

Capability, Architecture and Performance SDV-EV in China, Germany and Japan

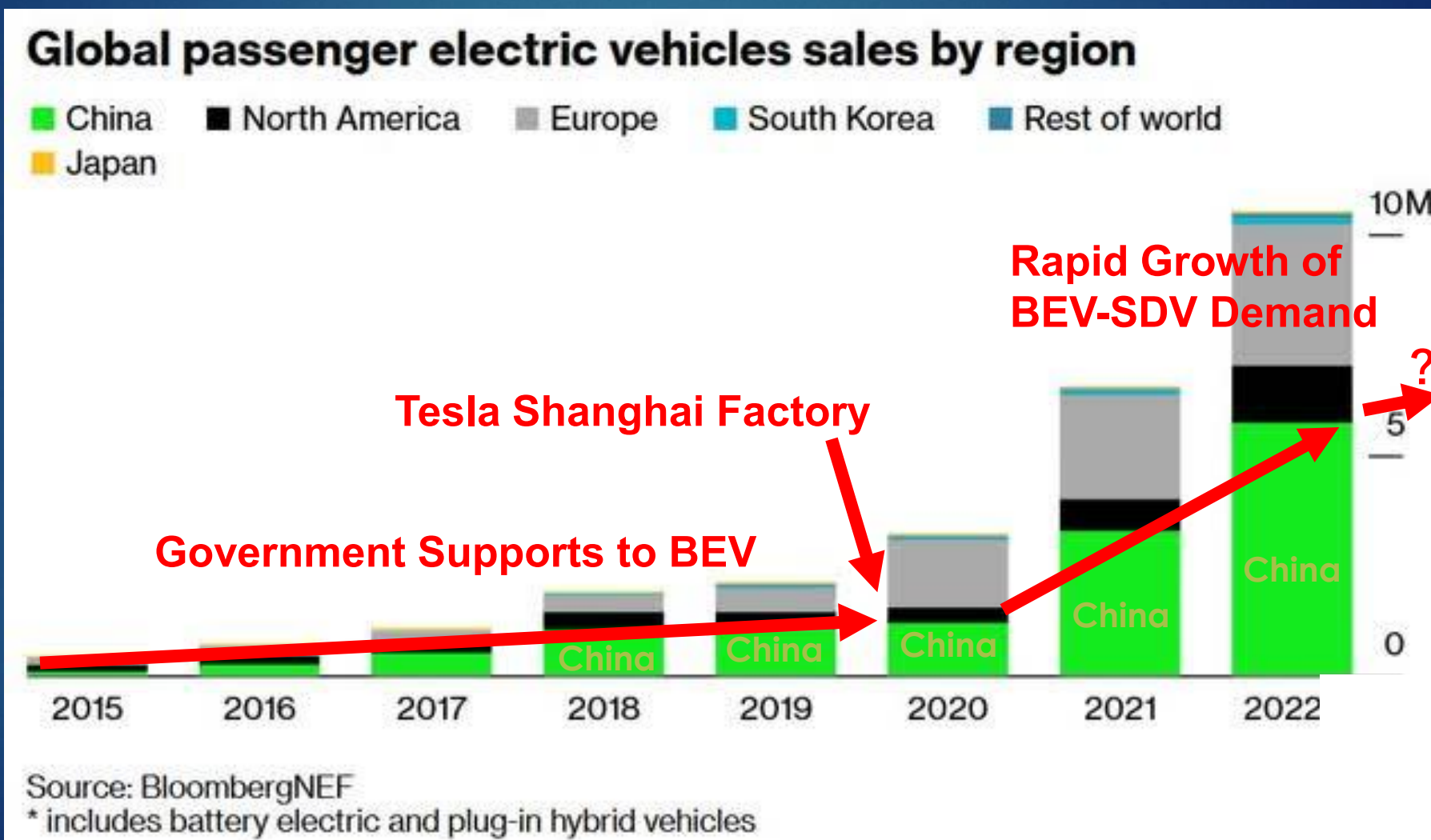
October 2026

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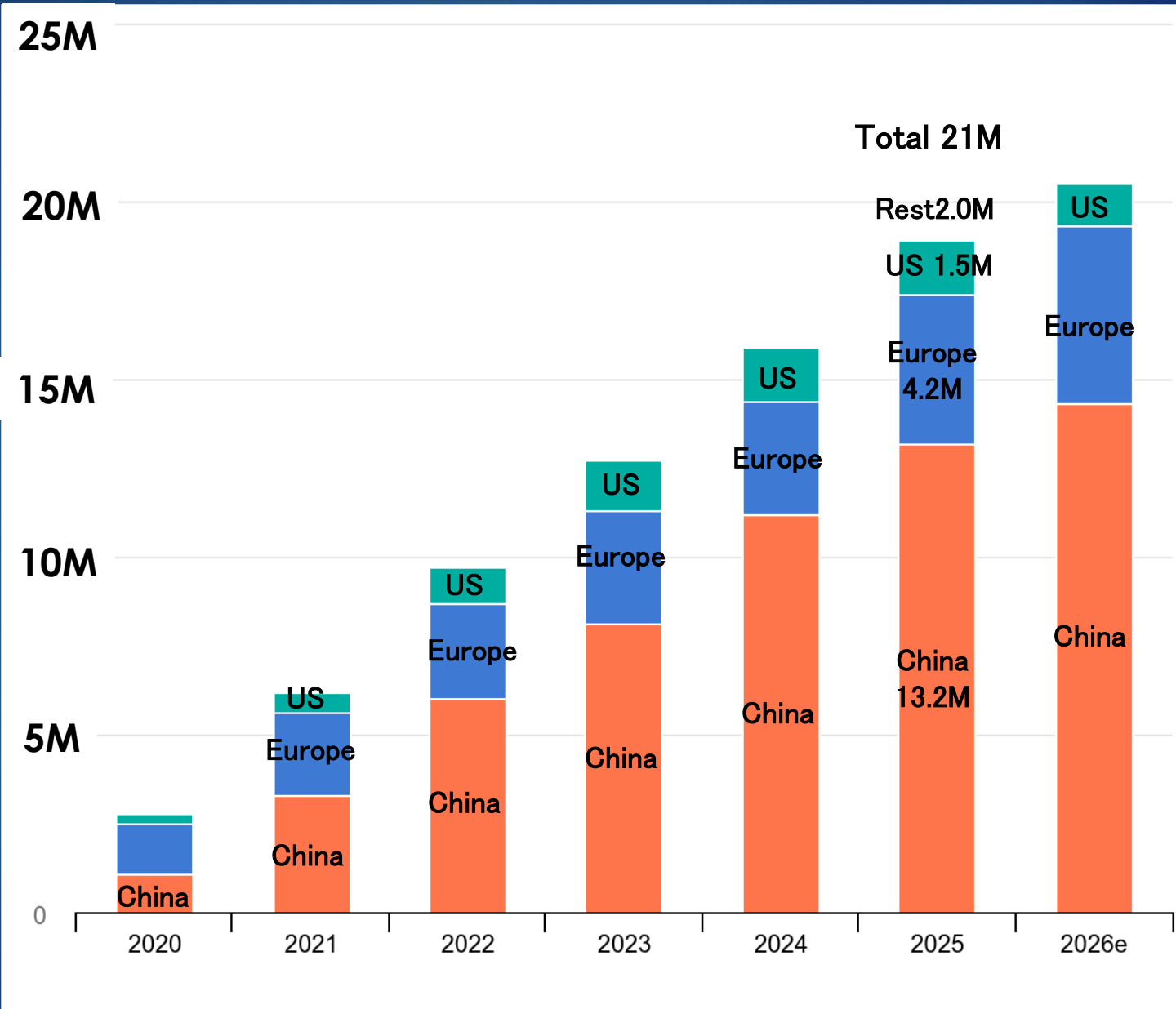
Rapid expansion of China's BEV market after 2020

2



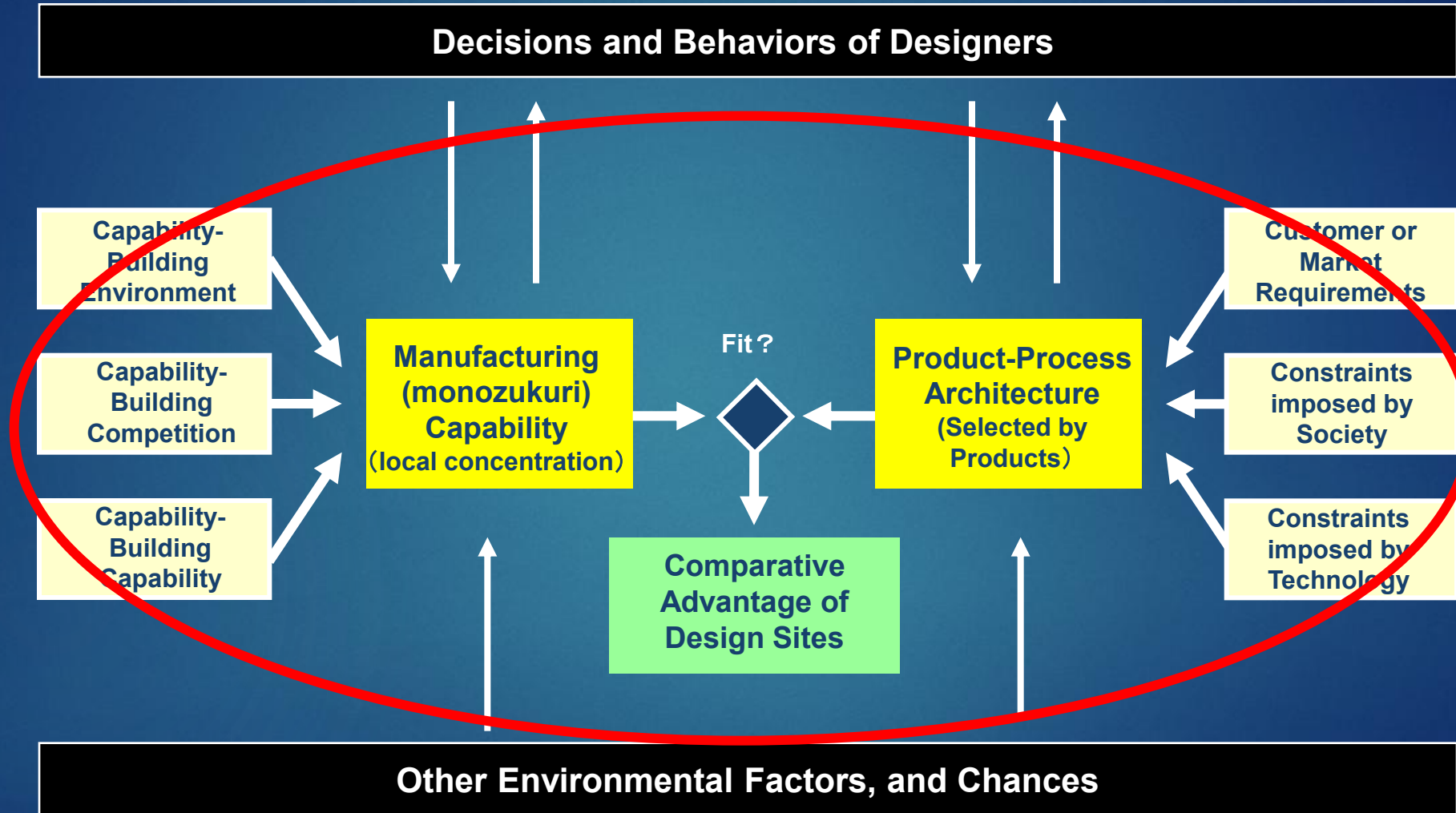
Rapid expansion of China's BEV market after 2020

China



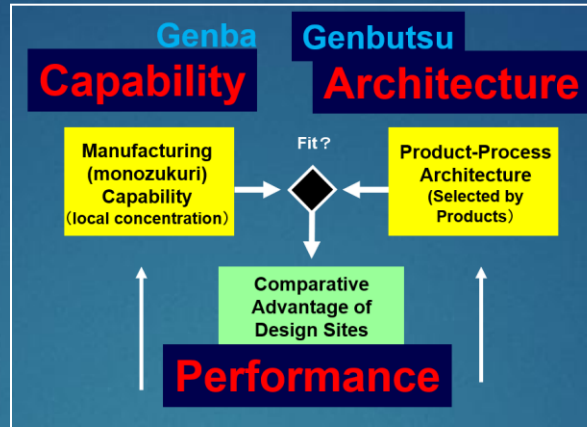
Capability-Architecture-Performance (CAP) Framework

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CAP Approach to Industry and Manufacturing

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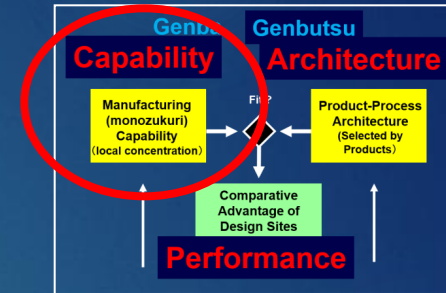
- 1 Design-Information-Flow View of Manufacturing (monozukuri)
- 2 Performance – Productive, Market, and Profit
- 3 Organizational Capability – Controlling/Improving Flows
- 4 Product-Process Architecture – Coordinating Structure and Function
- 5 **Capability-Architecture Fit** – Design-based Comparative Advantage

C: Capabilities Differ between Countries

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History matters.

Labor market conditions during the country's high-growth era



US, China . . . : Fluid labor market & abundant labor force in high-growth era

- Quick matching of skills and tasks → *Short-term employment*
- *Single-skilled workers*, standardization, simplification, specialization,
- *mass production*, Fordism → *Specialization capability*

Japan, Germany . . . Stable labor market & chronic labor shortage

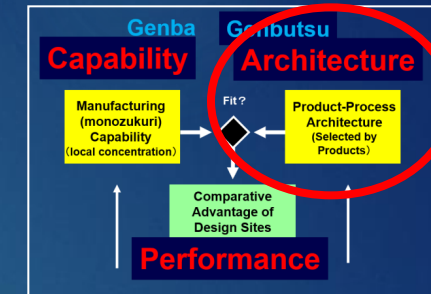
- High switching cost of labor → *Long-term employment*
- *Multi-skilled workers, teamwork*, multi-tasking, coordination,
- flexible production, *Toyota/Lean System* → *Coordination capability*

A: Architectures Differ between Products

Functional requirements and physical constraints matter

Optimal designs for tougher functional requirements/constraints

→ Complex products with integral architecture

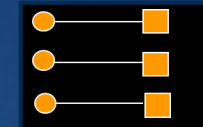


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Modular Hardware/software: Milder functional requirements & constraints

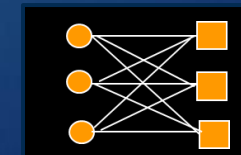
Weight-free (nearly) → Physical laws do NOT dictate product design

- Combinations of *language and logic* as design rules
- Structural/functional *independence* between parts & design elements
- Relatively *open-modular architecture* (*coordination-saving* design)



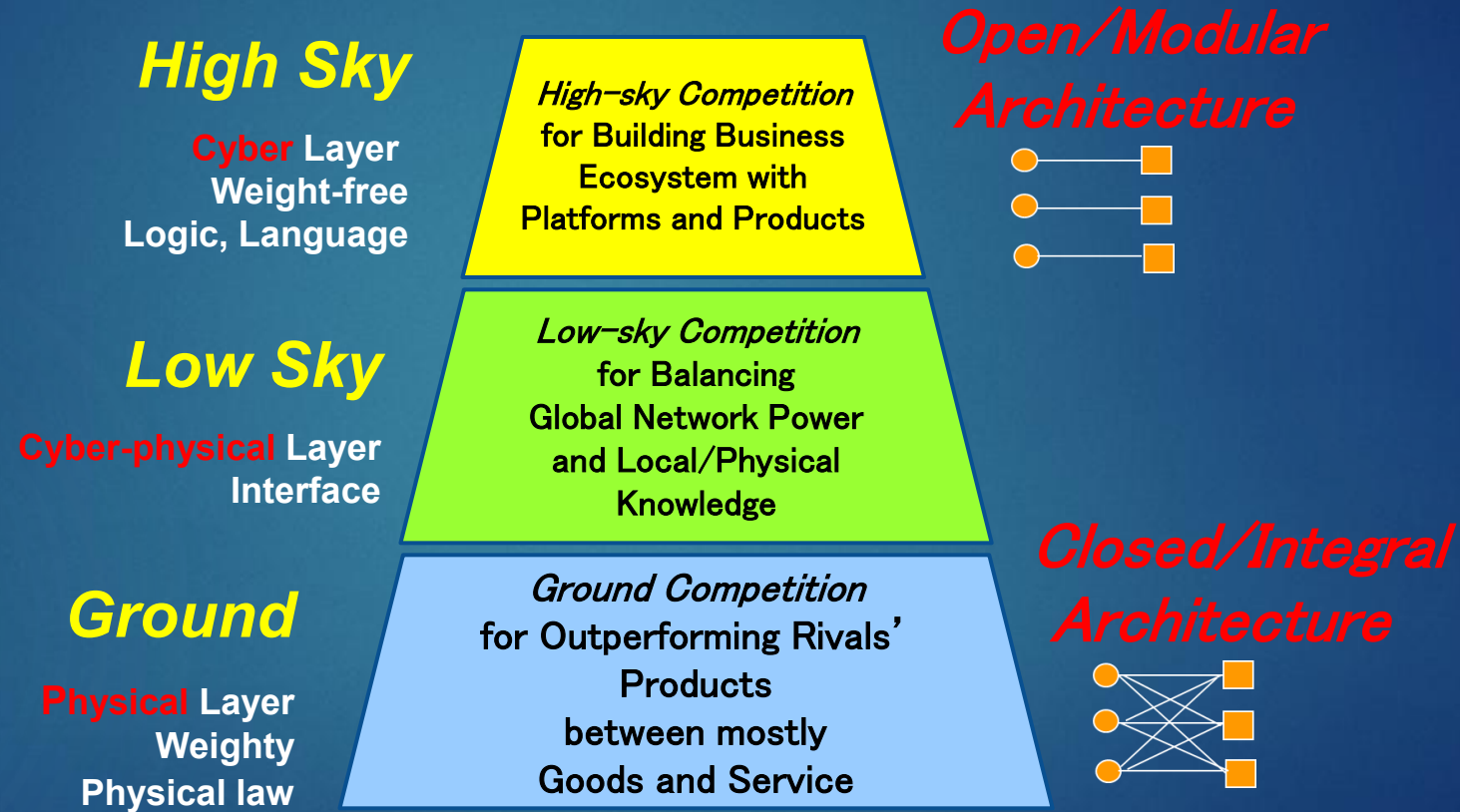
Integral Hardware/software: Stricter functional requirements & constraints

- *Weighty* physical artifacts → *Physical laws* dictate product design
- Complex *structure-function causality* between physical components
- Structural/functional *interdependence* between parts & design elements
- Relatively *closed-integral architecture* (*coordination-intensive* design)



A: Design Layers and Architectures: High Sky, Low Sky, Ground

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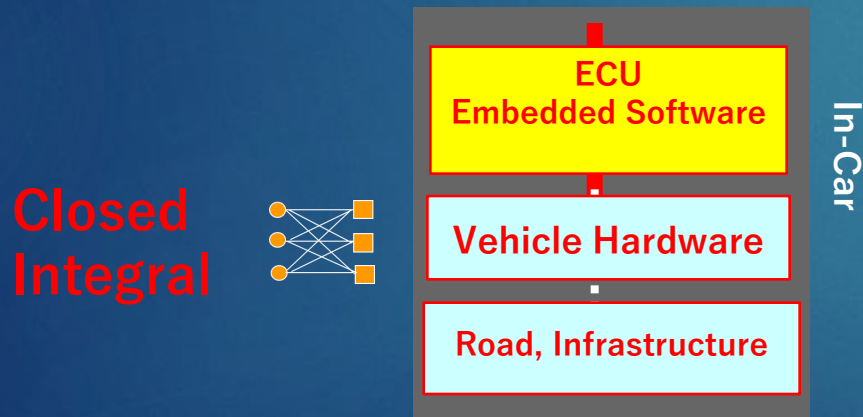
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Design Layers of Traditional Cars and SDVs

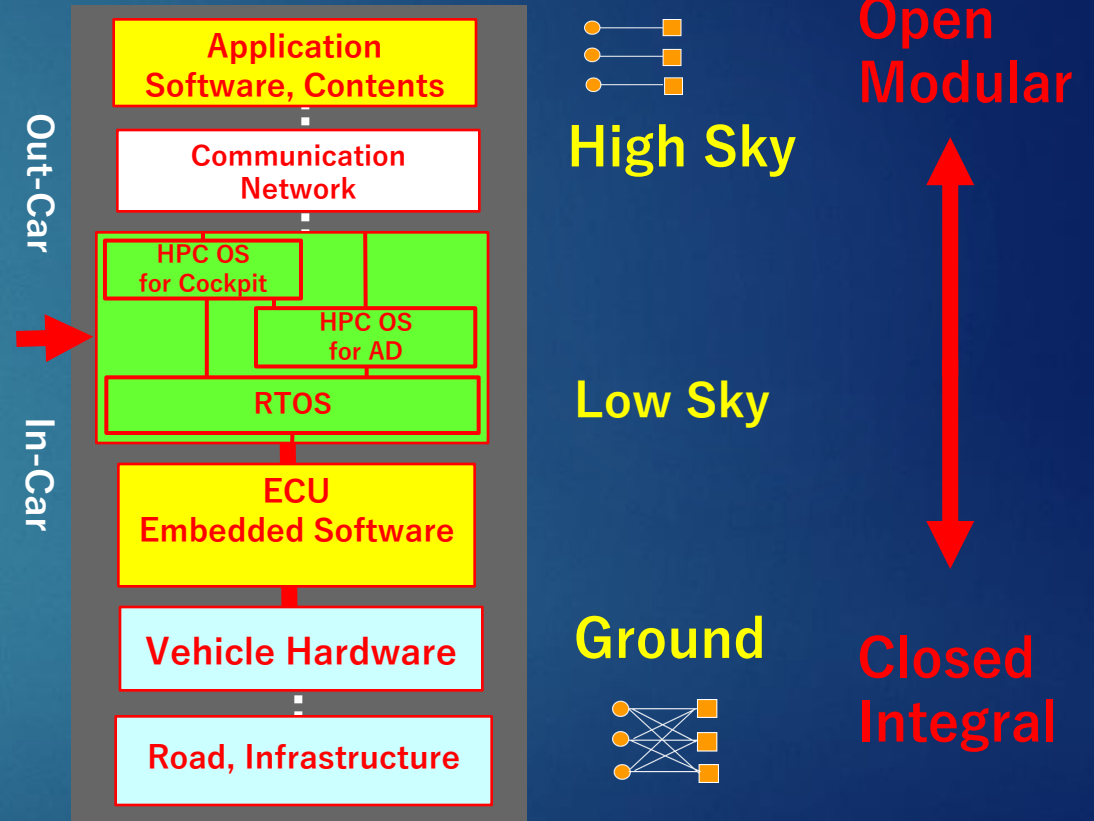
② SDVs' Design Layers (Closed and Open Mixed)

— closed interface
..... open interface

① Traditional ICE Cars' Design Layers (Closed)



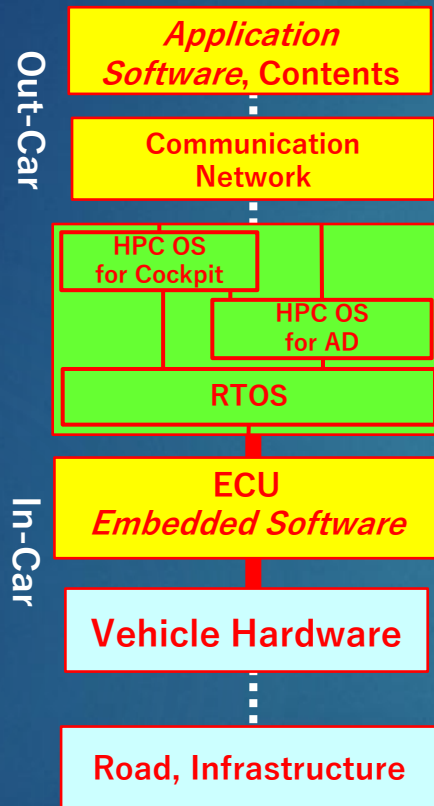
Vehicle OS →



SDVs as “Software-architecture Divided Vehicles” ?

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SDVs' Design Layers



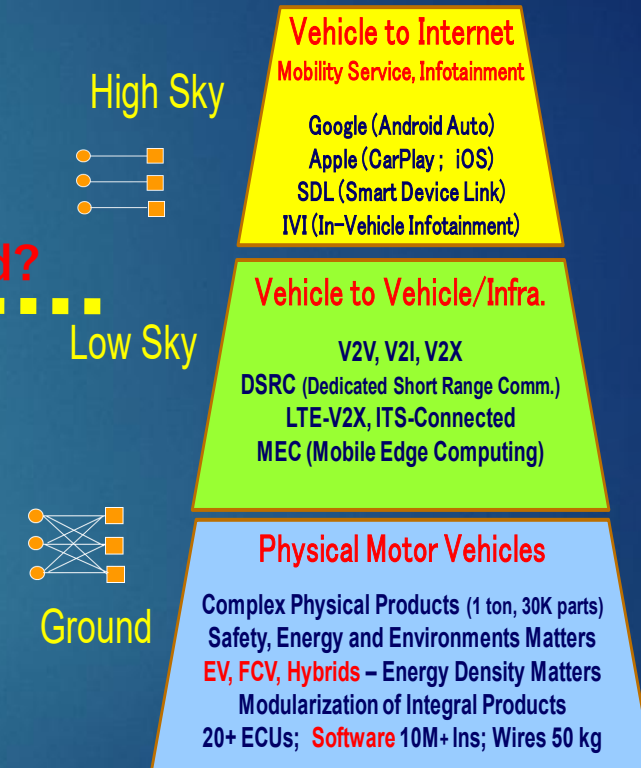
Modular Architecture

Modular
Integral

Divided?

Integral Architecture

Industry Structure



Fujimoto (2024)
CEIBS Auto Forum

Software's Architectural Types

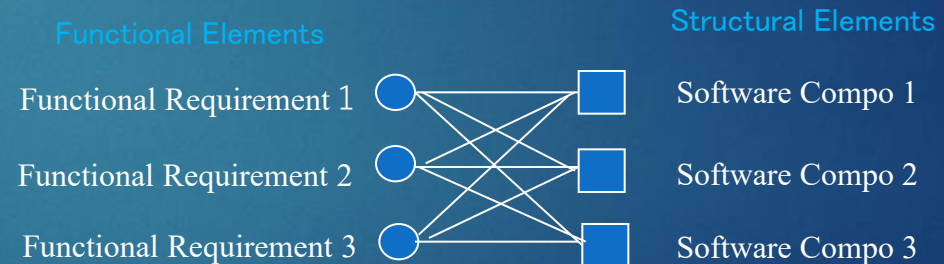
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Software with *Modular Architecture*



e.g., **AI, OS, Applications, etc.**

Software with *Integral Architecture*



e.g., **Embedded Software in ECU for
High Performance Vehicles**

Different logic dominates High Sky, Low Sky, and Ground

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AI, UX, Services

-- ruled by speed, experience & repetitive learning

Automotive OS, E/E Architecture, Platform, Middleware, APIs, Cross-Domain Control

Structural Design, Interfaces & Collaborative Verification
Determine Capability

Vehicle Control & Functional Safety

-- ruled by reliability, discipline, and long-term validation

High Sky

Vehicle to Internet Mobility Service, Infotainment

Google (Android Auto)
Apple (CarPlay ; iOS)
SDL (Smart Device Link)
IVI (In-Vehicle Infotainment)

Low Sky

Vehicle to Vehicle/Infra.

V2V, V2I, V2X
DSRC (Dedicated Short Range Comm.)
LTE-V2X, ITS-Connected
MEC (Mobile Edge Computing)

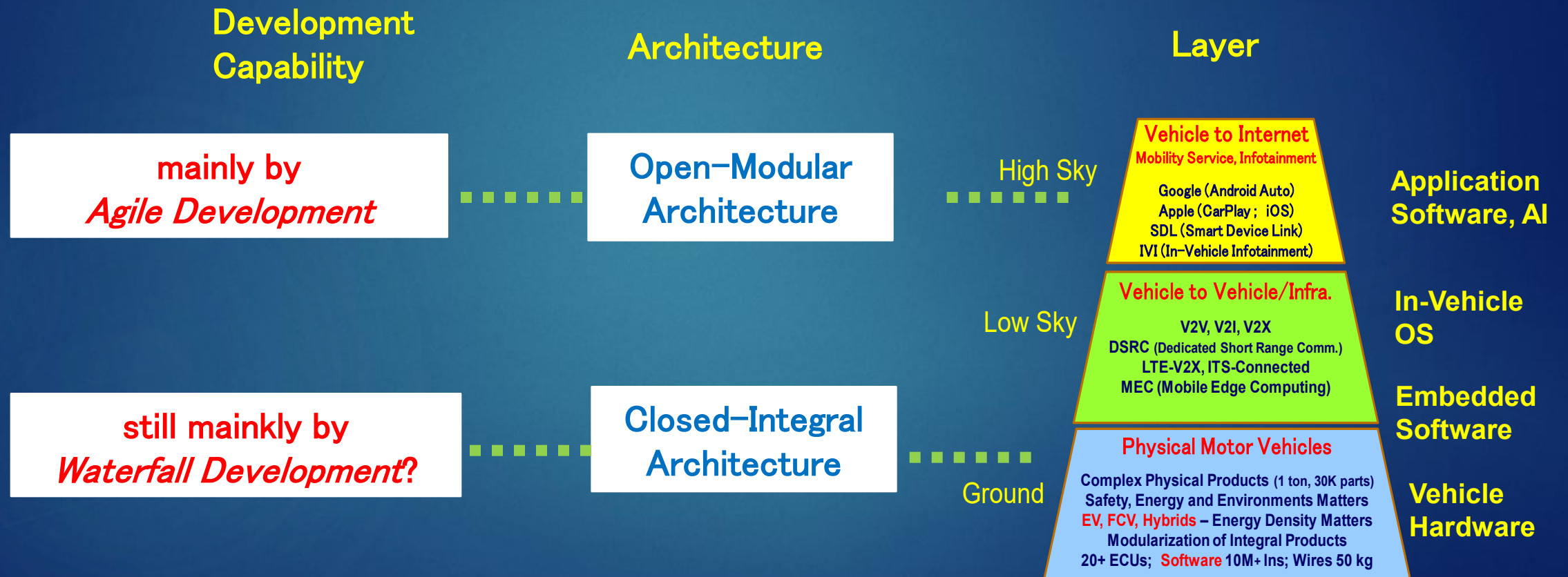
Ground

Physical Motor Vehicles

Complex Physical Products (1 ton, 30K parts)
Safety, Energy and Environments Matters
EV, FCV, Hybrids – Energy Density Matters
Modularization of Integral Products
20+ ECUs; **Software** 10M+ Ins; Wires 50 kg

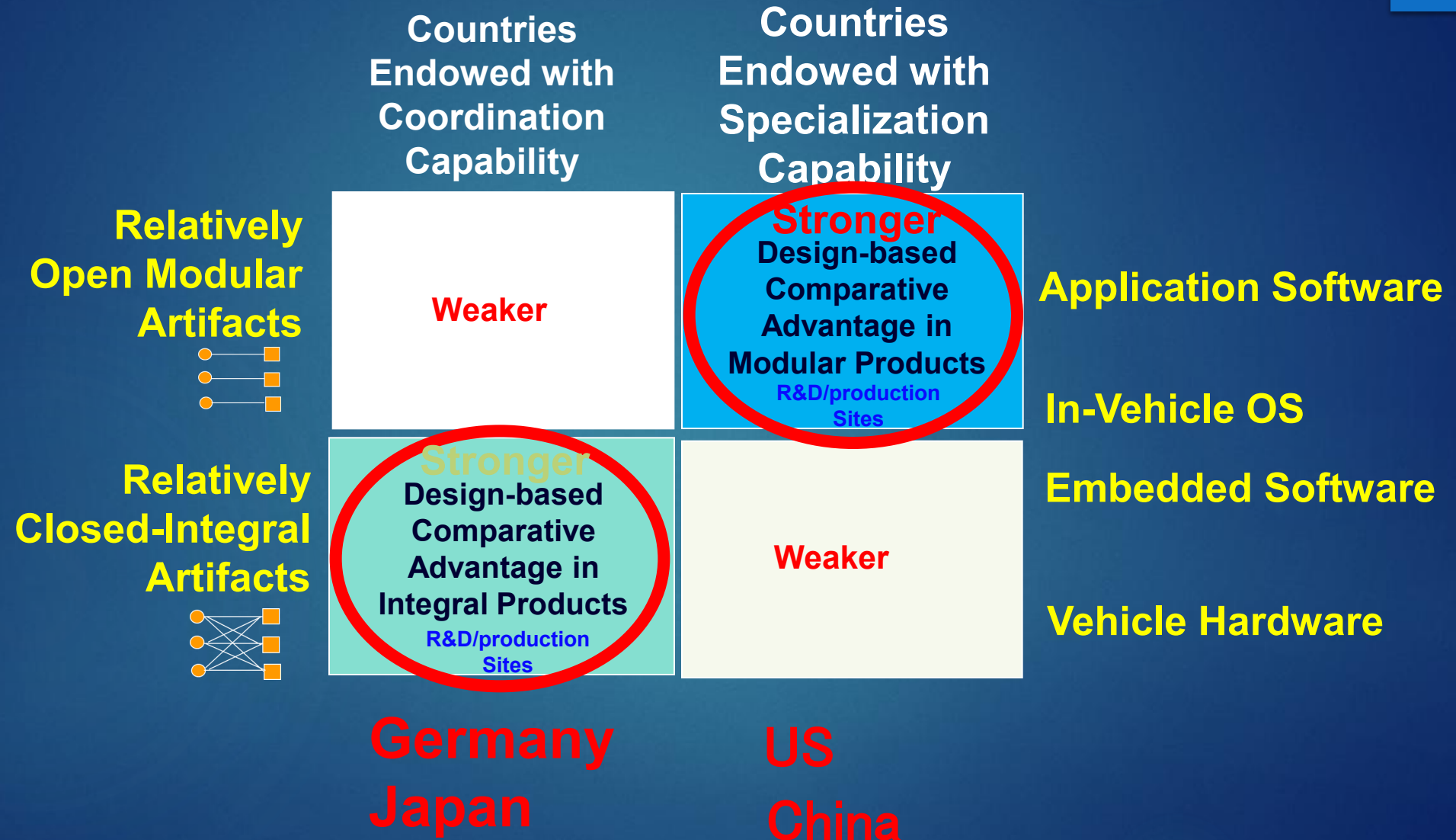
Software Architecture and Development Capability

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P: Design-based Comparative Advantage in Automobile Hardware & Software

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The in-car OS of the “Low Sky” layer by Germany, Japa, China and US (Dr. Zhou)

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Low Sky Layer: Connecting OS, EEA, Chip, AI, and Vehicle Control, serving as the main battleground for capability integration and organizational collaboration.



Conceptual diagram based on existing research materials by Takahiro Fujimoto and Shubin. This is not a ranking table of technical performance and corporate competitiveness.

Zone Controller SDV-EV: Prevalent Architecture ?

(July 2026, Presentation by Professor Nobe)

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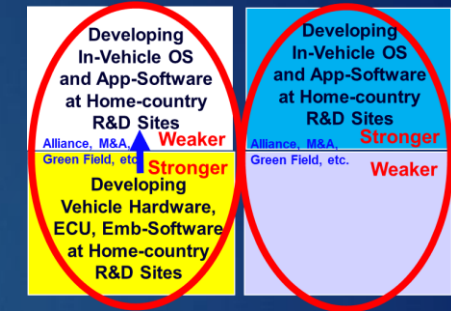
- ▶ Zone Controller architecture consists of (1) a centralized control (general-purpose SOC) on a system on chip, and (2) four to five zone controllers that integrate the previously distributed ECUs into their main functions.
- ▶ The main components of the ZONE-type architecture
 - ▶ (1) **Central SoC (General-Purpose OS)** includes memory, CPU, and GPU. Calculations are completed in 10 milliseconds.
 - ▶ (2) **Real-time OS (RTOS)** is connected to the central SOC. On top of that, various vehicle control application software such as electrical systems, lane changes, and navigation are installed.
 - ▶ (3) **ZCUs (Zone Controller Units)** distributed across several locations. Specialized Functions Dedicated chips can be customized using ASICs and FPGAs. These dedicated chips remain. X by Wire, CAN (analog), and Ethernet (digital communication) connect the central SOC and ZCU
 - ▶ (4) Connecting on-premises cloud and generative AI with central SOC.
- ▶ This simplifies the harness (Ethernet, CA N), 48 volts, AI-SDV that evolves intelligence using data, reduces manufacturing and BM costs, and may enable a 30% cost reduction.
- ▶ As a result, zone-type SDV-EVs have strong competitiveness through advanced feature updates and lower prices. This is not being achieved. GM and Ford are losing competitiveness. Tesla, Division 1 Chinese cars, and BMW Neue Klasse are zone-type. BYD is surprisingly behind in this regard.

Three Basic Types of Hardware-Software Links

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Three types of hardware-software links that Automaker X may choose

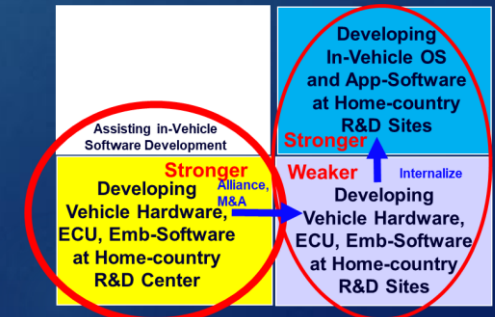
1. **Vertical Link:** Automaker X (e.g., Japanese, German) develops vehicle hardware, embedded software (ECUs), in-vehicle OS, and key application software internally or with its Tier-1 suppliers in vertically integrated manners.



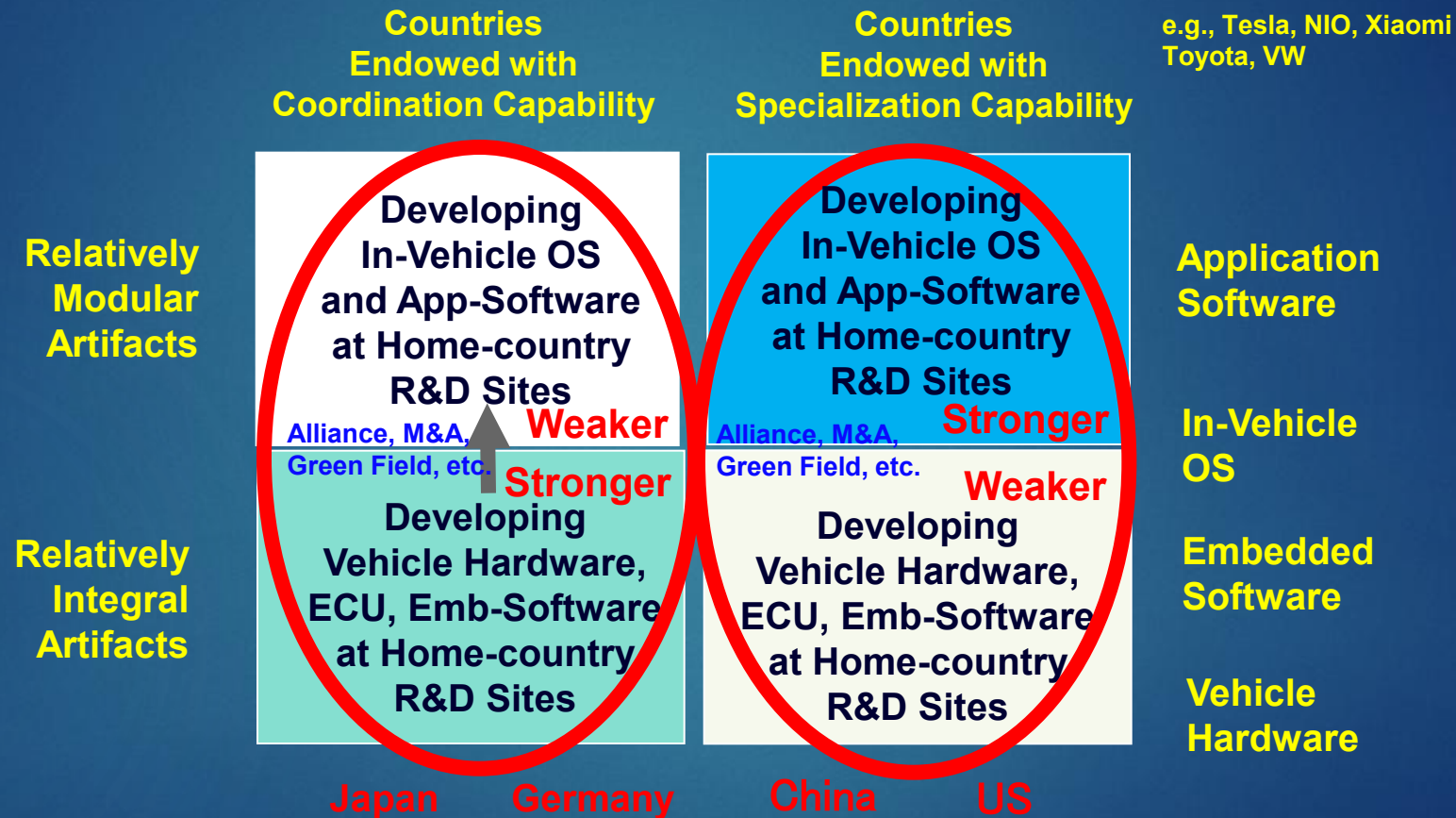
2. **Diagonal Link:** Automaker X (e.g., Japanese, German), with Tier-1, develops vehicle hardware and embedded software (ECUs). In-vehicle OS may be developed by X, or jointly with local software firms. Application software for infotainment is developed by local forms.



3. **L-shape Link:** Automaker X, by international alliance or M&A, ties up with local automaker Y and utilize their vertically-integrated software resources.

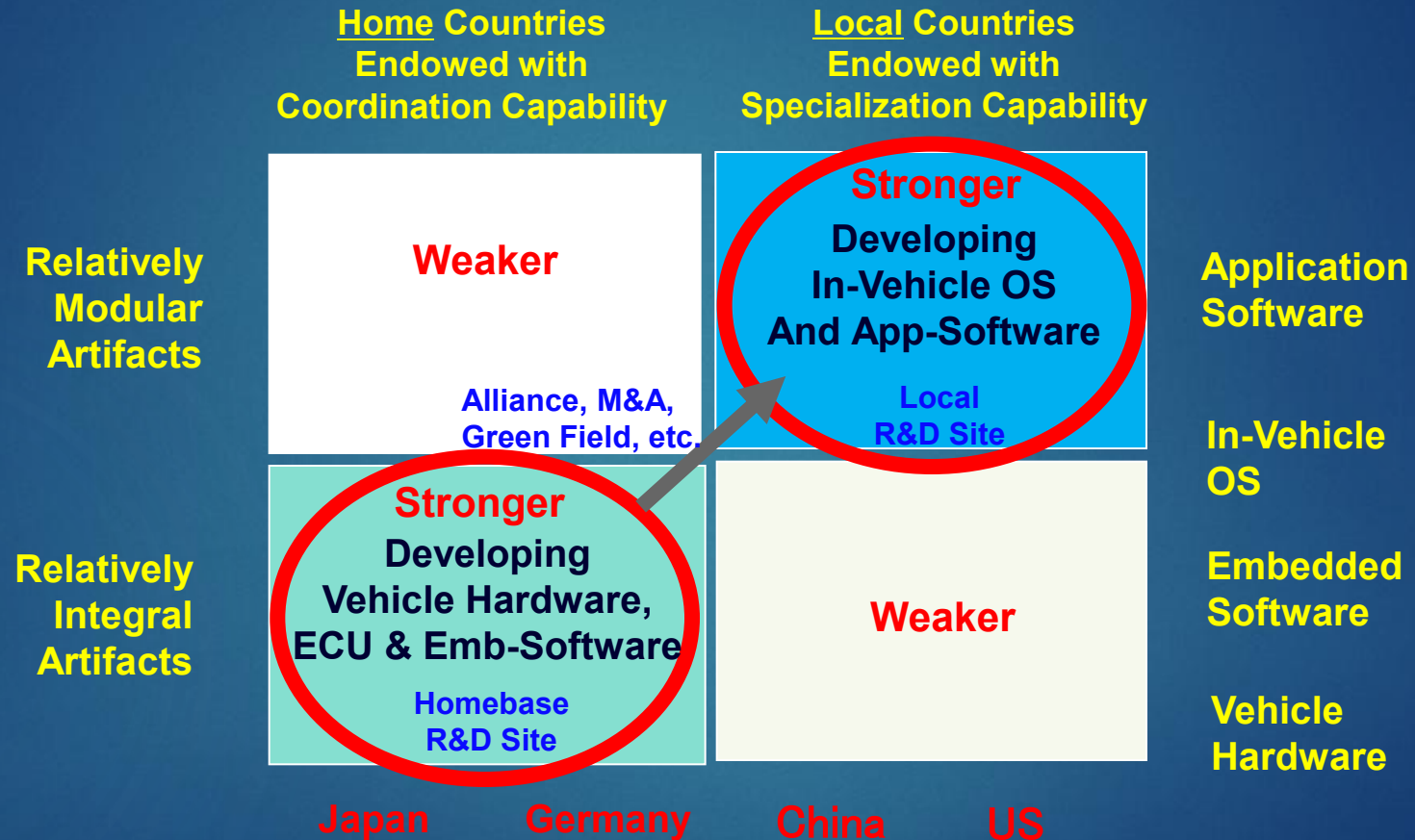


1. Vertical Links within Home Countries

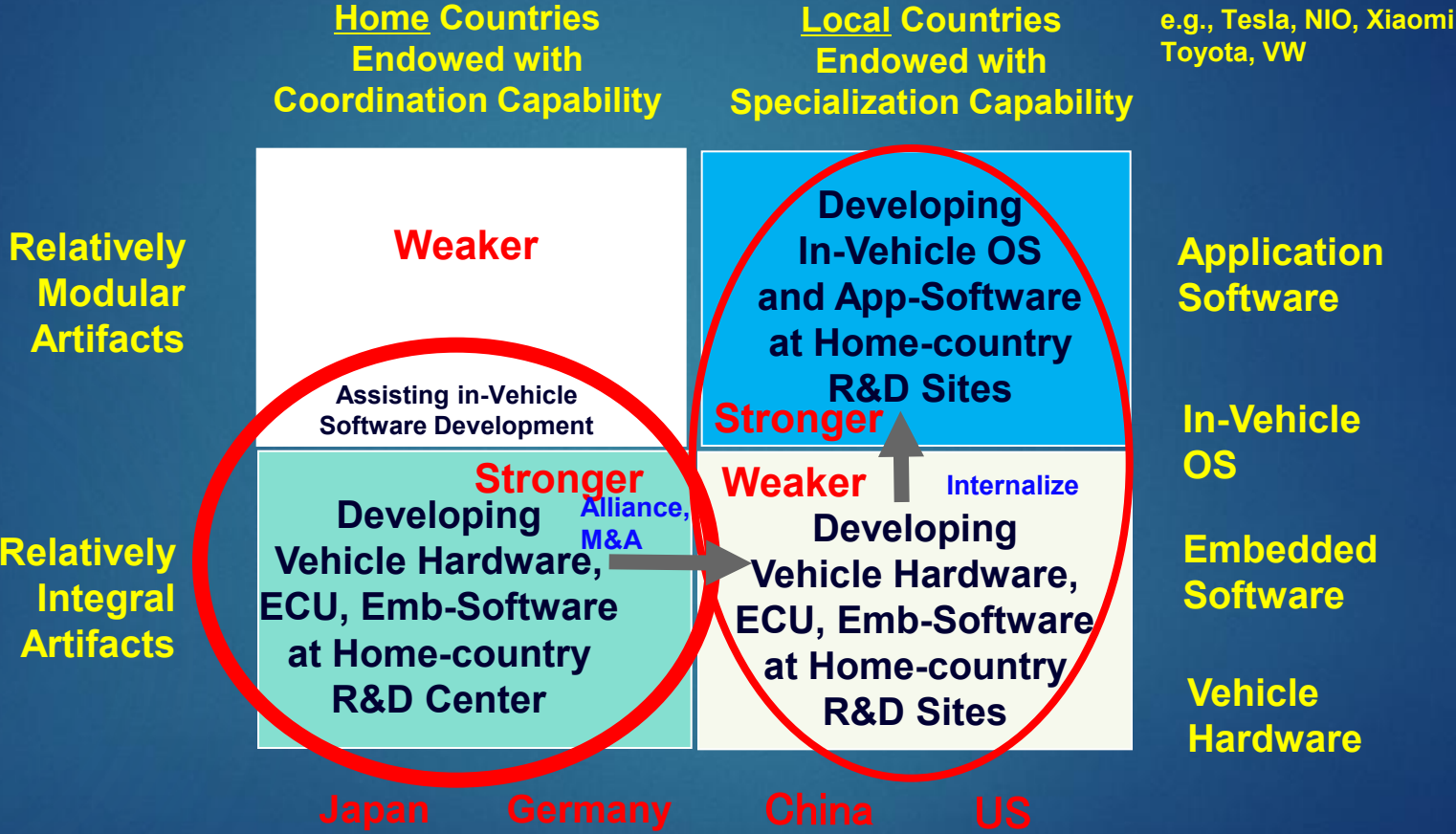


2. Diagonal Links between Stronger Hardware/Software Sites

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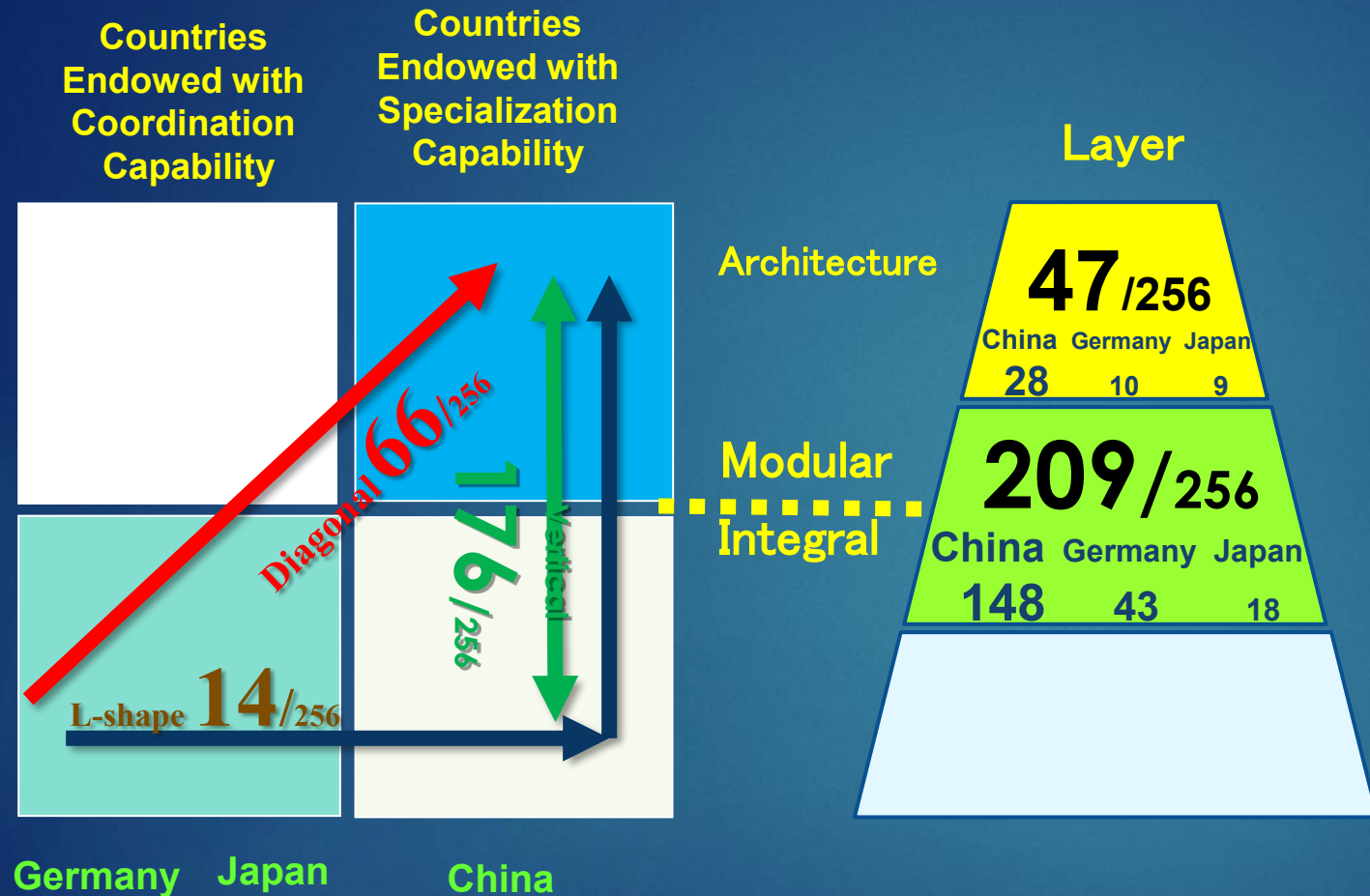


3. L-Shape Links between Hardware- & Software-driven Automakers

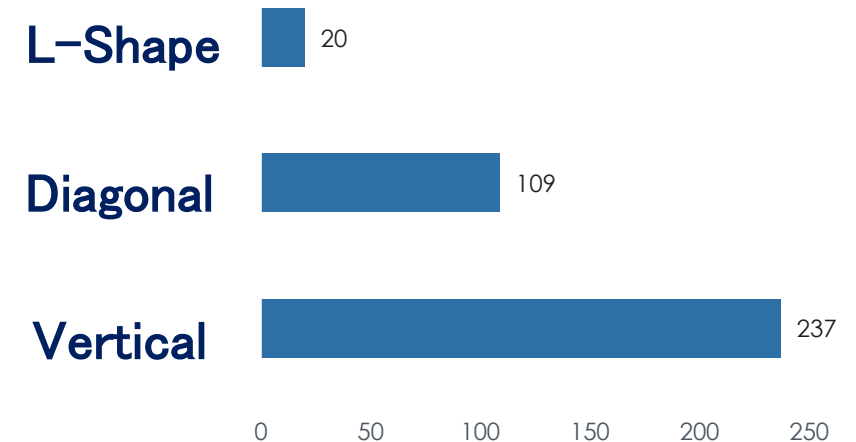


Early results on Inter-Firm International Alliances

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September 2026 (by Pin Zhou)



JAIBS Chubu Subcommittee | The 'Yin-Yang Fusion' in the AI+SDV Era, 2026 Dr. Zhou Pin | 2026.09.26 |

CAPAD International Alliance Survey (latest)

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- ▶ In countries: Many alliances among Chinese companies
International alliances between China-Germany, China-Japan, China-America, etc., also increasing
- ▶ Vertical 237, Diagonal 109, L-shape 20.
- ▶ Weak Ties: Non-equity contracts & joint development -- 246 cases (67%), Strong Ties: Investment/joint venture contracts -- 120 cases, (33%).
- ▶ **Low Sky** -- 311 listings (85%) **High Sky** – 55 (15%)
- ▶ Alliances within **Low Sky** are becoming increasingly important.
- ▶ international alliances to recombine different capabilities at the Low Sky and transform them into new organizational capabilities.

CAPAD Database by Dr. Pin Zhou (CEIBS)

Theoretical foundation – CAP (Capability-Architecture-Performance) Approach

CAPAD tracks the process of building AI+SDV capabilities by Chinese companies and connecting global OEMs and Tier 1 suppliers with Chinese capabilities through public alliances.

Latest Database

400 entries posted in 2026.09 -- growing continually

In-depth expert interviews

106 participants

Conclusion

A **Software-Defined Vehicle (SDVs)** consists of two architecturally different zones (i.e., *architecture-divided vehicle*): **closed-integral** (e.g., **hardware** and **embedded software** for safety); **open-modular** (e.g., **application software** for infotainment) layers.

German & Japanese automakers, endowed with **coordination capability**, tend to have design-based competitive advantage in SDV's integral part, including **hardware, embedded software and in-car OS for safety**.

Chinese ICT/software firms, endowed with **specialization capability**, may have design-based competitive advantage in SDV's modular part, including **application software, AI and out-car OS for infotainment**.

Chinese automakers enhanced competitive advantages in **SDV-EV**, where their competitive disadvantages in hardware is less serious.

German & Japanese automakers may accelerate **international inter-firm collaboration** with Chinese ICT/software firms or SDV-EV makers for **combining the design-based competitive advantages** of the two groups.

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