Software Defined Business Transformation with Scale-free Network

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Toshiba Corporation
Toshiba Senior Vice President, Chief Digital Officer
(Director, President and CEO, Toshiba Digital Solutions Corporation)

Shunsuke Okada
Many businesses contribute to economic security by supplying core infrastructure and key products that support industries.

<table>
<thead>
<tr>
<th>Year</th>
<th>1900</th>
<th>1920</th>
<th>1970</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>Generation and transmission systems</td>
<td></td>
<td></td>
<td>128 years</td>
</tr>
<tr>
<td>Water Supply &amp; Sewerage</td>
<td>Electric Systems</td>
<td></td>
<td></td>
<td>57 years</td>
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<tr>
<td>Broadcasting</td>
<td>Broadcasting systems</td>
<td></td>
<td></td>
<td>103 years</td>
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<tr>
<td>Airport</td>
<td>Surveillance radar system</td>
<td></td>
<td></td>
<td>59 years</td>
</tr>
<tr>
<td>Railway</td>
<td>Electrical equipment for domestic vehicles</td>
<td></td>
<td></td>
<td>122 years</td>
</tr>
<tr>
<td>Factory</td>
<td>Industrial motors</td>
<td></td>
<td></td>
<td>126 years</td>
</tr>
<tr>
<td>Store</td>
<td>Cash registers (predecessor of POS)</td>
<td></td>
<td></td>
<td>96 years</td>
</tr>
<tr>
<td>Elevators</td>
<td></td>
<td></td>
<td></td>
<td>56 years</td>
</tr>
<tr>
<td>Semiconductors and Storage</td>
<td></td>
<td></td>
<td></td>
<td>132 years</td>
</tr>
<tr>
<td>Lighting</td>
<td></td>
<td></td>
<td></td>
<td>66 years</td>
</tr>
</tbody>
</table>

*Based on internal research*
Evolution of the Digital Economy and Changes in the Business Environment

**Evolution of the digital economy**

**QX**
Quantum Transformation
Creating the quantum industry

**DX**
Digital Transformation
Data business
Matching business
Platform development

**DE**
Digital Evolution
Shift to services and recurring businesses

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**Connected markets**
Creating new social values

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**CPS1.0**

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Software Defined Transformation

Create a platform after separating apps, software and hardware

Current status

DE: Digital Evolution

DX: Digital Transformation

The key to change is “Software Defined”
SHIBUYA Approach: Evolving Process from DE to DX

Reviving the company (city) without stopping the business (train)

Step 0
- Separation of applications, software and hardware (and related services)

Step 1
- Become “software defined”: updating functions with a separated SW layer

Step 2
- Align processes and organizations with the SHIBUYA approach

Step 3
- Create new service businesses on the new platform

Step 4
- To DX

Visualization, analysis, organizational changes, system reforms, and feedback

- Categorize HW with high market value and commodity used within the system
- Incorporate HW (technology) with high market value and restructure HW with low market value
- Significantly reduce fixed costs and digitalize development, design, manufacturing and procurement, and maintenance processes

To CPS
- Energy Solutions
- Infrastructure Systems Solutions
- Building Solutions
- Retail & Printing Solutions
- Devices & Storages
- Digital Solutions
- Battery
- Data Business
- Building Solutions
- Retail & Printing Solutions
Lorenz Attractor

Impossible to predict

\[
\frac{dx}{dt} = -px + py \\
\frac{dy}{dt} = -xz + rx - y \\
\frac{dz}{dt} = xy - bz
\]

Source: Hatenablog
http://zellij.hatenablog.com/entry/20130207/p1
Tree Diagram Thought Network

Convenient, but the world just isn’t like that

Source: Phylogenetic tree of biological evolution (http://www.pitecan.com)
The World of Normal Distribution and Chaos

Real chaos is inequality

Example of Gaussian distribution

Example of power distribution

Source: DIAMONDonline (https://diamond.jp/articles/-/49684?page=3)

Source: The physics of the Web (https://physicsworld.com/a/the-physics-of-the-web/)
Albert-László Barabási Scale-Free Network

Scale-free networks that produce innovation

Source: "The Architecture of Complexity From network structure to human dynamics", A. Barabási, 2007
Percolation: The Phenomenon of Immediate Change Once a Critical Point is Passed

Innovation occurs above the critical point

Cluster growth process

Source: CYBERNET (https://www.cybernet.co.jp/ansys/case/analysis/399.html)
From “things” to “events” is wrong
⇒ the “platforms” where things happen are important

A Scale-free Network Example
Receipts to your Smartphone

Download the app and register
Show your membership barcode at the cashier
Pay just as always

The shopping receipt is in your smartphone!
High Utilization of Smart Receipt Introduction Coupons

From the demonstration project in Okinawa

Sales campaign coupon

- Primary High utilization 56.7%
  (3,876 issued / 2,196 used)

- Secondary High utilization 49.0%
  (4,450 issued / 2,181 used)

Reciprocal Customer Transfer

Big spenders 9.5x
(6 → 75)

Okinawa Co-op ↔ PETBOX
DE Case Study: Software Defined Transformation of Elevators

Develop elevator system as a service (SaaS) that can continually update elevator and building operations

Before
Inseparable HW and SW

After
Separated HW and SW

Add functionality via the cloud

Elevator Cloud

HW
SW

App
(Existing Control Panel)

Toshiba Elevator Cloud Service
ELCLOUD
Connected Elevators that evolve and create new value

Elevators and robots work together
Robots move about freely on each floor and provide a variety of services

From smartphone app
Able to call elevators

In market from Nov. 2023

*Not applicable to some elevator models
DE & DX Case Study: Secure Space Management Solution

Walk-through Body Scanner using Millimeter-Wave Radar

High-Definition Radar Imaging in less than 1 second

High-Definition Imaging with Fewer Scanning Points

Conv. : Massive sensors

Toshiba : less than 10%

Lens Focusing Processing on SW

Gun

Liquid

Model Gun

Water Flammable

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DE & DX Case Study: Secure Space Management Solution
Modularization from Commercial Sensors, and Systematization from Modules

Original designed module achieves system scalability and operational flexibility
DE & DX Case Study: Secure Space Management Solution
Platform for Secure Space Management

Building safe and secure space with diverse operators through a platform

Challenges for Operators

- Difficult to adjust to various scenes and sites
- Need for professional knowledge of radar technology

<Toshiba’s Platform Concepts>

1: Software Defined Architecture
2: Service Provisioning (Automated Calibration, DB update, etc)
3: Open environment for customization

Minister for Internal Affairs and Communications Award 2023
Modern system development, system optimization, verification requires:

- Large scale simulation of a coupled multi-domain system.
- Integrated use of simulation models over multiple teams.

Industry 4.0 and 5.0, Gaia-X, Catena-X accelerate Collaborative MBD.
International organizations and groups are working toward interoperability on model exchange at any time and anywhere. Toshiba supports these activities!
DX Case Study: Cross-company Collaborative Model-based Development Distributed Co-simulation Platform - VenetDCP

High Inter Connectivity
Coupling multiple tools and models running at different locations
Supporting SSP & FMI standards
Easy-to-use administrative user interface for tool-coupling

Protection of Model Confidentiality
Distributed co-simulation without disclosing model to other teams

Remote Operation and Automation
Remote simulation start & stop, parameter change from other location
Automating distributed co-simulation without operator

Simulators with verified interoperability
- Altair Twin Activate
- ANSYS Twin Builder
- AVSimulation SCANeR
- AVL CRUISE M
- Dassault Systèmes Dymola
- dSPACE VEOS
- dSPACE SCALEXIO
- dSPACE MicroAutoBox
- ESI SimulationX
- ETAS COSYM
- Gamma Technologies GT-SUITE
- IPG CarMaker
- MathWorks Simulink
- Modelon Impact
- National Instruments LabVIEW
- OpenModelica
- Python
- Siemens Simcenter Amesim
- Siemens Simcenter STAR-CCM+
- Unreal Engine
- Vector CANoe

All brand and product names are registered trademarks or trademarks of their respective holders.
DX Case Study: Cross-company Collaborative Model-based Development
Thermal management co-simulation interconnecting overseas sites

- Thermal management co-simulation of electric vehicle using high confidential supplier models
- Confidential models are stored on the provider’s machine and can be simulated without disclosing the contents
- Co-simulation can be remotely operated from Toyota overseas team
- Oversea team can develop thermal management which is highly adapted to local driving condition and environment

Model User
TOYOTA
(Oversea team)

Model Provider
TOYOTA
(Japan)

Supplier
High confidential models

Vehicle model

Virtual machine 1
Remote operation utility
GT-suite

Virtual machine 2
Simulink and GT

Cloud Server

Distributed Co-Simulation Platform

VenetDCP

Battery model

Air-conditioning system model

Model User

Drive pattern with local driving condition and environment

Thermal management simulation

Driving pattern with local driving condition and environment

Driving Time

Temperature [°C]

3000
5000
7000
9000
11000
13000
15000
17000
19000
21000

Case 6
Case 8

Ref. "モデル流通によるモデルベース開発(MBD)の効率化", TOYOTA MOTOR CORP., IDAJ SYMPOSIUM 2023, 10th Nov 2023
The Future Created by Quantum Technologies (2030-)

A world optimized by quantum technologies

Quantum Transformation

QX

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QX Case Study: Advantages of Quantum Computing

Static Problem Solving
- Computerized Drug Discovery
- Combinational Optimization of Materials

Dynamic Problem Solving
- Financial Portfolio Optimization, Best Arbitrage
- Optimized Electricity Distribution
- High Level Natural Language Recognition

Communications

Huge Data
Q-STAR Progress and Use Case Studies

2021 Establishment

- 2021.5 Founder’s Association Established
- 2021.9 Establishment of Q-STAR
- 11 Members

2022 Discussion and use case creation

- 2022: 65 Members
  - 8 Working Groups
  - 5 Subcommittees
- Discussed over 50 use cases

- Participated in the review working group to create "Vision of Quantum Future Society"

- Participated in the working group to create ‘Strategy of Quantum Future Industry Development’

2023 Demonstration Stage

- 2023.1 MOU signed to establish International Council of Quantum Industry Associations
- 87 Members (as of Nov. 2023)
  - 8 Working Groups
  - 6 Subcommittees

- Selected 16 of the discussed use cases and made industry roadmap
Q-STAR has created QRAMI (Quantum Reference Architecture Model for Industrialization) as a reference architecture model to view future quantum business, and aim to use it as a global tool for common understanding.
Quantum Key Distribution - Recent Global Deployments

- **Implemented PoC for financial blockchain with US-based J.P. Morgan Chase & Co.** (February 2022)
- **Implemented trials in industrial networks with NCC & BT** (October 2020)
- **Supplier to multiple national Quantum secured networks for EuroQCI project** (2023)
- **Continuing trial with US-based Verizon**
- **Jointly constructing 124 mile quantum test bed integrating solid state quantum memory nodes** (April 2022)
- **QKD multiplexing trial with Orange** (2023)
- **Q-SDN with UPM and Telefonica** (2023)
- **Commercial quantum-secured metro network trial in London with BT associated with EY** (since April 2022) and newly joined by HSBC (since July 2023)
- **Validated IOWN Secure Optical Transport Network with NTT** (Nov 2021)
- **Launched collaboration in the quantum cryptographic communications business in Southeast Asia with Singapore-based SpeQtral** (August 2021)
- **Implemented long-range hybrid quantum-secured network with Korea-based KT** (March 2022)
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The Challenge

Optimization

Large-scale, combinatorial

Large-scale combinatorial optimization is a challenging computing process to find the best combination among an exponential number of candidates

Real world problems:

Toshiba Solution

SQBM+

Quantum-inspired solution

Solves large-scale combinatorial optimization problems through an Ising machine that emulates quantum bifurcation mechanics

SQBM+ process:
SQBM+ : Key Features

Achieve quantum-level performance on classical infrastructure

- **Large-scale**: Can handle up to 10 Million variables
- **Fast**: 10-100 times faster than competing quantum-inspired solutions
- **Software-based**: No special quantum hardware needed
- **Classic Infrastructure**: Compatible with GPU/FPGA
Demo videos are available through the YouTube links

1 Real-time

- Multi-object Tracking
  - Real-time tracking of multiple objects in videos
  
  ![2D graph maximal matching](https://www.youtube.com/watch?v=bWMZjwHtm5g)

2 Interactivity

- Interactivity improvement for optimal route search
  - Instantly presents patrol routes to visit points specified by user

  ![Traveling salesman problem](https://www.youtube.com/watch?v=NSh3nQTpOW8)

3 Stream Data Process

- Maximum Independent Set Detection
  - Fast extraction of independent components from large stream data

  ![Maximum independent set problem](https://www.youtube.com/watch?v=WIDoO-DJClo)

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**SQBM+ Use case: Capability Enhancement for IT systems**
Today’s Key Messages

What remains unchanged
“Committed to People, Committed to the Future”
Continue to support daily lives of people and the society, and to contribute for the economic security assurance

What we aim to achieve with the evolving digital economy
Our business: Transformation through “DE→DX→QX” to develop data service as a primary source of revenue
Our challenges: Break through both the internal and the external rigidity
Our action: SHIBUYA Approach → Being “software defined” is key

Contribute to the achievement of carbon neutrality and a circular economy through digitization
The Essence of Toshiba

Committed to People,
Committed to the Future.