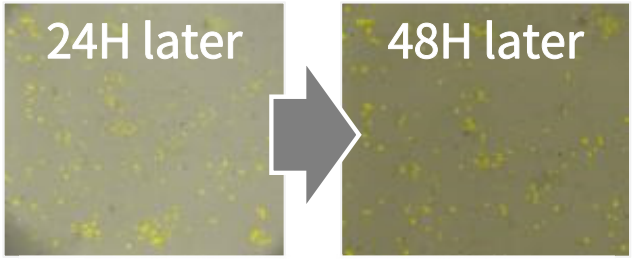
*1 National Institute of Radiological Sciences, National Institute for Quantum and Radiological Science and Technology

Biodegradative liposomes

Safe and highly efficient delivery of desired gene to cells in precision medicine that realizes higher cancer cure rates

98% success in delivering genes to cells

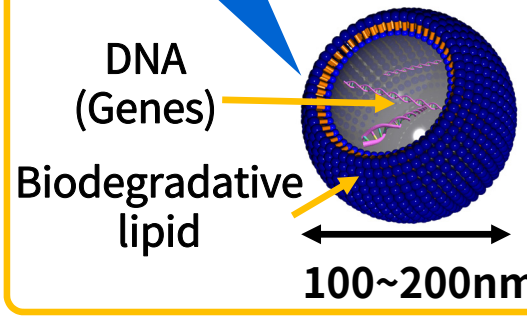
Convert gene activity into light and succeed in observing live cells



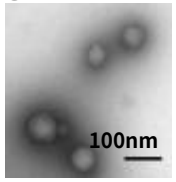
Time-lapse imaging

Liposome

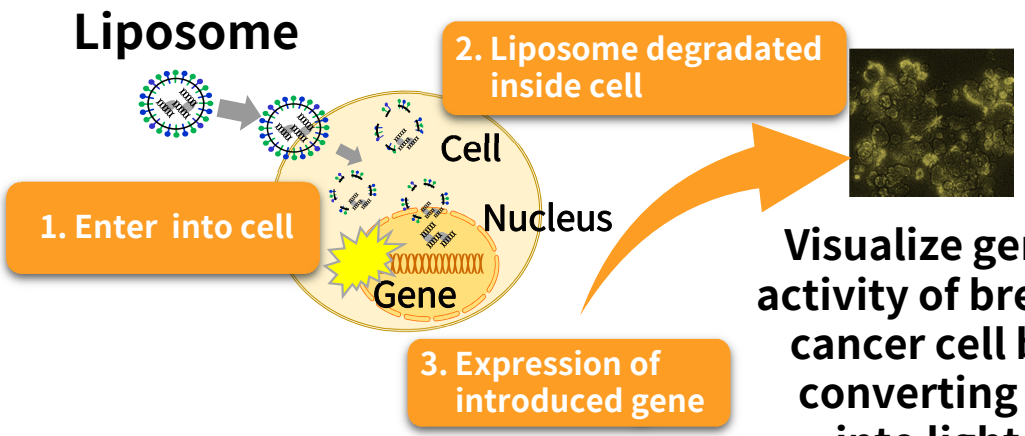
Toshiba's original nano-sized lipid carrier that delivers genes to cells with high efficiency



microscopic image of liposome



■ Gene delivery flow



Visualize gene activity of breast cancer cell by converting it into light

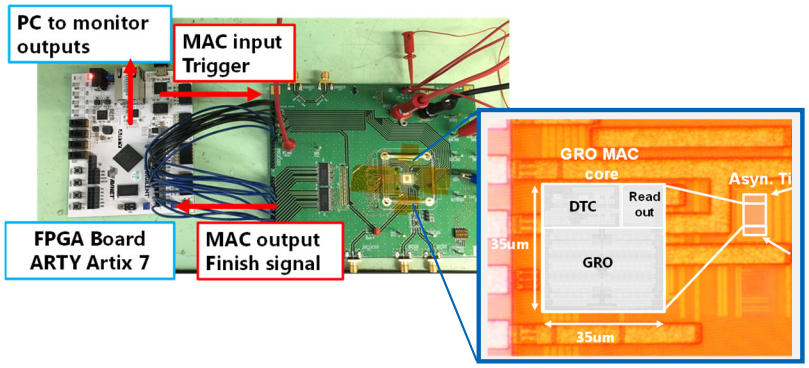
Presented at the 57th annual autumn meeting of the Japanese society of clinical cytology

AI Hardware

Ultra low-power AI chip meeting the demands for processing large amount of sensing data at the edges

Reduced power consumption by 88%, compared to conventional chip

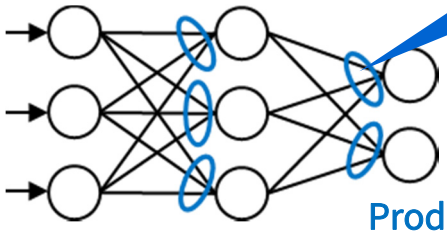
Real time AI processing even with battery power



Prototype board and chip
(28nm CMOS technology)

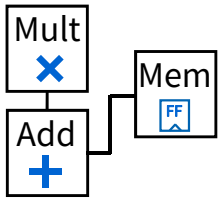
Less power used for Product-sum operation for DNN (inference processing)

Neural network model

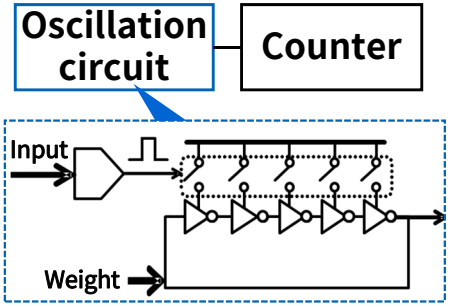


Product-sum operation

Conventional structure



Proposed analog structure



Perform multiply-accumulate operation by new calculation method

Joint research with Stanford University

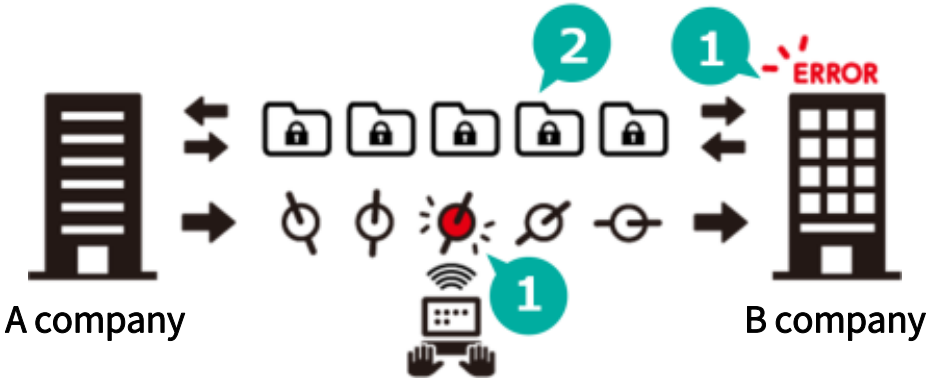
Quantum cryptographic communication

Protecting security of confidential information, such as genome medical data transmitted via networks

Achieved key distribution speed of 10.2Mbps and improved Toshiba's own world's record
(tested with a 7km installed fiber in a field environment)

Proposed a new method for achieving quantum key distribution over 500km, a new world record

Principles



1. **Transmit photons and share encryption keys**
(Use principles of quantum physics to detect eavesdropping; only secure keys can be used)

2. **Encrypt confidential information by one-time-pad cipher using encryption keys and transmit the encrypted information**

Joint research with the University of Cambridge

03

Examples of Toshiba's CPS

1. Stabilized energy supply and demand
2. Improved maintenance of railways
3. Automated logistics centered on robots

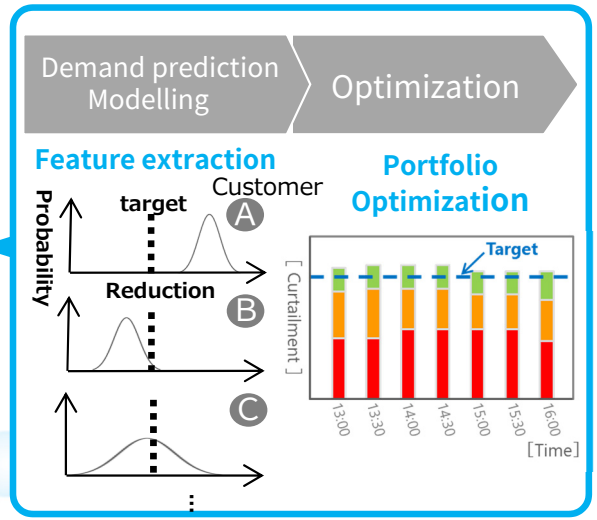
Stabilized Energy Supply and Demand

Utilize characteristics of each Distributed Energy Resource
Harness extensive experience & knowledge of equipment
Apply prediction & optimization technologies

Cyber

Prediction, forecasting & optimization technologies

Virtual Power Plant (VPP)



IoT Integration

Optimal control

Physical

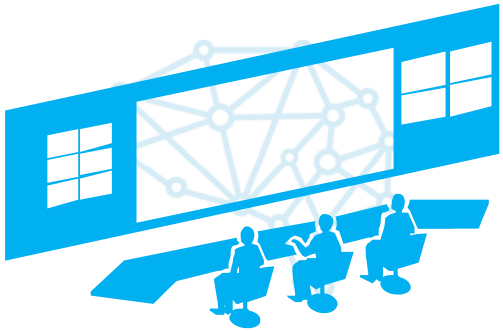
- **Power saving (Negawatt)**
- **Battery Storage (Industry, Residential)**
- **PV & Wind power**
- **Electric Vehicles**
- **Hydrogen**

Improved maintenance of railways

Contribute to improvement of locomotive maintenance with control technology based on deep knowledge of features of rechargeable batteries, motors, etc. and operational data analysis technology

Cyber

Analyze



Maintenance plan

Hybrid locomotive

Physical

Rechargeable battery

(World's first acquisition of European safety certification for a railway system using rechargeable battery)

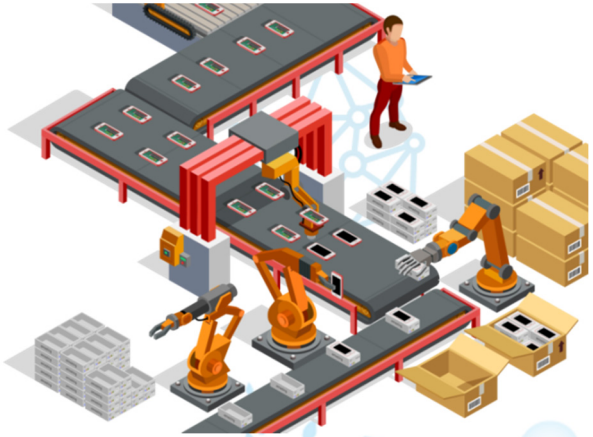
Permanent Magnet Synchronous Motor

Automated logistics centered on robots

Contribute to automation of logistics solutions with high processing performance based on object recognition, motion planning, and control at edge and link them with higher level data

Cyber

Recognition



Direction

Picking of atypical object

Physical

Recognition

Grip and motion planning

Sensing
(image, location, distance, force, etc.)

Robot control

World Robot Summit: Overall victory in the robot competition received the Minister of Economy, Trade and Industry award (2018/10)

04

Research & Development Investment and Structure

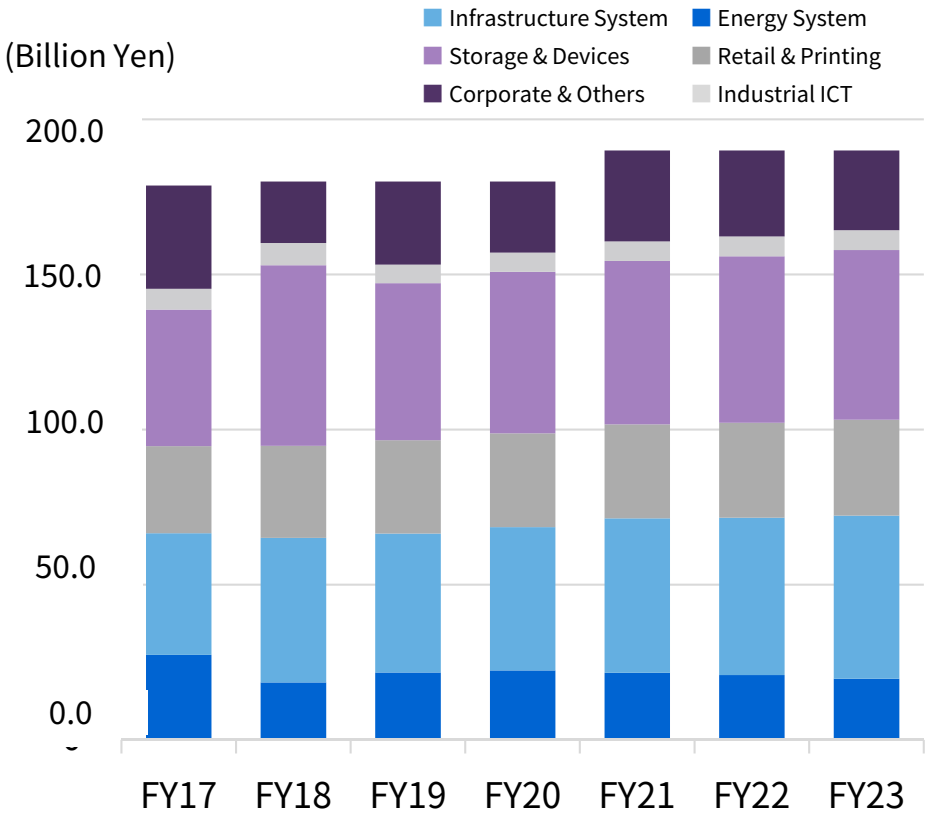
1. R&D investment
2. Transformation of operating processes
3. R&D structure
4. Role of each R&D organization
5. Open innovation
6. New business incubation

R&D Investment

Accelerate investments to support profit and medium- to long-term growth

R&D investment *1

Total investment plan：JPY 930.0B (FY19-23)



Major R&D projects

Energy system

Focus on growth fields such as renewable energy technology (e.g. PV, Wind power, VPP*2), asset management solutions and environmentally friendly products (supercritical CO_2 power cycle etc.)

Infrastructure system

Focus on growth fields such as SCiB™, power electronics, robotics

Storage and device

Focus investment on the development of power devices and large capacity HDD for data center

Industrial ICT

Focus on development for business model transformation such as SPINEX™, RECAIUS™ and SATLYS ™

***1 Excluding Toshiba Memory, *2 VPP: Virtual Power Plant**

Transformation of operating processes to improve earning power

Optimize the entire value chain from R&D to products

Management strategy

Specification guidance and configuration

Modularization

CAE/DMU*1

Manufacturing Simulation

VR/MR*2

Operation Simulation

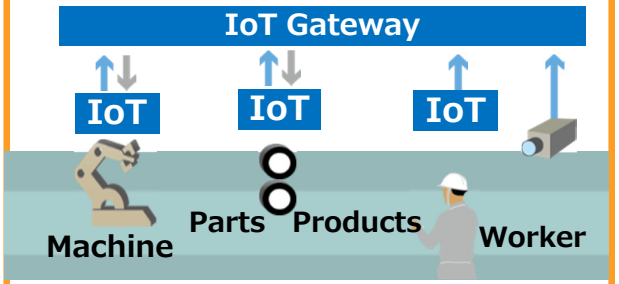
Marketing → Planning → Development/Design → Procurement → Manufacturing & Testing → Maintenance

Modularization/Standardization/IT

Digital engineering

Designing process optimization

Manufacturing process IoT



Manufacturing process optimization

On-site IoT

Maintenance process optimization

*1: CAE: Computer Aided Engineering / DMU: Digital Mockup *2: VR: Virtual Reality / MR: Mixed Reality

R&D Structure

Establish "Research & Development Div." to produce outstanding and fundamental common technologies by collecting expertise of individual corporate laboratories

Toshiba Corporation

- Research & Development Div.
  - Corporate Research & Development Center
  - Corporate Software Engineering & Technology Center
  - Corporate Manufacturing Engineering Center
- Digital Transformation Strategy Acceleration Div.
- Materials & Devices Division

<Key group companies' R&D organizations>

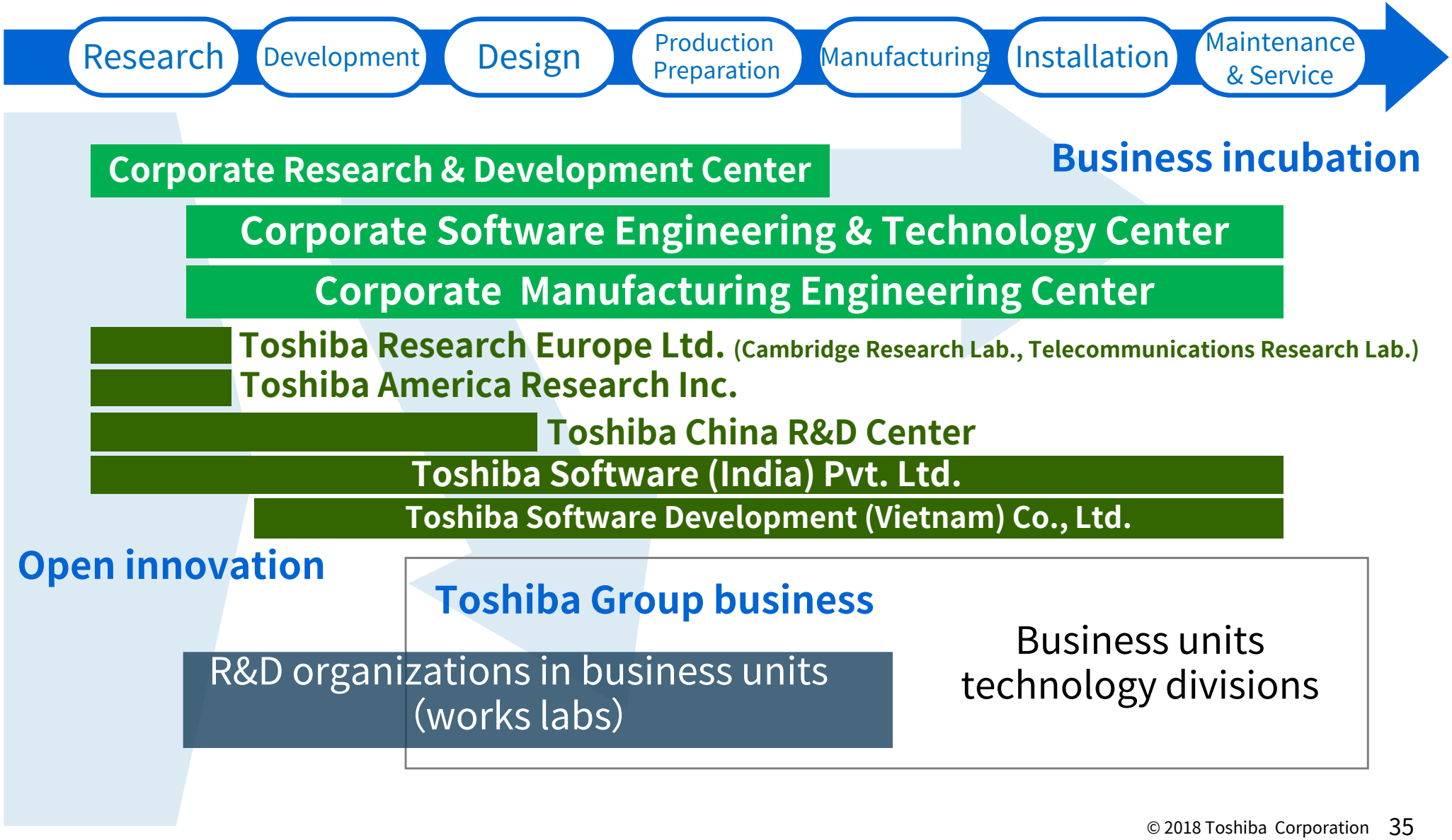
- Toshiba Energy Systems & Solutions Corp.
  - Energy Systems Research and Development Center
- Toshiba Infrastructure Systems & Solutions Corp.
  - Infrastructure Systems Research and Development Center
- Toshiba Electronic Devices & Storage Corp.
  - Center For Semiconductor Research & Development
- Toshiba Digital Solutions Corp.
  - Software & AI Technology Center
  - Industrial ICT Security Center
- Toshiba Tec Corp.
  - Technology and engineering divisions

<Overseas R&D organizations>

- Toshiba Research Europe Ltd.
  - Cambridge Research Laboratory
  - Telecommunications Research Laboratory
- Toshiba America Research Inc.
- Toshiba China R&D Center
- Toshiba Software (India) Pvt. Ltd.
- Toshiba Software Development (Vietnam) Co., Ltd.

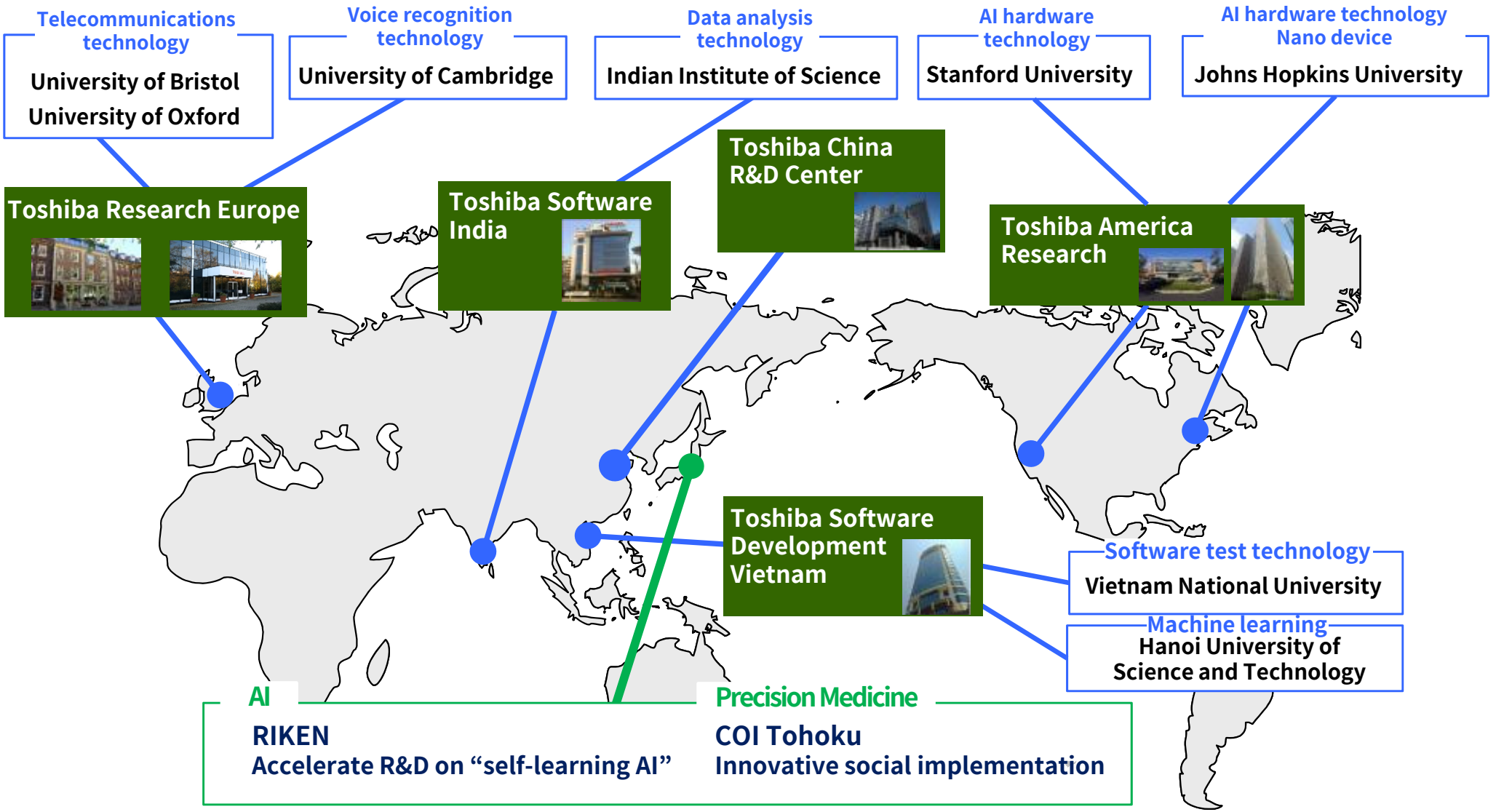
Role of Each R&D Organization

By pulling together the ranges of corporate labs for business processes and technologies, deliver technology solutions from research to manufacturing and maintenance



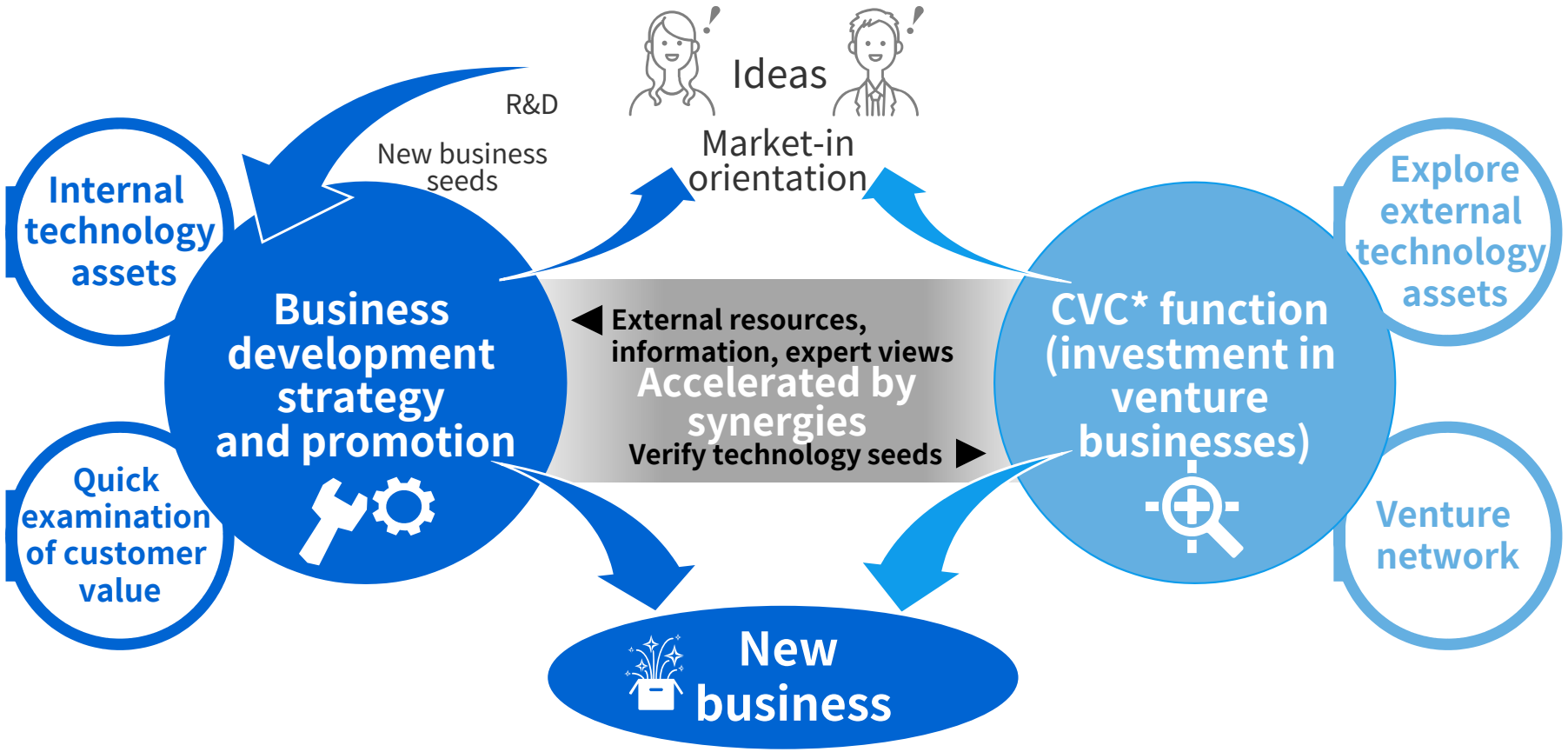
Open Innovation

Establish overseas research sites for advanced technologies in the US, Europe and China, and accelerate R&D in cooperation with top universities and research institutes in Japan and overseas



New business incubation

Introduce a new business creation mechanism that leverages our venture spirit



* CVC：Corporate Venture Capital

05

In conclusion

We turn on the promise of a new day


Committed to People, Committed to the Future

TOSHIBA